

SAVANNAH HARBOR EXPANSION PROJECT CHATMAN
COUNTY, GEORGIA AND JASPER COUNTY, SOUTH
CAROLINA: FINAL GENERAL RE-EVALUATION RE-
PORT AND ENVIRONMENTAL IMPACT STATEMENT
JANUARY 2012

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SAVANNAH HARBOR EXPANSION PROJECT

Chatham County, Georgia and Jasper County, South Carolina

January 2012

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Appendix C
Attachment 3
Parts 41-48

Volume 7



**US Army Corps of
Engineers**
*Savannah District
South Atlantic Division*



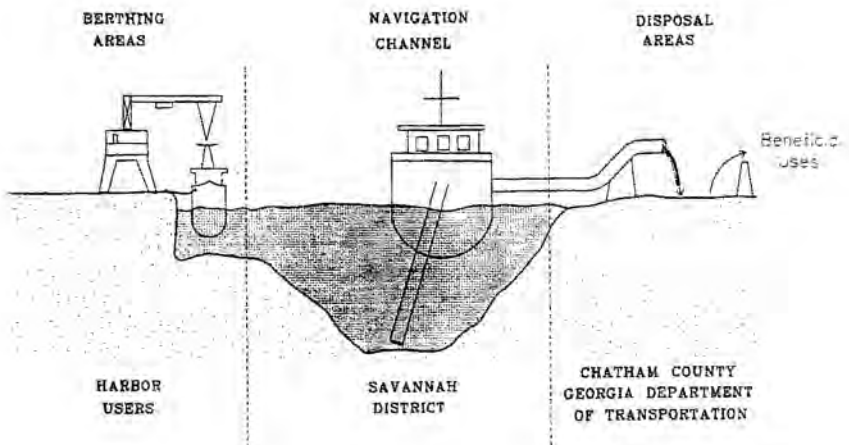


US Army Corps of Engineers
Savannah District
South Atlantic Division

APPENDIX

SAVANNAH HARBOR LONG TERM MANAGEMENT STRATEGY

August 1996



APPENDIX A

RESOURCE MANAGEMENT MEASURES AVAILABLE

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RESOURCE MANAGEMENT MEASURES AVAILABLE

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APPENDIX A

RESOURCE MANAGEMENT MEASURES AVAILABLE

A.1.00 Overview. Operation of Savannah Harbor is very complex, with many activities being conducted by a variety of organizations. There are a number of ways in which each resource of the harbor could be managed. This section of the EIS describes the different options which are available for management of those resources. Each of the many activities which are performed are intended to attain a specific goal. The discussion centers around the following goals:

- * Minimizing Federal Dredging Costs
- * Minimizing Non-Federal Dredging Costs
- * Minimizing Total Dredging Costs
- * Minimizing Disposal Area Costs
- * Minimizing Environmental Impacts
- * Maximizing Beneficial Uses of Dredged Material

A.1.01 Minimizing Federal Dredging Costs. Several options are available for reducing the Federal dredging costs. Most can be grouped into just a few categories, each of which are discussed in the following paragraphs.

A.1.02 A. Maintenance Material Volume. The volume of dredged material required to be removed to maintain authorized depths in the Navigation Project is relatively fixed. The volume of required maintenance dredging is primarily a factor of the sedimentation load from upriver and the size of the navigation channel. A larger channel cross-section generally results in a slower water velocity and, subsequently, a higher sedimentation rate. This tendency is no longer true when the existing channel captures all of the sediment passing through or across it. The only method of reducing the volume of material to be dredged would be to reduce the size of the channel which is maintained, something which would produce unacceptable economic costs. The volume of dredging required does vary somewhat from year to year, depending mainly on the amount of rainfall experienced upriver. However, the overall volume does not vary widely from the relatively predictable average of 7.2 million cubic yards (MCY) per year.

A.1.03 Material which accumulates in the Navigation Project originates from a variety of sources. Sediment which washes off uplands in the river basin constitutes the majority of the material. Although the drainage basin extends up the entire Georgia/South Carolina border, even into North Carolina, the majority of the sediment which reaches the estuary originates below the J. Strom Thurmond Dam. The major impoundments located above that point effectively trap sediments which are suspended upstream of those points. Most of the suspended materials transported down the river originate from agricultural fields and construction sites. EPA has recognized this situation and has begun to institute programs to reduce the volume of sediments which enter streams from what are typically considered non-point sources. Much more progress must be made before the effects of non-point sources are considered to be at acceptable levels. Both Georgia and South Carolina are implementing stricter standards on runoff from construction sites through the Stormwater Pollution Prevention Program. Those programs are reducing the sediment load on streams and further compliance would make them even more effective. The sediment load transported down the river consists of both coarse-grained particles, which deposit at the upper end of the harbor, and fine-grained particles which deposit in the middle of the harbor after mixing with the salt water. The coarse-grained particles are generally too heavy to significantly affect the continued functioning of wetlands located along the river. The other main origin of suspended material is the large intertidal estuarine wetland which serves as the primary source of detritus to the intertidal and nearshore area. Those materials are fine-grained and do significantly aid the continued functioning of the estuarine wetlands. No effective method is available to reduce this natural source of suspended materials which enter the water column of the harbor. Regulatory changes in the upper drainage basin which could reduce the amount of suspended sediments which enter the harbor from upstream sources are beyond the scope of the LTMS Study and this EIS.

A.1.04 B. Advance Maintenance. Advance maintenance sections extend the length of time during which the authorized channel depths are available. Advance maintenance also reduces annual maintenance costs by concentrating the sediment to be removed, thereby allowing the maintenance dredges to operate at a higher efficiency. The increased dredging efficiency results in lower unit costs and subsequently lower total Federal dredging costs.

A.1.05 One method of further reducing Federal dredging costs would be to increase the use of advance maintenance sections where they are warranted in the harbor. The District does monitor the shoaling distribution in the harbor and periodically evaluates the feasibility of additional advance maintenance sections. The environmental impacts of additional advance maintenance expected to be necessary in the near future were evaluated in the LTMS study and are considered in this EIS.

A.1.06 C. Sediment Basin. The Sediment Basin in Back River was designed to concentrate the fine-grained sediment at one location rather than it being spread out along the shipping channel. This concentration has two results; (1) it increases the depth of sediment to be removed from one location, thereby allowing a dredge to operate more efficiently, and (2) the location at which the material settles is close to the disposal areas. Those two factors both lead to a lower unit dredging cost and subsequently lower Federal dredging costs. If the trapping efficiency of the Sediment Basin were increased so that it could trap a larger proportion of the harbor's sediments, the Federal dredging costs would be reduced.

A.1.07 One method of increasing the basin's trapping efficiency would be to resume operation of the Tidegate. The Tidegate was constructed to work in partnership with the Sediment Basin to have a large percentage of the inner harbor sediment shoal outside the navigation channel. One result of the 1990 suspension of the Tidegate's operation was a reduction in the trapping efficiency of the Sediment Basin since still water would no longer exist behind the Tidegate during ebb tides. This resulted in a 2.0 MCY per year reduction in shoaling in the Sediment Basin.

A.1.08 Another method of increasing the efficiency of the basin would be to remove material from the basin more frequently to maintain a deeper average depth in that location. Material has typically been removed from the basin every 9 months. Shortening the dredging interval to every 6 months should increase the trapping efficiency by roughly a third.

A.1.09 Another method of increasing the efficiency of the basin would be to enlarge the size of the basin. However, increases in the width of the basin would be likely to have associated real estate costs. Increases in the depth of the basin would produce concerns about low dissolved oxygen, which could impact aquatic life in the vicinity. The Sediment Basin was originally authorized and constructed with its bottom elevation 2 feet deeper than the channel depth. No changes were made to the basin's depth in the 1993 harbor Deepening Project, so the bottom elevation of the basin is now 2 feet shallower than that of the

channel. Restoring the original 2-foot depth offset would restore some of the efficiency which the basin lost when operation of the Tidegate was ceased in 1990.

A.1.10 D. Tidegate. As expressed previously, the Tidegate was constructed to work in partnership with the Sediment Basin to have a large percentage of the inner harbor sediment shoal outside the navigation channel. Discontinuation of the Tidegate's operation has resulted in an increase in Federal cost to maintain the navigation channel. One method of reducing those costs would be to resume operation of the Tidegate. A resumption of the Tidegate's operation would increase the salinity levels in Back River and its adjacent marshes. Salinity impacts to those marshes was the primary reason the Tidegate was taken out of service. Restoring operation of the Tidegate would require approval from the Corps' Washington Offices.

A.1.11 E. Disposal Area Location. Eight confined disposal areas are available for use by the Corps for disposal of material removed from the Savannah Harbor Navigation Project. Those areas are distributed along the length of the navigation channel. The location of a disposal area impacts the cost of disposal as a result of the distance which the material has to be transported to the site. A shorter transportation distance would normally translate into a reduction in dredging cost. This is one of the important factors in the low cost of removing material from the Sediment Basin; the availability of a disposal area immediately adjacent to the dredging. Having disposal areas located closer to where the sediment accumulates could further reduce dredging costs. At Savannah, the two locations with the greatest distance between disposal areas are (1) on the Bar Channel where disposal sites are basically located at both ends of the 60,000 foot reach, and (2) in the upper harbor between Stations 60+000 and 93+000. Pumping distance normally does not present a significant problem in the inner harbor area since the large hydraulic dredges which typically work in the harbor can pump close to 10,000 feet without a significant reduction in production. At distances beyond 10,000 feet a booster pump, with its associated costs, is often required. Development of other disposal areas along the Bar Channel could reduce dredging costs if pipeline dredges were to be used to maintain that reach. Otherwise, the shallowness of the nearshore bars make sites adjacent to that reach inaccessible to hopper dredges.

A.1.12 F. Environmental Windows. Environmental windows and other restrictions limit dredging operations to ensure that environmental resources receive appropriate protection. Those limitations often increase the cost of dredging. Careful, thorough planning can reduce the impacts of those limitations, but if the restrictions were lifted or reduced, lower dredging costs would result. The restrictions which typically have the most impact on the cost of dredging or disposal operations are as follows:

- * Window excluding dredging above R.M. 5 from March 15 to June 1 for protection of striped bass.
- * Window excluding hopper dredging from December 1 to April 1 for protection of sea turtles.
- * SC DHEC-OCRM requirement for confined disposal facilities to limit wetland impacts.
- * Requirements for chemical/biological testing of sediments to ensure acceptability of material for dredging.

A.2.00 Minimizing Non-Federal Dredging Costs. Non-Federal interests maintain adequate depths in the berthing areas located along the navigation channel. Those areas are used to dock the vessels during cargo loading/unloading operations. The individual dock owners have typically obtained a Section 404 Dredge and Fill Permit and state Water Quality Certification for dredging and disposal of material from their berths.

A.2.01 Agitation Dredging is typically used by the dock owners to remove shoaled material from the berth. Two types of agitation dredging have been permitted. One consists of dragging a device through the sediment to resuspend the material, allowing the ebbing tide to remove the material from the berth and redistribute it elsewhere along the riverbed. The second consists of using a hydraulic dredge to remove the material from the berth, with disposal being in the navigation channel where it is spread out by tidal currents. Dock owners are subsequently billed by the Corps for the costs of removing material which has redeposited in the navigation channel.

A.2.02 Agitation dredging is a relatively low cost method for removing material from berthing areas. No disposal area costs are directly involved and equipment can be relatively simple and, therefore, inexpensive to operate. Methods to further reduce the costs of maintaining depths in the berths would include increasing the permitted depth of dredging allowed at berths. A greater depth should allow a longer time period between agitation dredging events as the material would have more depth to

accumulate before impacting vessels. The larger volume of material removed at one time should increase the efficiency of the dredging process, thereby reducing the unit cost.

A.3.00 Minimizing Total Dredging Costs. Total dredging costs would be minimized when the sum of the Federal and non-Federal dredging costs are lowest. One method of producing this may be to eliminate the costs associated with moving the same sediment more than once. Typically dock owners use agitation dredging to remove deposited sediments from their berths, with subsequent redeposition of those sediments in other portions of the harbor. The Corps believes that the majority of those sediments settle in the navigation channel, where it is subsequently removed by the Corps during its channel maintenance dredging. Dock owners pay the Corps a fee to fund removal of their sediments from the navigation channel. Under this scenario, dock owners pay twice for movement of material deposited in their berths. Their initial cost for removing the material from their berths is combined with the payment made to the Corps. If non-Federal interests were to excavate the material from their berths and deposit those sediments directly in a confined disposal area, only one removal cost would be incurred. Depending on the cost of that removal, this may reduce the total cost incurred by the dock owners and, therefore, reduce the total dredging costs for the harbor.

A.3.01 Another possible method of minimizing total dredging costs would be to combine the Federal and non-Federal dredging. Under certain circumstances, it may be possible for non-Federal interests to contract for removal of berth sediments with the dredging contractor employed by the Corps to maintain the navigation channel. If such an arrangement could be reached, the total costs for maintenance of the channel and berths would likely be minimized as separate mobilization costs would be eliminated. The Corps would have to be certain that its dredging contractor could perform the work required of it within the time frame allowed, before it would release the dredge to work on projects outside its contract with the Corps.

A.4.00 Minimizing Disposal Area Costs. The non-Federal sponsor of the Navigation Project expends considerable money each year maintaining and making capital improvements to the confined dredged material disposal areas.

A.4.01 A. Dike Raising. A confined disposal area is generally useable as long as its dikes can contain the dredged material intended to be deposited in it, as well as the water which transports the material to the site. When dredged material is placed into a site, it uses up some of the site's disposal capacity. Dikes are raised periodically to produce additional

storage capacity within the disposal area. The higher dikes allow more material to be placed in the site, thereby extending its useful life. When an area becomes full and the dikes cannot be raised further due to concerns about their structural stability, a new disposal site would have to be obtained. Since the costs of obtaining a new site can be quite substantial, raising the height of dikes at existing sites is generally the best way to minimize disposal area construction/improvement costs.

A.4.02 B. Underdrains. Increasing the drainage through a soil matrix will result in faster consolidation of the material. Thus, adequate drainage will result in a given mass of soil taking up less space. Underdrains can be used in a disposal area to remove subsurface water from the deposited dredged material. Their use would reduce the storage volume used by a given mass of deposited material, thereby extending the period of time until the next dike raising is needed. This would lower the annualized cost of the disposal area improvements.

A.4.03 C. Rotation. The planned rotational use of multiple disposal areas would allow more time for the deposited material to dry and, thereby consolidate. If the use of areas can be alternated, then the drying time can be extended to over a year. The additional consolidation would extend the period of time until the next dike raising is needed, thereby lowering the annualized cost of the disposal area improvements and extending the useful lives of those sites.

A.5.00 Minimizing Environmental Impacts. One of the goals of harbor operation is to minimize impacts of operational activities on the environment. This goal is in recognition that there are multiple interests related to operation of a harbor, and that coexistence of the navigation channel and the harbor's environmental resources is required.

A.5.01 A. Dredging. Dredging can produce environmental impacts in a variety of ways. Minimizing those impacts is one goal of harbor operations. The major areas where dredging impacts the environment are described in the following paragraphs.

A.5.02 1. Sea Turtle Window. If hopper dredges are used, there is a potential for impacting endangered sea turtles. To minimize the impact of using this type of equipment, the National Marine Fisheries Service established a window where hopper dredges can only be used in Southeastern ports from December 1 to

April 1. Research has demonstrated a low occurrence of turtles in the harbors at that time. Impacts to sea turtles could be further reduced from any of the following measures:

- * Disallowing use of hopper dredges completely.
- * Narrowing the window of allowable hopper dredge use to times when no turtles are present at a harbor.
- * Developing and using a drag head which would not allow sea turtles to be impacted.

A.5.03 2. Striped Bass Window. Striped bass populations in the Savannah River have declined recent years. The turbidity produced by an operating cutterhead dredge has the potential for impacting Striped bass eggs and young. Those life stages are more sensitive to environmental factors such as turbidity. An exclusion window has been established so that no dredging will occur above R.M. 5 from March 15 to May 31.

A.5.04 Impacts to sensitive striped bass life stages could be further reduced by (1) extending the beginning of the exclusion window to a date just before spawning begins, and (2) extending the end of the exclusion window to ensure that the fry of even late spawning fish would have sufficient time to develop to the point where they have much more resistance to the effects of turbidity.

A.5.05 A three-year study was begun by Savannah District in 1994 to determine the geographic distribution of Striped bass in Savannah Harbor during the Spring and when the eggs and young are present. That study was recently extended by the Corps for a fourth year. The data will provide information on where the eggs and young are located in the harbor so that protection measures can be applied appropriately.

A.5.06 3. Right Whales. Right whales transit the nearshore area off the Georgia coast in the winter months as part of their journey to the calving grounds located off the northern Florida coast. Any motor-powered vessel could injure these whales if a collision occurred. Since hopper dredges are only allowed to work during those months as a result of operating restrictions placed to ensure protection of sea turtles, potential impacts on right whales exist from the use of this equipment. Potential impacts are presently reduced by a combination of actions which include worker training, onboard observers, aerial observers and speed restrictions.

A.5.07 Impacts to right whales could be further reduced from any of the following measures:

- * Disallowing use of hopper dredges completely.
- * Further restrictions in dredge operating speeds.
- * Dredge operating restrictions during adverse weather conditions.
- * Radio tagging of all right whales to allow complete knowledge of their locations at all times.

A.5.08 4. Impacts to Dissolved Oxygen in Savannah River. Dissolved oxygen (DO) is required by nearly all forms of aquatic life. The turbidity produced when a dredge resuspends deposited sediment can result in a reduction in the DO in the water column. Materials attached to the fine-grained sediment particles serve as food sources to oxygen consuming bacteria. Although with a hydraulic dredge most of the turbidity is removed from the site, some turbidity does escape to the surrounding water. The passage of large vessels which draw most of the depth in the channel also produce turbidity in the river when the force of their propellers resuspends sediments off the bottom.

A.5.09 Sediments can accumulate for short periods in naturally-deep holes in the riverbed. As these sediments accumulate, the respiration of the organisms present consume the available DO, producing a low DO condition on the riverbed at that location. The depth in those holes may be restored during other periods of the year when higher flow rates occur. The Sediment Basin was constructed as a spot where fine-grained sediments could accumulate and low DO conditions do occur there. Advance maintenance sections could produce similar conditions if they are constructed so that currents do not readily pass through them to bring additional oxygen-laden close to the sediments.

A.5.10 Impacts to DO could be further reduced from any of the following measures:

- * Disallowing dredging completely during the summer months when DO is naturally low in the harbor.
- * Reducing the speed of the rotating cutterhead so that less turbidity escapes from the cutterhead.
- * Reducing the speed of vessels whose bottom approaches the channel floor.
- * Performing channel maintenance dredging more frequently so that sediment does not accumulate so thickly that anaerobic conditions are produced.
- * Designing advance maintenance sections so that some current does pass through the section.

A.5.11 5. Turbidity. The suspension of fine-grained particles also causes environmental problems in other ways. Suspended solids can coat fish gills and membranes of other aquatic species across which those organisms obtain oxygen from the water. As those membranes become clogged, respiration increases in an attempt to compensate for the lower transfer efficiency. This higher respiration stresses the organism and can result in larger quantities of other contaminants being absorbed. Smothering of organisms which live on the bottom can also occur as sediments with high turbidity levels redeposit out of suspension. Impacts from turbidity could be reduced from any of the following measures:

- * Disallowing dredging completely during the summer months when DO is naturally low in the harbor.
- * Disallowing agitation dredging completely during the summer months.
- * Disallowing the hydraulic form of agitation dredging where the resuspended material is discharged back into the river channel.
- * Decreasing the speed of vessel transiting the harbor.

A.5.12 6. Sediment Quality. Sediments which are removed from the channel are comprised of many materials. Basic inorganic substances such as sand constitute a majority of the upper harbor and Bar Channel sediment. Organic and fine-grained materials make up the majority of the material which settles in the middle reaches of the harbor. Many substances are adsorbed onto organic and fine-grained particles, so chemicals dissolved or suspended in the water tend to accumulate in fine-grained sediments.

A.5.13 Dredging essentially relocates material from one site to another. The process of dredging does not "contaminate" the sediments which are being moved. Since there is a potential for release of compounds back into the water column where they would generally be more available for aquatic life, the environmental impacts from dredging would be reduced if the sediments contained fewer chemical compounds.

A.5.14 Evaluations of dredging usually include consideration of the quality of the sediment. The judgement of quality usually is based on the levels of various toxic chemical compounds in the material. Materials are considered "contaminated" when they contain "unacceptable" levels of certain compounds. These levels are established primarily through laboratory studies which evaluate the concentrations at which the survival, growth or reproduction of aquatic organisms are affected. When this occurs with sediments to be dredged, then excavation of those sediments becomes more difficult and expensive as tests must be performed

to ensure that unacceptable concentrations are not released into the water column. Should concentrations reach certain levels, additional procedures would be required at the disposal areas.

A.5.15 The primary chemical compounds which are found in Savannah Harbor sediments include heavy metals and hydrocarbons. Pesticides, which are often of concern in other areas of the country, are generally not found in the sediments of the Savannah River. The timber industry, which predominates land usage in the watershed, uses relatively few pesticides when compared to other more intensive agricultural practices. The hydrocarbons found in the harbor are primarily a byproduct of the burning of fuels. Those compounds would be expected where motor-powered vessels are used. The heavy metals are both a component of the region's natural soils and components of industrial discharges. Those discharges, which also contain a variety of other chemical compounds, are permitted by the states through the National Pollution Discharge Elimination System (NPDES). The NPDES permit program was established by the Clean Water Act of 1972 and is administered by the states for EPA. As industrial development along the river increases and Georgia and South Carolina permit discharges of more pollutants into the Savannah River, the river's sediments will contain more of those compounds. That will increase the concentrations of those materials in the sediments to levels where the sediment could possibly be considered contaminated. Therefore, one mechanism of reducing both the potential environmental impacts of dredging and the cost of dredging would be for the states to reduce the total volume of pollutants which they allow to be discharged into the Savannah River watershed.

A.5.16 B. Disposal Areas. Operation of the disposal areas can produce environmental impacts in a variety of ways. Minimizing those impacts is one goal of harbor operations. The major areas where operation of the disposal areas impacts the environment are described in the following paragraphs.

A.5.17 1. Weir Discharge Quality. Water which transports the sediment from the riverbed to the confined disposal area is discharged back to the environment through the weirs. The weirs allow the detention time and discharge rate to be controlled. As detention time increases, more finer-grained particles which settle slower are retained within the disposal area. Sometimes actions which occur within the disposal area can degrade the quality of the water passing through it. The initial filling of an area which contained extensive vegetative growth on the disposal area floor can result in a reduction in the DO in the water as the decomposing vegetation withdraws oxygen out of the water column. When this occurs, the DO in the water being discharged may be less than that of the water from the dredge pipe.

A.5.18 Impacts from the weir discharge quality could be reduced from any of the following measures:

- * Equalize flow across the weirs so that flow is not concentrated along one pathway.
- * Discontinue discharges when state water quality standards are not being met.
- * Discharge a level of suspended solids which causes no harm to aquatic life.
- * Pond the water within the area as high as the dike height will allow to maximize the settling time and, thereby the solids retention within the area.
- * Remove excessive growths of vegetation within an area before disposal operations flood the area.

A.5.19 2. Timing of Dike Improvements. Dike improvements can result in environmental impacts if performed at the wrong time. As stated previously, migratory birds do nest on the dikes and Federal law requires that those nesting birds be protected. Impacts on migratory birds from dike improvements could be further reduced only from the following measures:

- * Better compliance with the existing laws.
- * Schedule and perform dike improvements outside the bird nesting season.

A.5.20 3. Extent of Dike Improvements. Dike improvements can result in environmental impacts if performed improperly. All dike raisings are now designed with the outer toe of the existing dike remaining fixed. In this way, all construction occurs inside the footprint of the existing disposal area, with no impacts to additional wetlands. Impacts on wetlands from dike improvements could be reduced from any of the following measures:

- * Strict adherence in the field to the dike raising design where all fill is placed within the boundary of an area's existing footprint.
- * Continued raising of existing dikes so that no new disposal areas would need to be developed.

A.5.21 4. Timing of Disposal Activities. Disposal operations can result in environmental impacts if performed at the wrong time. As stated previously, migratory birds do nest in the disposal areas. Impacts on migratory birds from disposal activities could be reduced from the following measures:

- * Better inspection of the areas to ensure that nesting birds are not present when disposal activities begin.
- * Schedule and perform disposal activities outside the bird nesting season.

A.5.22 C. Increasing Fish and Wildlife Value. Not only can operation of a harbor result in adverse environmental impacts, but it can also produce benefits for fish and wildlife. Increasing the beneficial aspects of harbor operations on fish and wildlife is another goal of harbor operations. The major areas where harbor operations could benefit the environment are described in the following paragraphs, with potential benefits to fish being described first, then potential benefits to wildlife.

A.5.23 1. Shortnose Sturgeon Habitat. Shortnose sturgeon are considered endangered under the terms of the Endangered Species Act and, as such, have been designated as worthy of special considerations due to their low population levels. This species of fish is found in the upper reaches of the harbor, generally near the salt water interface. The sturgeon are found in deep areas of the harbor during the summer months where somewhat cooler water exists. Dredging could be used to create and maintain additional deep-water areas for this species. For these areas to serve as refuge areas for these fish, the areas should be either located outside the shipping channel, or extend below the normal depth of the channel. Periodic maintenance of these areas would be necessary as the normal sediment load would otherwise refill those holes. Since dredging has not been linked with direct adverse impacts on this species, the required periodic maintenance would not be expected to produce adverse impacts. This species is known to be quite tolerant of low DO, so development of low DO in the refuge areas would not decrease their value to this species.

A.5.24 2. Fishermen Access. Much of the shoreline of Savannah Harbor is developed for industrial or commercial purposes. Little public access is available to the water. Some fishermen do presently cross existing fences to gain access to the shoreline, especially around the Tidegate. That facility and the shoreline of the diked disposal areas could be opened to provide access for fishermen. This would allow more use and benefit from the fishery resource located in the immediate project area. Concerns about property owner liability, safety, vandalism and ensuring the integrity of the dikes would have to

be fully addressed. It is likely that only pedestrian access would be acceptable, since even that would increase the use of the fishery resource. Development and maintenance of an adequate parking area would be needed to significantly increase fishermen access, and the concerns about liability, safety and vandalism would also have to be addressed for a parking facility.

A.5.25 3. Wildlife Habitat. The diked disposal areas constitute relatively isolated high ground which stands in marked contrast to the expansive wetlands and residentially- or industrially-developed high ground which surround those sites. The isolated high ground provides a rare habitat in this area. Shrubs exist along the entire perimeter of the dikes where the wetlands adjoin the constructed dikes. Wildlife use of the areas is somewhat limited by the lack of trees on the sites, but some trees do exist where the dikes are set back from the shoreline leaving an unused elongated tract of land. The wildlife habitat value of the disposal areas could be increased by having trees on more acreage. It is recognized that trees are generally not allowed on embankments because of (1) the way in which tree roots weaken the stability of the embankment, and (2) the difficulties the tree stems cause in inspection and repair of the embankment. Benefits to birds can be obtained more easily within the confines of the designed use of these tracts (dredged material disposal). The following paragraphs address those possibilities.

A.5.26 4. Bird Nesting Habitat. The disposal areas are used extensively by birds for nesting habitat. The value of these sites for these activities can be improved through either of three ways; creating new nesting areas, maintaining existing upland sites or increasing the nesting value of existing sites.

A.5.27 a. Creating New Areas. New nesting sites could be obtained within existing disposal areas through the following methods:

- * Shaping the deposited material into mounds so that dry areas would exist even when disposal operations are occurring.
- * Maintaining a water level within an area during the nesting season such that dry areas exist within the flooded site.
- * Holding water in an area until the nesting season.

A.5.28 New nesting sites could also be created through the construction and maintenance of an island in the nearshore area. One site with potential for this purpose is north of the north jetty at the harbor entrance.

A.5.29 b. Maintaining Existing Upland Sites. Construction activities are sometimes necessary to maintain the present habitat value of a site. Colonial nesting birds prefer sandy sites which are essentially free of vegetation. At most sites, vegetation will increase over the years if no further

onsite activity occurs after initial placement of the material. Such is the case at the Jones/Oysterbed Island disposal area where dike raising is performed quite infrequently. Bird nesting can be improved by periodically removing the vegetation of a site which would otherwise be attractive. This could consist of simply back-dragging a bulldozer over the site to scrape off existing vegetation. An alternate method of producing a vegetation-free surface would be the deposition of more material on that site. If the new deposition completely covered the old vegetation, the value of the site to colonial nesting birds would be completely restored.

A.5.30 c. Increasing the Value of Existing Sites. The value of existing nesting sites within the disposal areas could be increased through the following methods:

- * Placing the dredged material away from the edge of the dike to produce a more isolated nesting site.
- * Restricting access by vehicles, pedestrians and land-based predators (raccoons) to a site used for nesting, to produce a more isolated nesting site.

A.5.31 5. Bird Feeding And Resting Areas. Birds also use the diked disposal areas as resting and feeding habitat.

A.5.32 a. Migrating Waterfowl. Migratory waterfowl use flooded disposal areas during both the Spring and Fall migrations. The value of the Savannah Harbor sites to these species is tied directly to whether a site is flooded. If disposal operations are underway or have only recently stopped so that water is still present in an area, the site will be used by waterfowl. The sites could provide more habitat for waterfowl if (1) disposal operations could be scheduled and performed during the times when the birds were passing through this region, or (2) water was held over until the birds passed through.

A.5.33 b. Shorebirds. Various shorebirds use the disposal areas during non-nesting seasons. Since these species are so dependent on shallow areas and shorelines, their use of the sites is primarily tied to the flooding associated with disposal operations. Expansive dry areas provide little habitat for these species. The value of a confined disposal area to shorebirds could be increased if a mixture of shallow/emergent areas was available throughout the non-nesting seasons.

A.5.34 c. Water Level Management. The value of a confined disposal area to shorebirds and waterfowl for feeding and resting is highly dependent on the existence and depth of water at the site. As expressed previously, shallow areas are generally best. Therefore, the value of a site for these activities would be maximized with a slowly falling water

surface. A drop of 2 to 3 inches every couple of weeks would probably be ideal, as it would continue to make new food sources available and expose new sites for resting.

A.5.35 6. Bird Watching. As mentioned previously, the diked disposal areas along Savannah Harbor receive extensive use by birds. Access to the sites is generally granted for researchers who are counting or otherwise studying bird use of the sites. Expanding the access to bird watching would result in an increase in an appreciation of the wildlife value which of these sites provide. This is not specifically a method of increasing the sites' wildlife value, but it would increase the human benefit of the wildlife using sites and the wildlife habitat which the sites presently provide.

A.6.00 Maximizing Beneficial Uses of Dredged Material. Dredged material can often be much more than an item requiring a place for disposal. Several beneficial uses are available for this material. Generally, these uses are to be encouraged as they result in a reduction in the volume of material placed in the confined disposal sites, thereby extending the useful life of those sites.

A.6.01 A. Construction Material. Often the sediment removed from a river can be used as a construction material. In some areas the river is mined to obtain sand for sale for construction purposes. The construction of roadbeds and building foundations often requires the addition of fill material to increase the elevation of a site or replace native soil which would not provide the required stability. Maintenance material removed from the upper reaches of Savannah Harbor is generally good sand and could be used as a construction material. Silty material is generally not as good for construction purposes as it has undesirable characteristics when wet.

A.6.02 1. Onsite. All of the dike construction and improvement projects which have been performed to date for the Savannah Harbor Navigation Project have used dredged material. This has had the combined effect of (1) removing material from a disposal site, thereby restoring previously used storage capacity, and (2) reducing transportation costs to get needed material to a construction site. Future use of this technique is dependent on the availability of suitable material. Higher percentages of silt exist in maintenance material excavated from the middle harbor.

A.6.03 2. Offsite. As expressed previously, maintenance material removed from the upper reaches of Savannah Harbor is generally good sand. The disposal area used for much of that material is Site 1N (Onslow Island North). Material placed on that site is removed by Chatham County and the GA DOT for construction purposes.

A.6.04 Harbor interests are presently investigating the feasibility of reusing sediments which have been removed from the middle reaches of the harbor. Those sediments are predominately fine-grained silts and may be useful in the construction of bricks. Initial testing indicates that the deposited material could be used to form a variety of quality bricks. More detailed testing is under consideration to determine the material variability and energy requirements for brick production. Subsequent studies would determine the economic viability of such an operation, including the potential siting of a production plant at the disposal areas. If the operation is found to be economically feasible, it could provide an effective means of beneficially using dredged sediments. The operation would reduce the volume of deposited material stored at the confined disposal facilities, thereby extending the useful life of those sites.

A.6.05 B. Beach Disposal. Dredged material which contains a very high percentage of sand and is located close to a beach can be placed on the beach to serve as a source of erodible material for waves and currents. This substitute fill material therefore protects the high ground against which it is placed from being lost to erosion. The value of this technique depends primarily on the quality of the dredged material, the type of equipment used, the cost of placing it on the beach and the length of time the material stays on the beach. The use of pipeline dredges requires excavation of a deep layer of material to ensure a high solids content in the deposited dredge slurry. If the solids content is too low, the large volume of water pumped by the dredge may move the deposited material off the upper beach slope into the lower submerged portion of the slope. This decreases the value of this procedure when expansion of the high beach is desired. However, when the goals are clearly defined and understood, and the design and construction parameters indicate that such placement would be successful, beach disposal is a very beneficial use of a material which would otherwise be discarded.

A.6.06 C. Wetland Creation. Wetlands have been recognized as having multiple valuable characteristics. The acreage of these habitats has been greatly reduced as the result of filling, draining and salinity changes. Dredged material can be used to raise the elevation of a submerged site to the point that the site is suitable for the growth of wetland vegetation. Where the design parameters indicate that such placement and subsequent

vegetative growth would be successful, deposition of dredged material to create wetlands is a very beneficial use of material and a way of stemming the loss of this valuable habitat.

A.6.07 D. Bird Islands. Isolated shorelines which provide nesting, resting and feeding habitat to shorebirds have become increasingly rare as man's development increases adjacent to water. Dredged material can be used to raise the elevation of a submerged site to the point that an isolated island can be created for use by shorebirds. Where the design parameters indicate that such placement would be successful, deposition of dredged material to create bird islands is a very beneficial use of material and a way of stemming the tide of the loss of this valuable habitat.

A.6.08 E. New Islands. Creation of isolated offshore islands can also be beneficial for other purposes. If the conditions are right, the newly created site may provide good nesting habitat for endangered sea turtles. Offshore islands would also provide a degree of storm protection from the adjacent coastline by reducing the wave impact which reaches the coast. Small offshore islands may be viewed as being aesthetically pleasing, thereby providing a visual benefit to one's view from the coast.

A.6.09 F. Nearshore Berms. Placement of dredged material in the nearshore area could also be designed to construct and/or maintain nearshore berms. These submerged mounds of material can be designed to be either stable or unstable. An unstable berm would be one that erodes and serves as a source of material for waves and currents in the nearshore sand sharing system. A stable berm is one that generally does not erode, but maintains its shape except in response to large infrequent storms. Either design provides a variation on bottom topography, which can serve as a valuable habitat for fish.

A.6.10 G. Within Disposal Areas. Dredged material can be used beneficially within the disposal areas to provide valuable wildlife habitat. This aspect was described previously, but use of the deposited material in this manner is considered a beneficial use of material.

APPENDIX B

BIOLOGICAL ASSESSMENT
OF
THREATENED AND ENDANGERED SPECIES

BIOLOGICAL ASSESSMENT
OF
THREATENED AND ENDANGERED SPECIES

SAVANNAH HARBOR LONG TERM MANAGEMENT STRATEGY (LTMS)
CHATHAM COUNTY, GEORGIA AND JASPER COUNTY, SOUTH CAROLINA
SEPTEMBER 1995

B.1.00 Project Description. Development of a Long Term Management Strategy (LTMS) for the dredging and dredged material disposal for the Savannah Harbor Navigation Project located in Chatham County, Georgia and Jasper County, South Carolina. The selected management plan would seek to maximize the use of disposal areas and identify efficient dredging schemes. Extensive engineering, economic and environmental analyses were conducted on the following three alternatives; (1) the Federal least cost dredging plan; (2) the Federal least cost dredging plan with diking of Disposal Area 14A; (3) a crust construction/rotation method with diking of Disposal Area 14A. A Mitigation Plan was developed to replace the functional values of wetlands which would be lost by the construction of dikes at Disposal Area 14A and miscellaneous disposal area operations in South Carolina. Additional alternatives were considered to allow incremental evaluation of new dredging or disposal techniques. Those alternatives included (4) installing underdrains which drain to either Savannah or Back River, (5) construction of nearshore submerged berms, (6) construction of a feeder berm off Tybee Island, (7) use of a hydraulic dredge to maintain berthing areas with direct deposition of the excavated sediments in a confined disposal facility, (8) sediment control features consisting of advance maintenance deepening the Sediment Basin and turning basins, and deepening the advance maintenance section near the Kings Island Turning Basin to provide off-channel storage of sediment, and (9) disposal of suitable material on Tybee and Daufuskie Islands. Alternative 8 consisted of the combination of the crust construction/rotation method, the diking of Disposal Area 14A, and the new dredging and disposal techniques and options.

B.1.01 The Federal least cost dredging plan involves the use of the closest acceptable disposal area. Material would be pumped the shortest distance possible and all existing inner harbor disposal areas would be used. The crust construction/rotation method involves the use of dried material from within the disposal areas to raise the dikes, thus avoiding the need to haul construction fill material for long distances to the sites to increase the capacity of the disposal areas. The disposal area must be taken out of use for 18 months to allow for extensive ditching and windrowing of the disposal area for proper drying

Thus, the use of disposal areas must be rotated. To allow an efficient rotation between disposal areas, the crust construction/rotation alternative included the diking and use of Disposal Area 14A, a currently undiked but previously used disposal site.

B.1.02 The nearshore/offshore disposal location to be used for a specific dredging contract would be decided during project design and award based on identification of the least cost, environmentally-acceptable disposal option. If disposal at a different location is found to be more desirable for environmental or other reasons but would be more costly than the one designated as the least cost, environmentally-acceptable, it could be pursued using appropriate cost sharing authorities.

B.2.00 Environmental Setting. The project area is located mostly in Chatham County, Georgia, and Jasper County, South Carolina. These counties lie in the Coastal Plains physiographic province. The area is roughly bisected by the Savannah River which, including certain of its tributary channels, constitutes the boundary between the states of Georgia and South Carolina. The river enters the study area flowing in a generally southerly direction, then bends in the vicinity of Savannah to flow in a generally easterly direction to the Atlantic Ocean. Mainland areas are separated from the ocean by a line of barrier islands and intervening salt marshes and tidal rivers. The mouth of the Savannah River is located just north of Tybee Island.

B.2.01 The mainland of Chatham County, Georgia, is dominated by the City of Savannah. The city center is located on the southern bluff of the Savannah River approximately 18 miles above the river's mouth. The lands south of the city center and west of the coastal marshes are primarily devoted to urban development. Urban and industrial development extends northwestward along the Georgia side of the river, gradually giving way to natural woodlands and agricultural areas in the western part of the county.

B.2.02 The mainland of Jasper County, South Carolina, is predominately rural. Lands opposite the city of Savannah are characterized by a system of dikes, canals, and former rice fields constructed in the 18th and 19th centuries. The South Carolina side of the Savannah River is dominated by a brackish/salt marsh system.

B.2.03 Tidal fluctuations within Savannah Harbor are semi-diurnal, averaging 6.8 feet at the mouth of the harbor and 7.9 feet at the upstream limit of the harbor. The tidal influence extends upriver approximately 45 miles to Ebenezer Landing, Georgia. The project area enjoys a temperate climate characterized by warm, humid summers and mild winters. The

seasonal mean temperatures are 51 degrees in Winter, 64 degrees in Spring, 80 degrees in Summer, and 66 degrees in Autumn. Precipitation averages 48.9 inches per year, with about one-half falling during summer thunder showers. Snow is rare. The frost-free season averages approximately 270 days. Hurricanes pose an occasional threat, mainly in September and October.

B.2.04 The Savannah area is rich with natural resources associated with a coastal environment. The Savannah River, other coastal streams, sounds, and adjacent Atlantic Ocean waters contain an abundance of marine life, some of which has great commercial value, such as shrimp, blue crabs, and oysters. The barrier islands and marshlands support many species of plants and animals, all part of the highly productive biomass of an estuarine system.

B.2.05 South Carolina, by amendment dated May 28, 1993, to its Water Classifications and Standards, Regulation 61-68, has classified the portion of Savannah Harbor within its boundaries upstream from Fort Pulaski to the Seaboard Coastline RR as Class SB* and the portion oceanward as Class SA waters. Class SB is defined as tidal saltwaters suitable for primary and secondary contact recreation, crabbing, and fishing, except harvesting of clams, mussels, or oysters for market purposes or human consumption. Also suitable for the survival and propagation of a balanced indigenous aquatic community of marine fauna and flora. Class SA is defined as tidal saltwaters suitable for primary and secondary contact recreation. Suitable also for uses listed in Class SB, with the same exception. The State of Georgia, through its Rules and Regulations for Water Quality Control, Chapter 391-3-6, Revised May 29, 1994, has classified the Savannah River from mile 0 at Fort Pulaski to the open sea (including the littoral waters of Tybee Island) as recreation waters. From Fort Pulaski to Mile 27.4 (Seaboard Coastline RR Bridge), the river is classified as Coastal Fishing. The latter stretch of the Savannah River used to be classified as Industrial/Navigation. However, studies were conducted by the Georgia Department of Natural Resources during the fall of 1985 which resulted in the reclassification of that stretch of the river to Coastal Fishing.

B.2.06 In 1927, the U.S. Fish and Wildlife Service established the Savannah National Wildlife Refuge which encompasses 26,000 acres of lowlands and marshes along the eastern bank of the Savannah River beginning near river mile 18.5. The southern end of the Refuge lies adjacent to the upper three miles of Savannah Harbor. The refuge is located on the Atlantic flyway of migratory waterfowl. Approximately 3,000 acres of old rice fields and 18 freshwater impoundments have been developed into suitable resting and breeding areas for thousands of waterfowl that winter there each year. The Refuge is an important nesting area for the wood duck and provides excellent habitat for many

other species of birds, mammals, reptiles, and amphibians. The Refuge helps serve the recreational needs of the area through its fishing, hunting, and wildlife observation opportunities.

B.3.00 Threatened and Endangered Species. Table 1 is a list of the threatened or endangered species that might be in the project area. The list contains Threatened and Endangered Species which may be found in the Savannah Harbor Area, Chatham County, Georgia. These species were excerpted from a list provided by FWS, dated 5/31/89. In accordance with Section 7 of the Endangered Species Act of 1973, we have evaluated the impacts the proposed action could have on any threatened or endangered species potentially occurring in the project area.

B.4.00 Discussion of Potential Impacts. Savannah District has reviewed information concerning each of these species and evaluated the potential for the proposed action to impact these species. The results of our evaluation are contained in the following paragraphs:

B.4.01 Manatees (*Trichechus manatus*). Manatees inhabit sluggish rivers, sheltered marine bays, and shallow estuaries, eating most aquatic plants and any terrestrial plants they can reach. Records in Georgia are primarily random sightings and carcass finds and are not the result of systematic research. Systematic aerial surveys were initiated in 1976, and sight records have been increasing in south Georgia in recent years. The U.S. Fish and Wildlife Service has reported that several were observed in the harbor in the summer of 1987. The Georgia population is primarily migratory in nature and, therefore, fluctuates with season. The majority are sighted southward along the Georgia coast from Chatham County toward Florida. Manatees have been observed infrequently in the Savannah River as far upstream as the King's Island Turning Basin (Rathburn et al., 1981); however, their occurrence is rare. Manatees are found in Georgia and South Carolina mainly during the warmer months of the year. If all work on harbor maintenance were conducted during the winter, there would be less likelihood of harming these mammals. However, when dredging occurs during the summer, precautions to avoid injuring any animal present will need to be implemented. Such precautions will include but may not be limited to; instruction of personnel associated with dredging of the possible presence of manatees and the need to avoid the animals; operation of the vessels associated with the project at "no-wake" speeds at all times when in waters providing vessel drafts less than 4 feet from the bottom; boats used to transport personnel will be shallow-draft vessels, where navigation safety permits and will follow routes of deep water to the extent possible; designated endangered species watchers will be posted in each boat; and

TABLE 1

FEDERALLY LISTED THREATENED AND ENDANGERED SPECIES

SPECIES	STATUS	DISTRIBUTION IN GA
MAMMALS		
West Indian Manatee, <u>Trichechus manatus</u>	E	Coastal Waters
Florida Panther, <u>Felis concolor coryi</u>	E	Entire state
Finback Whale, <u>Balaenoptera physalus</u>	E	Coastal waters
Humpback Whale, <u>Megaptera novaeangliae</u>	E	Coastal waters
Right Whale, <u>Eubalaena glacialis</u>	E	Coastal waters
Sei Whale, <u>Balaenoptera borealis</u>	E	Coastal waters
Sperm Whale <u>Physeter catodon</u>	E	Coastal waters
BIRDS		
Peregrine Falcon, <u>Falco peregrinus</u>	E, T(S/A)**	Entire State
Bald Eagle, <u>Haliaeetus leucocephalus</u>	E	Entire State
Piping plover, <u>Charadrius melodus</u>	T	Coast
Wood Stork, <u>Mycteria americana</u>	E	Southeastern swamps
Bachman's Warbler, <u>Vermivora bachmanii</u>	E	Entire State
Kirtland's Warbler, <u>Dendroica kirtlandii</u>	E	Coast
Red-cockaded Woodpecker, <u>Picoides borealis</u>	E	Entire State
REPTILES		
American Alligator, <u>Alligator mississippiensis</u>	T(S/A)*	Coastal plain
Eastern Indigo Snake, <u>Drymarchon corais</u>	T	Southeast
Kemp's ridley (Atlantic) Turtle, <u>Lepidochelys kempii</u>	E	Coastal waters
Green Turtle, <u>Chelonia mydas</u>	T	Coastal waters
Hawksbill Turtle, <u>Eretmochelys imbricata</u>	E	Coastal waters
Leatherback Turtle, <u>Dermochelys coriacea</u>	E	Coastal waters
Loggerhead Turtle, <u>Caretta caretta</u>	T	Coastal waters
FISHES		
Shortnose Sturgeon, <u>Acipenser brevirostrum</u>	E	Coastal rivers

NOTE:* Alligators are biologically neither endangered nor threatened. For law enforcement purposes they are classified as "Threatened due to similarity of appearance". Alligator hunting is regulated in accordance with State law.

** The US FWS has proposed that this subspecies be removed from the Federal List of Threatened and Endangered Species, see the Federal Register, 30 June 1995, pp. 34406-34409.

contractors will keep a log detailing all manatee sightings, collisions, deaths or injuries during the contract period. Any sighting or collision will be reported to the Fish and Wildlife Service. Provided the above conditions are placed on all dredging contracts in the warmer months, the proposed management plan would not jeopardize the continued existence of this species nor will habitat determined to be critical be destroyed or modified.

B.4.02 Whales. There are six species of whales listed as endangered in the State of Georgia: Right whale (Balaena glacialis), Sei whale (Balenoptera borealis), Blue Whale (Balaena musculus), Sperm Whale (Physeter macrocephalus), Finback whale (Balaenoptera physalus), and Humpback whale (Megaptera novaeangliae). These species could be found in transit through the area during migrations.

B.4.03 Right whale. Right whales visit the coasts of Georgia and Florida to calve in shallow coastal water. The winter calving season for the right whale appears to begin as early as September and can end as late as April. The peak of whale abundance and calving appears to be from December through March. The right whale is of particular concern in Savannah in that it is expected to occasionally be found off shore as individuals transit the coast towards their wintering/ calving grounds.

B.4.04 The National Recovery Plan for the Northern right whale, dated December, 1991 (NMFS, 1991), defines the coastal waters of the southeastern United States and, especially, the shallow waters from Savannah, Georgia, south to Cape Canaveral, Florida, as the wintering ground for a small but significant part of the Atlantic right whale population. According to the recovery plan, most records of sighting involve adult females, many of them accompanied by very young calves, although a few juveniles and males have been sighted in the region. The area surrounding Savannah Harbor which could be affected by commercial ships visiting the harbor or dredges used to maintain channel depths in the Navigation Project is not within the critical habitat defined by the NMFS for this species.

B.4.05 A more recent study than the recovery plan (Kraus et al., 1993) has found the area around the Florida/Georgia border and Jacksonville, Florida, in the widest area of the shallow-water shelf in the Georgia Bight, to be the primary and probably only calving ground for western North Atlantic right whales. They found cow/calf pairs to be primarily limited to the coastal waters between latitudes 27 degrees 30 minutes N and 32 degrees N. They also report right whales to be concentrated between Daytona Beach, Florida and Brunswick Georgia. Highest densities are around Jacksonville, Florida, and the Florida/Georgia border. Most whales occur between December and February within 15 miles

of shore (but can be seen between November and late March). A few sightings have been reported as early as September and as late as June. This study documents six right whale sightings between Brunswick and Savannah. They quote an earlier estimate that no more than 350 right whales survive in the western North Atlantic and state that there have been 272 sightings of 87 identified non-calf right whales and 66 calves between 1980 and 1992. They further state that 74 percent of the known reproducing females have been documented off the southeast coast for the period 1980 to 1992.

B.4.06 Recent known occurrences of right whales in the Savannah area.

a. 1992 (Dec 1992 to Mar 1993). Aerial surveys for right whales have been conducted for the past two years by the Savannah District during Savannah Harbor bar channel dredging. During the December 1992 bar channel dredging, aerial surveys were conducted by Christopher Slay, New England Aquarium, from November 30 to December 20, 1992. Surveys were flown on all but one day, December 19, 1992. One right whale was spotted during the survey (December 8, 1992). These data indicate that 5 percent of the survey days resulted in detection of a right whale.

b. 1993 (Dec 1993 to Mar 1994). Two right whales were spotted by a pilot boat and the pre-dredge turtle survey crew on December 4, 1993. Aerial surveys were flown every day that weather permitted from 12/12/93 to 2/22/94 (58 days flown out of 73 possible). Whales were spotted on 12/12/93 (3 subadults), 12/18/93 (cow/calf pair), 1/23/94 (cow/calf pair). These data indicate that 5 percent of the survey days resulted in detection of right whales. However, 2 out of 19 survey days in December (11 percent) resulted in detection of right whales.

c. 1994 (Dec 1994 to Mar 1995). Aerial surveys were conducted as weather allowed between December 1 and 31, 1994. Twenty complete surveys were flown and one whale was spotted on December 5, 1994 (5 percent of survey days).

d. 1995 (Dec 1995). No aerial survey was conducted. No whales were sighted from the dredge during the Bar Channel dredging performed from December 5 to 26, 1995.

e. Analyses by Kraus et al., 1993, on the mean latitude of whale sightings by week, indicate that areas at or north of Savannah fall within one standard deviation of the mean for December 1 to January 4. This is also true for the weeks of March 16 through April 5.

B.4.07 Human activities, including pollution, ship traffic, fisheries activities, and habitat loss, have been suggested to be significantly affecting the species (Kraus et al., 1993). Ship strikes are known to be a major cause of mortality in the right whale (NMFS, 1991), although there are apparently no documented strikes by ships associated with any southeastern dredging project (NMFS, 1991). Most right whales spotted in the southeast are found from 1 to 15 nautical miles from shore (Kraus et al., 1993, Ellis et al., 1993). Kraus et al. 1993, found that swimming speeds of cow-calf pairs averaged 0.41 km/hr and whales not accompanied by calves averaged 0.51 km/hr. Movements of individual cow-calf pairs ranged from less than 1 km/day to 38.8 km/day. One statistical test found that non-cow right whales travel significantly farther and faster than right whales accompanied by a calf. They also found that cows with calves are more active at the surface than other classes of right whales in the region. It appears that the behavior of this species, including its swimming speed, makes it particularly susceptible to impact from collisions with ships.

B.4.08 Available data indicate that right whales can be expected to transit the Savannah bar primarily during the month of December for the fall migration and for the spring migration to begin transit in mid-March. Impacts from hydraulic dredging associated with maintenance dredging of Savannah inner harbor are expected to be minimal. Some Bar Channel dredging operations, such as hopper dredging and vessel traffic associated with offshore hydraulic dredging, could potentially impact this species unless protective provisions are in place to avoid collisions.

B.4.09 To ensure that the proposed work does not impact the right whale, the District would abide by the conditions set by the NMFS in its extant Biological Opinion. The District has also established precautionary collision avoidance measures to be implemented during dredging operations that take place during the time right whales are present in waters off Savannah harbor. These measures are not limited to hopper dredging but are also applied to any dredging activity that requires transporting of dredged material through waters that might contain right whales to an offshore or nearshore disposal site. These measures apply to the dredge and any attendant vessel associated with the dredging activity with a length of over 20 feet.

B.4.10 Each dredging contract for the Savannah Harbor Bar Channel will contain the following provisions. Each contractor will be required to instruct all personnel associated with the dredging/construction project about the possible presence of endangered right whales in the area and the need to avoid collisions. Each contractor will also be required to brief his personnel concerning the civil and criminal penalties for

harming, harassing or killing species that are protected under the Endangered Species Act of 1973 and the Marine Mammal Protection Act of 1972. Dredges and all other disposal and attendant vessels are required to stop, alter course, or otherwise maneuver to avoid approaching the known location of a right whale. The contractor will be required to submit an endangered species watch plan that is adequate to protect right whales from the impacts of the proposed work. The conditions in the current regional opinion, which the District would also abide by as long as the opinion is in effect, include the following: Monitoring by endangered species observers with at-sea large whale identification experience to conduct daytime observations for whales between December 1 and March 31. During daylight hours, the dredge operator must take necessary precautions to avoid whales. During evening hours or when there is limited visibility due to fog or sea states of greater than Beaufort 3, the dredge must slow down to 5 knots or less when transiting between areas if whales have been spotted within 15 nm of the vessel's path within the previous 24 hours. (Contractors will be required to use daily available information on the presence of right whales in the project area.) One hundred percent dedicated daytime whale observer coverage is required between December 1 and March 31. Monitoring by sea turtle observers is allowed between April 1 and November 30. If a Right Whale Early Warning System (RWEW) is in place, it will be deemed to provide adequate information on the presence of whales during dredging operations. The District agrees to abide by and incorporate into its dredging contracts within the critical habitat area all mutually agreed upon operating rules emanating from this RWEW system.

B.4.11 Other whales. Dredging activities are not expected to affect other species of whales for two reasons. One, no other species of whales are expected to occur with regularity in nearshore waters where dredging would occur. Second, other whales are not known to exhibit behaviors that would make them susceptible to ship collisions as is known to be the case for the right whale.

B.4.12 Eastern Cougars (Felis concolor cougar). There have been no confirmed sightings of eastern cougars in the area of Savannah harbor in recent years. The proposed management plan would not include substantial land-use changes that would provide or degrade any habitat suitable for these cats. Neither would the management plan destroy or modify any habitat determined critical for the species' survival.

B.4.13 Wood Stork (Mycteria americana). Wood storks are known to frequent the more protected estuarine areas of the region for both feeding and nesting. Wood stork rookeries are located on hammocks and along the edges of the marsh behind the barrier islands. This species has been observed in the Savannah Harbor area, particularly at the Savannah National Wildlife Refuge and in the Wright River adjacent to the dredged material disposal areas. They occasionally rest within the disposal areas and feed there when conditions are right. A recent high number of 55 individuals were observed feeding in the disposal areas on 23 September 1995. These birds have a unique feeding technique and require higher prey concentrations than other wading birds. Optimal water regimes for the wood stork involve periods of flooding, during which prey (fish) populations increase, alternating with dryer periods during which receding water levels concentrate fish at high densities. Fish trapped in the dredged material disposal areas during maintenance dredging may provide a source of food for wood storks once dewatering of the disposal areas are near completion. Continued use of upland disposal sites could be considered a minor enhancement of wood stork feeding habitat. Finally, the proposed plan would not destroy or modify any habitat determined critical for the species' survival.

B.4.14 Bald Eagle (Haliaeetus leucocephalus). Bald eagles are found in the Savannah Harbor area. They have been observed resting and hunting in the dredged material disposal areas north of Savannah. A recent high number of 4 individuals were seen flying over the disposal areas on 23 November 1994. Two active nests are located at the Savannah National Wildlife Refuge and several eaglets have been fledged from these nests in recent years. Bald eagles have also nested along the Wright River north of the disposal areas. The proposed management plan would not affect the existing nest sites or areas immediately adjacent to them. The proposed plan may enhance the disposal areas for eagles by attracting migrating birds to the diked disposal areas. Standing water in these disposal areas is known to be used by waterfowl in winter and during their migrations, and eagles will feed on waterfowl. The proposed management plan would also not destroy or modify any habitat determined critical for the species' survival.

B.4.15 Peregrine Falcon (Falco peregrinus). The American peregrine falcon (*F.p. anatum*) was listed as endangered in 1970 under the Endangered Species Conservation Act of 1969, and was listed as endangered under the Endangered Species Act of 1973. Other races were listed as threatened or endangered due to similarity of appearance in 1984. The US FWS now proposes (FR 30 June 1995, pp. 34406-34409 to remove the species from the endangered species list. This is a large, rapid flying falcon

that feeds on other birds. It occurs throughout much of North America, with few nesting birds in the plains or southeast. Birds that nest in subarctic areas generally winter in South America, while those that nest at lower latitudes exhibit variable migratory behavior. Peregrine falcons declined precipitously in North America following World War II. Research implicated DDT as causing egg shell thinning, resulting in nesting failures. Following restrictions on DDT, the population size of the species has increased. In the fall and spring, small numbers of this species -- usually 1 or 2 individuals -- can sometimes be seen feeding on shorebirds in the disposal areas. The proposed management plan should maintain or increase the numbers of shorebirds using the disposal areas. That should be beneficial to this species.

B.4.16 Piping Plover (Charadrius melodus). This species is a small, stocky shorebird that resembles sandpipers. Preferred habitats for the species are sandy beaches along the ocean and inland lakes, bare areas in dredge disposal sites, and natural alluvial islands in rivers. Shorelines with little vegetation are preferred for both nesting and feeding. These plovers feed primarily on fly larvae, beetles, crustaceans, mollusks, and other invertebrates that they pluck from the sand (Bent, 1929). Breeding grounds along the Atlantic Coast range from Newfoundland to North Carolina. Wintering areas on the Atlantic Coast are from North Carolina southward through Florida and in the Bahamas and West Indies. The piping plover departs for wintering habitats by early September and returns to the breeding grounds in late March or early April. This species has been observed in the past on Tybee Island during the winter months (Steve Calver, personal observation) and could be expected at that time on other shorelines near the coast. A January 1991 survey by the GA DNR located 27 individuals on the Georgia barrier islands (information from Dwight Harley, 4/30/91). A January 15, 1996 survey found 124 individuals along the Georgia coast (Mike Harris (GA DNR), personal communication). The primary threats to the piping plover are modification and destruction of habitat and disturbance of nesting adults and chicks (US FWS, 1985). This species' occasional use of the dredged material disposal areas would not be impacted by the proposed management plan. The bird island construction proposed as part of the mitigation plan for diking Disposal Area 14A is expected to provide additional wintering habitat for this species. Proposed disposal operations on Daufuskie and Tybee Islands could provide additional wintering habitat by increasing the amount of both high tide and intertidal beach. The proposed plan would not destroy or modify any habitat determined critical for the species' survival.

B.4.17 Red-cockaded Woodpecker (Picoides borealis). This species requires forested habitat of at least 50 percent pine 30 years or older. No habitat that could potentially be used by this species would be impacted by the project. No known colony of these woodpeckers is located along the Savannah Harbor or on adjacent properties. The project would not destroy or modify any habitat determined critical for the species' survival.

B.4.18 Bachman's warbler (Vermivora bachmanii). The present distribution of Bachman's warbler is unknown. Some authors consider it to probably be extinct (Post & Gauthreaux, 1989). Sightings in the mid 70's came from Charleston County, South Carolina; several Louisiana locations; Kentucky; Maryland; and near the Long/McIntosh County line in Georgia. This species formerly bred mostly in swamps with an understory of cane. It is currently extremely rare with very few recent sightings. Most authorities agree that if the Bachman's warbler still exists it is most likely in the I'on Swamp area in Charleston and Berkeley Counties, South Carolina. No habitat used by this species would be impacted by the project. The proposed management plan would also not destroy or modify any habitat determined critical for the species' survival.

B.4.19 Kirtland's warbler (Dendroica Kirtlandii). This very rare warbler breeds in Michigan and winters in the Bahamas. It is a rare transient along the Southern Atlantic Coast, including Georgia and South Carolina. We are aware of no estimate of the number of individuals migrating through the state. It would be expected to occur as a very rare migrant in coastal scrub and forest land, especially after storms. No habitat would be impacted by this project that this species might use. Moreover, the proposed management plan would not destroy or modify any habitat determined critical for the species' survival.

B.4.20 Eastern Indigo Snake (Drymarchon corais couperi). The eastern indigo seems to prefer high, dry, well-drained sandy soils, closely paralleling the sandhill habitat preferred by the gopher tortoise. However, especially during the warmer months, indigos also frequent streams and swamps, and individuals are occasionally found in flat woods. The proposed plan would not destroy or modify any habitat determined critical for the species' survival.

B.4.21 Sea Turtles. Five species of sea turtles are found along the Georgia and South Carolina coast which are listed as endangered or threatened. These are the Kemp's (Atlantic) Ridley turtle (Lepidochelys kempii), green turtle (Chelonia mydas), Leatherback turtle (Dermochelys coriacea), Loggerhead turtle (Caretta caretta), and Hawksbill turtle (Eretomochelys imbricata). All species of marine turtles listed previously are presently classified as Federally endangered, except the green sea turtle and the loggerhead turtle, which are listed as threatened. The loggerhead turtle is known to nest on Tybee Island. The Kemp's ridley, leatherback, hawksbill, and green sea turtles also inhabit Georgia waters, but nest in other areas. (Schroeder, 1987; Schroeder and Warner, 1988; and Teas and Martinez, 1989; The U. of Georgia Cooperative Extension Service, 1992; US FWS, 1993). Green turtles and leatherback turtles have been known to nest in Georgia on rare occasions (US FWS, 1993). The stranding records for Chatham County, Georgia indicate that 4 turtles were stranded in the county from January 1 to June 30, 1989 and 212 stranding occurred in the State of Georgia during 1989. Approximately 95 percent of these stranding occurred from May to November.

B.4.22 Since the turtles are known to occur in the vicinity of the Bar Channel, there is a potential that they may be directly impacted by certain dredging operations within the bar channel. Recent research by WES and historic data indicate that hopper dredges in a given situation are much more likely to cause adverse impacts to sea turtles than stationary dredges (hydraulic pipeline, clamshell, bucket). Those impacts are apparently the result of the speed at which the equipment moves across the bottom of the channel. The high speed of hopper dredges does not allow sufficient time for turtles to recognize the danger and avoid entrainment. Because of the potential impacts to sea turtles, use of stationary dredges would be preferred. However, due to the high cost of stationary dredges, hopper dredges are still used, and their use is environmentally acceptable, provided restrictions to minimize their environmental impact are included in their operation. The Corps (WES, 1994) has conducted research on the distribution and abundance of sea turtles in order to develop restrictions on hopper dredging which would minimize its impact on sea turtles. They have found that turtles are usually either missing or present in only very low numbers in Savannah from December through March. The WES study states that caution should be taken when using absolute dates for arrival and departure of sea turtles. Other factors such as seasonal differences in temporal movements and water temperature effects (relatively low abundance was found in the winter months when surface water temperatures were less than or equal to 16 degrees C.) may be at play. Restrictions on hopper dredge operation have been developed and agreed upon by NMFS and the Corps which minimize those impacts. Those restrictions are being refined as

research in this area continues. Current restrictions are listed at paragraph 7.00 below. These may change with increased knowledge of sea turtle distribution and abundance and as new hopper dredging equipment and techniques are developed. If, in a specific dredging operation, costs for equipment types are identical, use of a stationary dredge would be preferred since it would be expected to have less impact on sea turtles. To ensure that dredging operations are not likely to adversely impact sea turtles, all dredging operations would be done in compliance with the appropriate Biological Opinion for navigation channels in the southeast issued by the NMFS.

B.4.23 Disposal Operations on Tybee and or Daufuskie Islands may affect nesting loggerhead turtles, by impacting nesting areas. The nesting season for loggerheads in this area extends from May 1 through August 30 and the hatching season extends to October 31 (US FWS, 1993). Tybee Island beach represents approximately 3 percent of the Georgia beaches available for nesting turtles. However, only about 7 turtles are known to have nested on Tybee Island in recent years (7 in 1989, 3 in 1990, 7 in 1992, GA DNR, 1992). A recent communique with Georgia DNR indicates that 20 nests were located on Sea Island the year nourishment occurred (1990) with an additional 31 nests in the unnourished area. In 1991, 56 nests were found in the nourished area and 55 nests in the unnourished area. It thus appears that nourishment can be beneficial to turtles. Loss of sea turtles would not be expected from the proposed disposal on Tybee or Daufuskie Islands because of the conditions in the contract that would be in place to protect nesting turtles. Disposal in these areas would be expected to enhance the area for turtle nesting by creating more beach area suitable for nesting.

B.4.24 If the project is constructed during the turtle nesting season, a turtle nest monitoring program would be conducted to insure protection of any turtles that may try to nest on the existing beach or the newly formed beach. The District has developed a monitoring program which has been used at Tybee Island. A copy is attached. Any agreements concerning renourishment would include a requirement that appropriate nest relocation procedures be followed, if necessary, to prevent impacts to nesting turtles. Our nest relocation guidelines are also attached.

B.4.25 Loss of turtles could also occur by means of broken eggs resulting from sand compaction after beach nourishment. Such an event is expected to be unlikely because the dredged material grain sizes are expected to match existing beach sand sufficiently to avoid major compaction problems. However, if post dredging examination of the nourished beach finds sand compaction to be greater than 500 cone penetrometer index units (cpu) and agreement is reached with US FWS that plowing could enhance the area for turtle nesting, the compacted area would be

plowed to a depth of at least 36 inches. Also, any escarpments in excess of 18 inches extending for more than 100 feet and exceeding 500 cpu would be mechanically leveled to the natural beach contour. If leveling is needed, appropriate nest relocation procedures would be followed. Artificial beachfront lighting is known to cause hatchling disorientation and misorientation (US FWS, 1993). To ensure protection to nesting sea turtles the following conditions would be adhered to:

- a. If the project is constructed during the turtle nesting season, a turtle nest monitoring program should be conducted to ensure protection of turtles that try to nest on the existing or newly formed beach. See the attached Turtle Monitoring Plan and nest relocation procedures.
- b. The beach would be monitored during the first and second winter/spring following completion of construction to determine post-nourishment compaction. This would be performed to ensure that the newly constructed beach provides suitable nesting material for endangered sea turtles. If the examination finds sand compaction within 50 feet of the toe of the dune to be greater than 500 cone penetrometer units (cpu), and the US FWS confirms that plowing is necessary, the compacted area will be plowed to a depth of at least 36 inches. Areas on which vegetation has been established would not be plowed.
- c. The beach would be monitored each year for escarpments. Any escarpments in excess of 18 inches high, extending more than 100 feet in length and exceeding 500 cpu would be mechanically leveled to the natural beach contour.
- d. Prior to any agreement with Tybee Island to utilize the beach as a disposal area, a guarantee will be obtained from the City of Tybee Island that their lighting ordinance for protection of the nesting habitat of sea turtles (Sec. 8-4-58 through Sec. 8-4-60) will be implemented and enforced from May 1 through October 31 for three years following the disposal operation. The District believes that lighting controls on Daufuskie Island would not be necessary at this time since the shoreline is not highly developed.

B.4.26 With implementation of the project as stated above, this project is not likely to adversely impact sea turtles. In fact, certain proposed actions in the plan have the potential to increase quality of existing nesting habitat (the proposed nearshore berms off Tybee Island) or produce new nesting habitat (the proposed bird island on the north side of the north jetty and direct nourishment on Tybee and/or Daufuskie Islands).

B.4.27 Shortnose sturgeon (*Acipenser brevirostrum*). The shortnose sturgeon is an anadromous species restricted to the east coast of North America. They have been recorded from New Brunswick to Florida. Throughout its range, shortnose sturgeon occur in rivers, estuaries, and the sea. The majority of populations have their greatest abundance and are found throughout most of the year in the lower portions of the estuary of their respective river (NMFS, 1984). It is considered to be more abundant now than previously thought (NMFS, 1984). This species is known to occur in the Savannah River (Hall et al., 1991). The shortnose sturgeon is a suctorial feeder. The preferred prey is small gastropods (NMFS, 1984). Hall et al., 1991, mention the small clam *Corbicula* as being a possible prey item in the lower Savannah River. Three sites just upstream of the project upper limit were identified as feeding areas (rkm 39.6, rkm 36, and rkm 35.7).

B.4.28 The species' general pattern of seasonal movement appears to involve an upstream migration from late January through March when water temperatures range from 9 C to 12 C. Post-spawning fish begin moving back downstream in March and leave the freshwater reaches of the river in May. Juvenile and adult sturgeon use the area located 1 to 3 miles from the freshwater/saltwater interface throughout the year as a feeding ground. During the summer, this species tends to use deep holes at or just above the freshwater/saltwater boundary (Flournoy et al., 1992, Rogers and Weber, 1994, Hall et al., 1991). This boundary was thought to occur in the Savannah River between river miles 20.5 and 23.6 in 1987 (Hall et al., 1991). We are not aware of any determination on how removal of the Tidegate from operation and the Deepening Project has affected its location. Available data also indicates that Kings Island Turning Basin at about river mile 19.3 is used as a nursery area for juvenile sturgeon (Hall et al., 1991). Our current best estimate is that sturgeon can be expected throughout the year somewhere within the area from about river mile 17.5 to 26.6.

B.4.29 Shortnose sturgeon may be present in Savannah Harbor during routine maintenance dredging. The channel and turning basin down to about River Mile 17 may function as a resting area for this species. It is not known how extensively the channels and turning basins are used as feeding areas. Since these areas

are dredged every year, they are not expected to be used extensively for feeding after a dredging operation. The species has apparently adapted to the yearly dredging routine. The fact that individuals of this species apparently seek out the Kings Island Turning Basin during the summer indicates that the maintenance of deep basins through the dredging program may actually be beneficial to the species' survival. This project is, therefore, not expected to impact feeding areas. Possible impacts due to normal maintenance dredging program would center around the potential for physical contact with the dredge or the plume created by its operation. Possible impacts to this species from maintenance dredging are discussed below.

a. Impacts from the dredge. Adult and juvenile sturgeons are believed to be very mobile, even when occupying resting areas during the summer months (deep holes and other deep areas such as the Kings Island Turning Basin). The potential for the adult and juvenile fish being hit by the cutterhead is very low. The eggs and larval sturgeons are not as mobile. Therefore, there is a potential for them being impacted either by being entrained by the dredge or being smothered/physically damaged by the materials in the dredge plume. However, the proposed dredging activity will be limited to the area below River Mile 21.3 and a 1991 study conducted indicates that two probable spawning sites for sturgeon are from River Mile 112 to 119 and from River Mile 172 to 174 (Hall et al., 1991). This should negate the possibility of sturgeon eggs or larvae being impacted by the dredging.

b. Impacts due to the dredge plume. Since spawning occurs far upstream of the dredging project, impacts to eggs and larvae are not expected. However, there is a potential for impacts to juvenile and adult fish feeding in the area or migrating through the area to spawn. Fish feeding in the area, being mobile, could easily avoid the dredge plume and likely would since a dredge creates a great deal of noise while operating. A widely held opinion among fishery biologists is that some anadromous fish immigrate to their upstream spawning grounds via dredged or natural channel corridors. These biologists believe that occurrence of a dredging project within or adjacent to these channels might interfere with these migrations. However, to our knowledge no technical information has been generated to support this argument. It is our contention that the presence of a hydraulic dredge working in the Savannah Harbor channel would have no adverse impact on this species or its migration upstream in late winter. Our reason for stating this is based on the following factors:

(1) The Savannah Harbor Channel has a top width of approximately 700 feet and a bottom width of 400 to 500 feet. The channel is from 42 to 44 feet deep at low water.

(2) Studies performed by Dr. D.F. Hayes in 1986 on a hydraulic cutterhead dredge operating in Savannah Harbor indicated that average suspended sediment concentrations within 1,600 feet of the dredge were generally raised less than 200 mg/l in the lower water column and less than 100 mg/l and 50 mg/l in the middle and upper water column, respectively.

(3) The Savannah River has a naturally high suspended sediment load which during storm events is expected to increase well beyond the 200 mg/l increase created by a hydraulic dredge. Also during storm events the higher suspended sediment loads would likely be more uniform throughout the water column due to mixing as the plume proceeds down stream. Therefore, the sturgeon would not be able to move up in the water column to avoid the increased sediment load as it would be able to do in a dredge induced situation.

B.4.30 Based on the above, it is highly likely that the sturgeons using the Savannah River have experienced frequent natural increased sediment loads well above those created by a hydraulic dredge. Also, in view of the width and depth of the channel it is likely that adult sturgeon migrating upstream to spawn could easily avoid the highest concentrations of suspended solids by moving laterally or vertically in the water column. Once dredging in an area is completed, the shortnose sturgeon would be expected to return to their resting areas. Once the benthos reestablishes itself, the channel and turning areas could again be used for feeding. As stated above, shortnose sturgeon have been documented in areas such as the Kings Island Turning Basin that are currently subject to periodic maintenance dredging (Hall et al., 1991). Based on the above the proposed management plan for the Savannah Harbor is not expected to have more than minimal adverse impact on this species. The plan would also not destroy or modify any habitat determined critical for the species' survival.

B.5.00 Quality of Dredged Material. Disposal of dredged material in the ocean is regulated by the Marine Protection Research and Sanctuaries Act of 1972. Section 103 of the Act provides for transport of dredged material for the purpose of disposing of it in the ocean only after the material is evaluated using criteria established pursuant to Section 102 of the Act. Criteria for determining suitability of dredged material for ocean disposal based upon the biological testing requirements of the 1977 Ocean Dumping Regulations (40 CFR 220-228) are contained in the EPA/Corps jointly developed 1991 "Evaluation of Dredged Material Proposed For Ocean Disposal - Testing Manual," commonly referred to as the "Green Book." Dredged material from the subject navigation channel is placed in an ocean disposal area only after it is found suitable for ocean disposal by the Corps,

with concurrence obtained from EPA. Disposal of the relatively clean sandy material from the bar channel at the disposal site should have no impact on any endangered species.

B.5.01 Inner harbor sediments are deposited in confined disposal areas. Effluent from these areas is defined as a discharge subject to Section 404 of the Clean Water Act. A Section 404(b)(1) Evaluation has been performed and this discharge has been found to meet the criteria in the Section 404(b)(1) guidelines.

B.5.02 Expected contaminant levels within the disposal areas have been evaluated for possible effects to wildlife, and are judged to be minimal. This evaluation is contained in Appendix F of the LTMS EIS.

B.6.00 Project Timing. Since the dredging program is constrained by several laws and regulations, delays in resolution of various issues may force projects beyond agreed upon windows.

B.7.00 Coordination. A BATES was included in the Draft EIS submitted to resource agencies in December 1994. In August 1995, the NMFS released a Regional Biological Opinion covering dredging for navigation channels. This BATES incorporates the conditions included in that opinion.

B.8.00 Determination. Based on the above evaluation, I find that operation of the Savannah Harbor as proposed in the Environmental Impact Statement portion of the Long Term Management Strategy and as outlined in this document will not have significant adverse impacts on these species provided the conditions listed below for the protection of Manatees, Sea Turtles, and Right Whales are made a part of the dredging contracts:

- a. The contractor will instruct all personnel associated with the dredging of the presence of manatees and the need to avoid collisions with the manatees.
- b. All personnel associated with the dredging will be advised that there are civil and criminal penalties for harming, harassing, or killing manatees which are protected under the Endangered Species Act of 1973 and the Marine Mammal Protection Act of 1972.

- c. Any collision with a manatee will be immediately reported to the Corps of Engineers' Contracting Officer's Representative (912) 652-5958, the Charleston Ecological Services Office of the US Fish and Wildlife Service (803) 724-4707, and the Georgia Department of Natural Resources (weekdays 8:00 a.m. - 4:30 p.m.; (912)2647218 or 1-800-272-8363; nights and weekends: 1-800-241-4113.
- d. All construction activities in open water will cease upon sighting of manatees within 100 yards of the project area. Construction activities will not resume until the manatee has not been seen in the project area for at least 30 minutes.
- e. The contractor will keep a log detailing sightings, collisions, or injury to manatees which occur during the dredging operations.
- f. A report summarizing the above incidents will be provided to the Savannah District for coordination with the U.S. Fish and Wildlife Service, Charleston Ecological Services Office.
- g. All vessels associated with the project will operate at "no-wake" speeds at all times while in the water where the draft of the vessel provides less than four feet of clearance from the bottom and that vessels will follow routes of deep water to the extent possible.
- h. The contractor will instruct all personnel associated with the dredging of the presence of Right Whales and the need to avoid collisions with these mammals. The contractor shall also brief all personnel on the habits and behavior of the right whale.
- i. The contractor shall restrict vessel speeds during the high risk season of December to March of each year such that collisions with adult or juvenile whales can be avoided.
- j. That the contractor shall be required to post a whale watch and submit a whale watch plan prior to conducting any dredging activities at the site. These measures apply to the dredge and any attendant vessel associated with the dredging activity with a length of over 20 feet.

- k. If the project is constructed during the turtle nesting season, a turtle nest monitoring program should be conducted to ensure protection of turtles that try to nest on the existing or newly formed beach. See the attached Turtle Monitoring Plan and nest relocation procedures.
- l. The beach would be monitored during the first and second winter/spring following completion of construction to determine post-nourishment compaction. This would be performed to ensure that the newly constructed beach provides suitable nesting material for endangered sea turtles. If the examination finds sand compaction within 50 feet of the toe of the dune to be greater than 500 cone penetrometer units (cpu), and the US FWS confirms that plowing is necessary, the compacted area will be plowed to a depth of at least 36 inches. Areas on which vegetation has been established would not be plowed.
- m. The beach would be monitored each year for escarpments. Any escarpments in excess of 18 inches high, extending more than 100 feet in length and exceeding 500 cpu would be mechanically leveled to the natural beach contour.
- n. Prior to any agreement with Tybee Island to use the beach as a disposal area, a guarantee will be obtained from the City of Tybee Island that their lighting ordinance for protection of the nesting habitat of sea turtles (Sec. 8-4-58 through Sec. 8-4-60) will be implemented and enforced from May 1 through October 31 for three years following the disposal operation. A determination on the need for lighting controls on Daufuskie Island, should it be chosen as a disposal site, is requested from responsible agencies.
- o. Each dredging contract for the Savannah Harbor Bar Channel will contain the following provisions:
 - 1. Each contractor will be required to instruct all personnel associated with the dredging/construction project about the possible presence of endangered right whales in the area and the need to avoid collisions. Each contractor will also be required to brief his personnel concerning the civil and criminal penalties for harming, harassing or killing species that are protected under the Endangered Species Act of 1973 and the Marine Mammal Protection Act of 1972.

2. Dredges and all other disposal and attendant vessels are required to stop, alter course, or otherwise maneuver to avoid approaching the known location of a right whale.
3. The contractor will be required to submit an endangered species watch plan that is adequate to protect right whales from the impacts of the proposed work. This plan will include provision on board the dredge and all attendant vessels of trained observers (in accordance with the NMFS Regional Opinion) to watch for right whales at all times the vessel is in motion. Observers would be required during those months when whales may be expected to be present in the area.
4. Contractors will be required to use daily available information on the presence of right whales in the project area. NMFS requires monitoring by endangered species observers with at-sea large whale identification experience to conduct daytime observations for whales between December 1 and March 31, when humpback and right whales occur in the vicinity of channels and borrow areas, north of Cape Canaveral. Monitoring by the sea turtle observers is acceptable between April 1 and November 30. Monitoring will be 100 percent for the first year of the biological opinion, unless subsequently altered upon authorization from NMFS. During daylight hours, the dredge operator must take necessary precautions to avoid whales. During evening hours or when there is limited visibility due to fog or sea states of greater than Beaufort 3, the dredge must slow down to 5 knots or less when transiting between areas if whales have been spotted within 15 nm of the vessel's path within the previous 24 hours. South of Cape Canaveral, surveys for whales should be conducted by endangered species observers during the intervals between dredge spoil monitoring. If a right whale is known to be within 15 nautical miles of the project area on a given day, hopper dredges and any attendant vessels 20 feet or greater in length will be required to limit speeds that night to 5 knots or less when in the project area. The project area is defined as the Bar Channel, Savannah ODMDS, and routes travelled between the two.

5. If a right Whale Early Warning System (RWEW), is in place, will be deemed to provide adequate information on the presence of whales during dredging operations. The District agrees to abide by and incorporate into its dredging contracts within the critical habitat area all mutually agreed upon operating rules emanating from this RWEW system.
- p. All hopper dredging will be generally be scheduled for December through March, and the following conditions will apply*:
1. One hundred percent inflow screening is required, and 100 percent overflow screening is recommended when sea turtle observers are required on hopper dredges in areas and seasons when sea turtles may be present. If conditions disallow 100 percent inflow screening, inflow screening can be reduced, but 100 percent overflow screening is required, and an explanation must be included in the preliminary dredging report.
 2. The sea turtle deflecting draghead is required for all hopper dredging during the months that turtles may be present, unless a waiver is granted by the COE SAD in consultation with NMFS.
 3. To prevent impingement of sea turtles within the water column, every effort should be made to keep the dredge pumps disengaged when the dragheads are not firmly on the bottom.
 4. A trained turtle observer will be placed on the hopper dredges to monitor for sea turtles for 100 percent of the period from November 1 to November 30 and April 1 to May 31. No sea turtle monitoring is required between December 1 and March 31.
 5. The water intake ports on the top of the draghead shall be screened with metal elliptical cages, or other suitable means to exclude sea turtles from entering the drag arm. No dredging shall be performed by a hopper dredge without a turtle deflector device in place.

6. Dredging shall be suspended upon the taking of more than one turtle in any day, the taking of one hawksbill turtle, or once five or more turtles are taken. Dredging operations will not commence, again, until coordination with South Atlantic Division and the NMFS has taken place and any remediation requirements are implemented, such as relocation trawling with a shrimp boat, to ensure compliance with the Endangered Species Act.
7. A report summarizing the take of sea turtles will be submitted to the National Marine Fisheries Service (NMFS) immediately following completion of the project.

NOTE: * These are the conditions currently being followed in accordance with the NMFS 1995 Biological Opinion for Navigation Channels in the Southeast, and additional guidance provided by South Atlantic Division. Should a new Biological Opinion be issued, the District would consider the conditions listed here void, and would abide by the conditions as stated in that opinion and any further guidance provided by South Atlantic Division.

APPENDIX C

SECTION 404 (B)(1) EVALUATION

SECTION 404 (B) (1) EVALUATION
FOR THE SAVANNAH HARBOR
LTMS STUDY
BY
THE SAVANNAH DISTRICT CORPS OF ENGINEERS

C.1.00 INTRODUCTION. Section 404(b)(1) of the Clean Water Act of 1972 requires that any proposed discharge of dredged or fill material into waters of the United States must be evaluated using the guidelines developed by the Administrator of the U.S. Environmental Protection Agency (EPA) in conjunction with the Secretary of the Army. These guidelines can be found in Title 40, Part 230 of the Code of Federal Regulations. The following evaluation is prepared in accordance with the guidelines and follows the recommended format contained in ER 1105-2-100, dated December 28, 1990.

C.2.00 SECTION 404(b)(1) EVALUATION.

C.2.01 Project Description.

C.2.02 Location. Savannah Harbor is a deep-draft harbor on the South Atlantic U.S. coast 75 statute miles south of Charleston Harbor, South Carolina, and 120 miles north of Jacksonville Harbor, Florida. The harbor comprises the lower 21.3 miles of the Savannah River (which, with certain of its tributaries, forms the boundary between Georgia and South Carolina along its entire length of 313 miles) and 11.17 miles of channel across the bar to the Atlantic Ocean.

C.2.03 General Description. This evaluation covers both maintenance of the existing Savannah Harbor Navigation Project and changes to that project proposed as a result of the Harbor's Long Term Management Strategy (LTMS). That study was conducted to develop a strategy which would maximize the efficient, effective and timely operation of the harbor, while providing appropriate safeguards for the harbor's environmental and cultural resources. Proposed changes identified in the LTMS Study consist of modifications to the present operation of the harbor.

C.2.04 Proposed changes to the authorized project consist of the following:

A) Diking of Disposal Area 14A to allow rotational use of the middle and lower harbor confined disposal areas, thereby extending their useful life;

B) A Mitigation Plan to compensate for the wetland losses resulting from the diking of Disposal Area 14A and miscellaneous disposal area operations in South Carolina. This plan has certain features that will result in Section 404 discharges:

(1) construction and maintenance of a Bird Island in the nearshore area off Jones/Oysterbed Island for use by shorebirds and colonial nesting birds; (2) clearing and maintenance (possibly through unconfined disposal of dredged material) of high ground outside the dike at Jones/Oysterbed Island for use by colonial nesting birds; and (3) installation of a water control structure at the Savannah National Wildlife Refuge to increase fisheries values of an existing impoundment.

C) Construction and use of an access road to Disposal Area 2A to allow deposited sediments to be removed, thereby extending the useful life of that site;

D) A commitment to mitigate for the wetland losses resulting from the construction of the access road to Disposal Area 2A and other minor wetland impacts from maintenance activities at existing disposal areas (replacement of weirs and construction/enlargement of pipe ramps) in Georgia;

E) Installation of underdrains which would drain to either the Savannah or Back Rivers to allow faster drying of deposited sediments; thereby enhancing the removal of those sediments and extending the useful life of the confined disposal areas;

F) Beneficial uses of nearshore sediments, consisting of construction and maintenance of submerged berms south of the Bar Channel, construction and maintenance of a feeder berm off Tybee Island, and placement directly on the Tybee and/or Daufuskie Island beaches. The nearshore/offshore disposal location to be used for a specific dredging contract would be decided during project design and award based on identification of the least cost, environmentally-acceptable disposal option. If disposal at a different location is found to be more desirable for environmental or other reasons but would be more costly than the one designated as the least cost, environmentally-acceptable, it could be pursued using appropriate cost sharing authorities;

G) Maintenance of berths by private interests through hydraulic dredging, with placement of excavated material directly in confined disposal facilities;

H) Improvements in the sediment control features, consisting of advance maintenance deepening of the Sediment Basin and turning basins, and deepening of the advance maintenance area at the Kings Island Turning Basin, with the intent of creating additional off-channel storage for deposition of sediments prior to the periodic Federal maintenance dredging; and

I) Miscellaneous disposal area operations consisting of the following: new pipe ramps, expansions of existing pipe ramps, installation of new weir/discharge pipes, replacement of existing weir/discharge pipes, additional bank protection in non-wetland eroded front dike areas, and bank protection along the Jones/Oysterbed Island Disposal Area.

C.2.05 This document includes an evaluation of the suitability of Bar Channel and other suitable maintenance material from the channel adjacent to Jones/Oysterbed Island for placement in the nearshore area and on nearby barrier islands beaches.

C.2.06 Authority and Purpose. In recognition of the benefits of long-term planning for the efficient use of resources, Congress authorized the development of a Long Term Management Strategy (LTMS) for the Savannah Harbor. The Savannah Harbor LTMS was conducted in response to House Report 102-555, submitted on June 11, 1992, by the House of Representatives' Committee on Appropriations, and Senate Report 102-344, submitted on July 27, 1992, by the Senate Committee on Appropriations. Both those reports refer to the Energy And Water Development Appropriation Bill of 1993. Funds were included in the FY 93 Federal budget to begin this work. Savannah District received funds and initiated work on this LTMS in December 1992.

C.2.07 The Savannah Harbor LTMS Study addresses the continued operation and maintenance of the Savannah Harbor Federal Project. Discharges from the dredging itself are considered de minimis and are not regulated under Section 404 of the Clean Water Act. This Evaluation does address weir discharges of effluent from high ground disposal of the harbor maintenance sediments. Ocean disposal of dredged material is covered under Section 102 and 103 of the Marine Protection, Research, and Sanctuaries Act of 1972, as amended. Discharge of dredged material both onto the eastern tip of Jones/Oysterbed Island, into the nearshore area off Jones/Oysterbed Island to construct and maintain a Bird Island, onto the beaches of nearby barrier islands, discharges to construct nearshore berms/feeder berms off Tybee Island, and stormwater runoff from dike construction would be considered discharges into waters of the U.S. and are under Section 404 jurisdiction.

C.2.08 General Description of Dredged or Fill Material. On May 8, 1992, 24 reconnaissance grab samples were taken of Bar Channel maintenance material. Analysis of these samples revealed six stations with over 15 percent fines by weight. Thirteen of the original samples were below 5 percent fines. Samples ranged from 1 to 53 percent fines, with an average of 12.6 percent fines.

Six resamples from the high fines areas underwent extensive testing. The average for all 30 samples is 13.4 percent fines. The District has determined, with the concurrence of EPA, that the Bar Channel material is suitable for ocean disposal. Results of the testing are discussed in the Revised Section 103 Evaluation for this project.

C.2.09 In 1982, 30 sediment samples were taken in the inner harbor. Those samples revealed that inner harbor sediments were comprised of an average of 64.2 percent sand. Samples taken downstream of Station 50+000 averaged 88 percent sand, with only 2 samples (80 and 74 percent) below a 90 percent sand level.

C.2.10 Description of the Proposed Discharge Sites. Inner harbor material (Station 0+000 and upstream) would be disposed of in the existing confined disposal facilities (CDFs): Disposal Areas 1N, 2A, 12A, 12B, 13A, 13B, 14B and Jones/Oysterbed Island, the proposed confined Disposal Area 14A, or other authorized open water disposal area (such as New Cut). Area 1S is an unconfined area and currently not used. Suitable material from the inner harbor adjacent to Jones/Oysterbed Island (upstream as far as Station 50+000) would also be used for beneficial uses. Material from the Bar Channel (Station 0+000 and oceanward) would be placed in the Savannah Harbor ODMDS, an upland CDF, or used beneficially on a barrier island shoreline or in the nearshore area. Some minor excavation and filling of wetlands and riprapping (less than 0.1 acres) may result from installation of the water control structure at the Savannah NWR. Six acres of wetlands may be impacted through various disposal area operations in South Carolina during the life of the project, including bank protection features along Jones/Oysterbed Island which will require impacts to 2.6 acres of wetlands. In addition, fill may be placed along other front dike areas where no wetlands exist and erosion is taking place. Suitable material from the project may be used for the following proposed beneficial uses: bird island construction and maintenance, beach placement at Tybee or Daufuskie Islands, nearshore submerged berm construction and maintenance, feeder berm construction and maintenance, and unconfined discharges within the Tybee NWR at the eastern end of Jones Island for construction and maintenance of bird nesting mounds. Shell hash or other inert material may be placed along portions of the nearshore bird island to reduce erosion and/or enhance fisheries habitat.

C.2.11 Description of Disposal Method. Hopper dredging is generally performed for removal of Bar Channel material oceanward of Station 0+000. Hydraulic cutterhead dredging is proposed to be available for the complete project. Other means of mechanical dredging, including or similar to backhoe and clamshell, are also proposed as available options for the whole project. Agitation dredging is considered to have greater environmental impacts than

the other listed dredging methods and is not a preferred method. Debris would be excavated by a clamshell or other mechanical dredge and placed in a diked disposal area. Where suitable riprap materials are uncovered during debris removal, they may be redeposited in a suitable location along the bank or side slope where riprap is desirable.

C.2.12 Factual Determinations.

C.2.13 Physical Substrate Determinations. This section considers factors described in Sections 230.11(a) and 230.20.

C.2.14 (1) Substrate Elevation And Slope. Maintenance dredging would maintain authorized depths and slopes in the navigation channel, turning basin, Sediment Basin and berthing areas. Local interests are responsible for maintaining berthing areas. Where beneficial uses are employed, elevations may be changed to produce beneficial results (bird nesting on a nearshore island, wave attenuation associated with the nearshore submerged and feeder berms' reduction of erosion damage to barrier island shorelines, and direct protection of barrier island shores).

C.2.15 (2) Sediment Type. Since the substrate is common to the area and has been disturbed in the past, the proposed activities are not expected to have an adverse effect on the physical substrate of the region. In addition, only materials of grain sizes suitable for a beneficial use would be so employed.

C.2.16 (3) Dredged / Fill Material Movement. Normally, inner harbor dredged material would be confined within diked disposal areas. Sediments with low fines from both the inner harbor and Bar Channel may be employed in beneficial uses. Bird islands would be located and constructed to minimize movement of fill material. Migration of material from underwater berms would be expected during storm events. Sands employed in nourishment of Daufuskie or Tybee Islands, or employed in the construction of berms would be expected to enter the nearshore sand transport system. Losses from these beneficial uses would be replenished as appropriate during future dredging events.

C.2.17 (4) Effect On Current Patterns, Water Circulation, Wind And Wave Action. Deepening turning basins and berthing areas would likely reduce flow velocities in the immediate vicinity. However, this impact is not expected to adversely affect water quality or surrounding lands. Deepening the Sediment Basin is expected to have no measurable impact on flow patterns, since velocities are already slow through that specific site. No effect is expected from disposal into the CDFs. However, such impacts are possible for the proposed beneficial uses. The nearshore berms are expected to attenuate waves

approaching Tybee Island from the northeast, especially higher amplitude waves. The orientation of the berms is designed to minimize the effects on tidal currents. No significant changes in current patterns and water circulation are expected. Construction of the bird island on the north side of the jetties may cause minor changes in current patterns and water circulation. However, the site proposed for island construction is presently shallow with deeper channels located on each side -- but outside the impact area, so no major currents are expected to presently occur in the area or be altered by construction of an island. Construction of the feeder berm off Tybee Island may cause minor changes in current patterns and water circulation. However, much of the existing water depth would still be present at the site, so currents are not expected to be significantly changed by construction of the berm. Placement of channel sediments on Tybee or Daufuskie Islands is not expected to affect current patterns or water circulation. It would be expected to lessen wave impacts to those beaches.

C.2.18 (5) *Physical Effects On Benthos.* Discharges from the CDFs are expected to have little impact on benthos. A study of effluent releases from the District's CDFs (Palermo, 1988) showed that the CDFs retain 99.67 percent of dredged solids. The released solids are expected to exist in such low concentrations as to have minimal impact on benthos. Discharges associated with beneficial uses would impact benthos in those areas. However, all areas proposed for beneficial uses are subject to shifting sands and are not expected to have either live hard bottom communities or other large benthos communities. Features requiring open-water discharges will have side scan sonar and benthic surveys completed during the final design process so that specific sites are selected to minimize impacts to benthos.

C.2.19 (6) *Physical Effects On Wetlands.* Effluent from the CDFs may continue to be discharged into wetlands of primarily the Wright and Back Rivers. The District has found no evidence that recent effluent discharges have destroyed wetlands at the outfall locations through burial of vegetation. The amount of solids discharged are expected to continue to be so minor as to cause little or no burial of wetland vegetation. Maintenance of the disposal areas is not expected to have more than minimal impact to wetlands. Dike raisings would take place towards the interior of the disposal areas, so wetlands adjacent to the disposal areas would not be impacted. Future disposal area operations would result in the loss of wetlands and their associated wildlife habitat values. Areas located adjacent to the confined disposal

facilities would be the sites affected. The wetland impacts of those disposal site management operations are described in detail in the paragraphs in Section 7 on Wetlands, but they are summarized as follows:

<u>ACTION</u>	<u>WETLANDS LOST (ACRES)</u>	
	<u>SOUTH CAROLINA</u>	<u>GEORGIA</u>
Access Road to Area 2A	----	2.89
New Pipe Ramps	1.70	----
Pipe Ramp Expansions	0.67	0.14
Weir/Discharge Pipe Installations	0.10	----
Weir/Discharge Pipe Replacements	0.43	0.04
J/O Island Bank Protection	2.63	----
Underdrain Installations	<u>0.21</u>	<u>----</u>
	5.74 Total	3.07 Total
	6.00 Use	3.20 Use

Approximately 305 acres of wetlands will be impacted by the diking and use of Disposal Area 14A. A total of about 314 acres of wetlands would be impacted through the diking and use of Disposal Area 14A and miscellaneous disposal area operations. The functional values of these wetlands would be lost as a result of their use for the Navigation Project. Mitigation for these losses includes operation of the disposal areas after a dredging project is completed (and during the disposal area's designated use times) to benefit wildlife, construction of a nesting island on the north side of the jetties, establishment of a bird nesting area on Jones Island, establishment of an escrow account with the SC DHEC-OCRM for in-kind mitigation, and construction of a water control structure at the Savannah NWR. Certain of these mitigation features themselves will result in Section 404 discharges, which are also covered in this evaluation. Some discharges into wetlands may result from construction and maintenance of the Jones/Oysterbed Island nesting area. The head section location will be chosen to minimize runback to wetlands. A complete discussion of the Mitigation Plan can be found in Appendix G.

C.2.20 (7) *Actions Taken To Minimize Impacts.* Turbidity and suspended solids in effluent from the CDFs will be measured periodically to ensure that those facilities are managed and functioning properly. A suspended solids standard of 500 mg/l will be used as the standard of acceptability of weir discharges. For other features requiring a Section 404 discharge, the most suitable materials for the particular project feature will be chosen.

C.2.21 Water Circulation, Fluctuations and Salinity

Determinations. This Section considers factors described in Sections 230.11(b), 230.22, and 230.23. The proposed work is not expected to result in any adverse effects on water circulation, fluctuations, salinity, or water quality degradation.

C.2.22 (1) *Water.* Savannah District recently completed testing of maintenance material in the Bar Channel. The material was found to be suitable for placement in the ocean and/or for beach nourishment. Material to be removed from the channel adjacent to Jones/Oysterbed Island may be used for beach nourishment, other beneficially purposes in the nearshore area, or in an unconfined manner on Jones/Oysterbed Island to create/maintain wildlife habitat. Material to be removed from the inner harbor would be placed in existing diked confined disposal facilities. Discharge of the effluent from those sites would meet applicable State water quality standards.

C.2.23 (a) *Salinity.* Dredged material would be pumped from an estuarine river of varying salinity and discharged into estuarine rivers (either the Back, Savannah, or Wright Rivers). No components of the proposed project would measurably alter the harbor's salinity regime.

C.2.24 (b) *Water Chemistry / Dissolved Gases (pH and Dissolved Oxygen).* Past monitoring of effluent discharges has indicated that pH is normally within water quality standards. The pH of the effluent from CDFs was occasionally observed to violate Georgia and South Carolina water quality criteria at the weir, but with minimal mixing was judged to result in no impacts. From October 1992 to April 1994, eight weir samples were taken where the pH ranged from 8.6 to 10.2 and one sample from Disposal Area 12B in July 1993 was recorded at 12.7. One sample from Disposal Area 2A had a pH of 5.3 (March 23, 1994). All other samples (229), which comprised 96 percent of the total observations, were within water quality standards.

C.2.25 The dissolved oxygen (D.O.) of weir effluent, measured at the weir, was measured to be below water quality criteria 51 times from October 1992 to April 1994. A total of 32 of those samples were from weirs with underdrains and 3 were from the private Colonial Oil disposal area that was used for part of the 1993/1994 Deepening Project. Only 19 samples were from normal CDF overflow weirs, and all of those were at Disposal Area 14B. Again, because of mixing, these discharges were not expected to cause more than minimal impact. Sampling of the Wright River during the low D.O. discharges from Disposal Area 14B did not detect any D.O. levels below state water quality standards. All underdrain weirs to the Wright River will be closed by the end of 1994. New underdrains would be installed to discharge to the Savannah or Back Rivers. It is expected that mixing with the

higher flows in those rivers would produce no impact from low D.O. weir discharges. Since the oxygen demand of the sediment material is not dependent on the location of the material, the total oxygen demand which harbor sediments place upon the river would not be affected by O&M work. In areas where sediment accumulates rapidly, that sediment which becomes buried and turns anoxic is outside of the influence of oxygen dissolved in the water and no longer places a demand on that critical water quality component. Therefore, construction of additional sediment holding capacity in the river allows settling of a volume of sediment in a deep storage area. This would remove that volume from the portion of the water column with ready exchange, thereby reducing the oxygen demand of the total sediment volume. The District has no evidence that any significant level of BOD/COD demand exists in the effluent or has ever caused a D.O. problem in receiving waters.

C.2.26 (c) *Clarity / Color / Odor / Taste / Nutrients / Eutrophication.* Savannah District has not identified any significant impact from any of these factors. Effluent from the CDFs primarily originated -- except for rain water -- in the Savannah River as bottom sediments and overlying river water. It was not involved directly in any industrial process.

C.2.27 (2) *Current Patterns And Circulation.*

C.2.28 (a) *Current Patterns / Flow / Velocity.* Normal maintenance of the Navigation Project is not expected to appreciably impact these factors, although current rates would theoretically decrease after a dredging event due to the increased cross-sectional area of the channel. Deepening turning basins and berthing areas would likely reduce flow velocities in the immediate vicinity. However, this impact is not expected to adversely affect water quality. Deepening the Sediment Basin is expected to have no measurable impact on flow patterns, since velocities are already slow through that specific site. Construction of the bird island proposed in the nearshore off Turtle Island could cause local changes in these factors. However, the site selected for that structure is a shallow water area with deeper channels to either side. No major currents are expected to exist within the site of the proposed island area itself. The bird island would also be expected to protect inland areas from the erosive action of wind-generated waves. The proposed offshore berms are expected to attenuate high amplitude northeasterly wind-generated waves. These berms would be oriented to minimize their impact on both ebb and flood tidal currents. The proposed feeder berm would also attenuate high amplitude northeasterly wind-generated waves which result in erosion of Tybee beach. Sediments which are deposited to

construct the feeder berm are expected to be moved by currents toward the adjacent barrier island shore. However, the feeder berm is not expected to significantly disrupt current patterns in that nearshore area.

C.2.29 (b) *Stratification / Hydrologic Regime.* Minimal impacts on these factors is expected.

C.2.30 (3) *Normal Water Fluctuations.* Tidal levels would theoretically be affected after completion of a dredging event, but the effects would be expected to be minimal.

C.2.31 (4) *Salinity Gradients.* No impact expected.

C.2.32 (5) *Actions That Will Be Taken To Minimize Impacts.* Nearshore berms will be oriented to minimize impact to tidal currents. Vegetation control will be implemented in the CDFs to minimize the impact of subsequent flooding on D.O. CDFs will be operated to maintain highest effluent quality in light of safety and biological concerns.

C.2.33 Suspended Particulate / Turbidity Determinations.

C.2.34 (1) *Expected Changes In Suspended Particulates And Turbidity Levels In Vicinity Of Disposal Site.* The kinds and concentrations of particulate matter in the vicinity of the weirs is not expected to differ greatly as a result of continued operation this project. Normal effluent turbidity is expected to be less than river turbidity during rain events. At other times, mixing with the receiving waters is expected to reduce turbidity rapidly to background levels. A test of one Savannah CDF found a solids retention rate of over 99.93 percent (Palermo, 1988). According to data collected from 1988 to March 1994, the average suspended solid level in the effluent from Disposal Area 2A was about 200 mg/L. In the remainder of the regular O&M disposal areas, the average suspended solid level was about 100 mg/l. This level is comparable to the background level of the Savannah River (20 to 50 mg/l). Discharges from the CDFs are expected to meet readily water quality standards with a minimal mixing zone.

C.2.35 Discharge of dredged sediment material into the subtidal habitat of the ocean, the Jones Island nesting area, or onto the beach is expected to result in a temporary increase in turbidity. Sediments that would be deposited in the open water nearshore environment or on Jones/Oysterbed Island would come from the Bar Channel or inner harbor areas near Jones/Oysterbed Island where

the composition of the sediment is primarily sand. Therefore, turbidity impacts would be expected to be temporary in nature as the sediments should settle out quickly and the minor amounts of fines in the sediments should quickly disperse.

C.2.36 (2) *Effects On Chemical And Physical Properties Of The Water Column.*

C.2.37 (a) *Light Penetration.* During weir releases, there may be a minor temporary reduction in light transmission due to increased turbidity in the area of the weir discharges. These effects would be localized, and limited to only a few weirs at any one time. Moreover, these effects would be minimized by proper management of the weir releases. Effects on the water column are primarily those associated with a reduction in light transmission, aesthetic values, and direct destructive effects on nektonic and planktonic populations.

C.2.38 During open water disposal operations at the ODMDS, there would be temporary reductions in light transmission due to increased turbidity in the area of the discharge. The temporary effects on the water column are primarily those associated with a reduction in light transmission, aesthetic values, and direct destructive effects on nektonic and planktonic populations.

C.2.39 Agitation dredging presently conducted by dock owners results in a temporary reductions in light transmission due to increased turbidity near the berth. Effects on the water column from those operations are primarily those associated with a reduction in light transmission, aesthetic values, and direct destructive effects on nektonic and planktonic populations. The proposed hydraulic dredging of berths with direct placement of excavated sediments into confined disposal areas would reduce the number of agitation dredging events performed in the harbor each year, thereby, reducing their adverse effects on light penetration. The proposed deepening of berths by dock owners would increase the efficiency of hydraulic dredging operation at those sites and reduce the number of dredging events required per year to maintain adequate depths at those facilities. Such changes would also decrease adverse effects of berth maintenance dredging on suspended solids and light transmission.

C.2.40 Open water disposal at the bird island site, Jones/Oysterbed Island nesting area, nearshore submerged berm and feeder berm sites, and at the beaches will lead to elevations in suspended solids along the shore until the fines in the discharge are swept offshore by tidal action. This will be a temporary condition, with the suspended solids in the water column returning to pre-discharge levels. The temporary effects on the water column are primarily those associated with a reduction in light transmission, aesthetic values, and direct destructive

effects on nektonic and planktonic populations, and are expected to be minor. The discharge is expected to have little impact on dissolved oxygen because of the rapid aeration in the surf zone.

C.2.41 (b) Suspended particulate matter is not expected to significantly affect dissolved oxygen levels of the receiving waters.

C.2.42 (c) *Toxic Metals And Organics*. The major concern for the effect of toxics associated with suspended particles would be associated with overflow effluent from the CDFs. Effluent from the CDFs recently underwent both chemical and biological testing (NMFS, 1994). This study found no concern for effluent from the overflow weirs. Arsenic was found in effluent from the underdrains. See discussion in "Contaminant Determinations" below.

C.2.43 (d) *Pathogens*. Since effluent originates from the Savannah River and no biological organisms are added during the dredging operation, no new pathogens are expected as a result of the dredging.

C.2.44 (e) *Aesthetics*. Some visual impacts from turbidity would be expected from the open water discharges. However, they are expected to be temporal in nature, and diluted by shore currents. Weir releases may also have some visual impacts, but such impacts are expected to be local and not as severe as experienced during a heavy rain event. Use of a hydraulic dredge with direct placement of excavated sediments in a confined disposal area would reduce ongoing adverse visual impacts from turbidity stemming from agitation dredging of berths.

C.2.45 (3) *Effects On Biota*. Suspended particulates may be expected to have some adverse impact on filter feeders, but those impacts are expected to be temporary. Open water disposal would occur infrequently, for relatively short durations, and would be subject to large mixing forces. Where appropriate, open water disposal would be timed so that possible turbidity impacts to larval estuarine fish and shellfish would be minimized. To minimize these impacts, it is the intent of the District that, if possible, no nearshore open water disposal operations would take place during the biologically critical reproductive season for area estuarine fish and shellfish. This critical time period is presently known to be March 1 to June 1. Should additional information modifying that time period come to the District's attention prior to a dredging event, it would be taken into consideration in scheduling the work. Overall impacts from open water disposal are expected to be minimal. To further reduce impacts to fish, endangered species, birds, and benthic communities, the District would follow the recommendations of the US FWS, which were included in their Section 2(b) Report on the

Tybee Island disposal portion of the Savannah Harbor Deepening Project, that whenever possible, open water disposal would be conducted in the early winter months. At the present time, review of current information does not reveal a necessity for conducting biological monitoring of the proposed open water sites.

C.2.46 CDF effluent would occur over a longer period of time and thus there is a greater potential for impacts. The NMFS 1994 weir study found that turbidity levels of 100 to 500 mg/l may be stressful to estuarine organisms. The CDFs would be managed to minimize effluent suspended particulates in the context of safe operation and mitigation goals. Effluent to the Savannah River would undergo rapid mixing with impacts restricted to areas close to the outfalls. At the outfalls to the Wright River, effluent would dominate the discharge areas (small tidal creeks) for larger distances than on the Savannah River side. However, the above referenced 1994 NMFS study of the Wright River outfalls found little impact associated with the overflow weirs.

C.2.47 Although benthic and side scan sonar surveys will be performed at the proposed open water sites and actual sites will be selected to minimize benthic impacts, a substantial loss of the benthic community at the open water disposal sites would be expected as a result of burial by dredged material. Some organisms, capable of upward burrowing, should survive. Since the material deposited in the open water disposal sites is expected to be generally similar to the native sediments in the nearshore area, rapid recolonization of the subtidal areas and intertidal shoreline should occur. No lasting changes in community structure is expected. Long term beneficial impacts from the open water disposal actions are expected at the bird island and beach nourishment sites for nesting birds, sea turtles and intertidal shorelife, since the intertidal zone is expected to be increased. Turbidity impacts would be minimized by scheduling disposal operations outside critical biological periods to minimize impacts to estuarine and larval fish.

C.2.48 Suspended particulates resulting from agitation dredging performed by dock owners could be expected to have some adverse impact on filter feeders and larval estuarine fish. The critical time period for these species is the reproductive season presently known to be March 1 to June 1.

C.2.49 (4) *Actions Taken To Minimize Impacts.* As stated above, only sediments containing predominantly sand would be used for open water discharges. Timing of open water discharges would be planned to include months of lowest impact to fishery resources. The CDFs would be managed to minimize effluent suspended particulates in the context of safe operation and wetland mitigation goals. To ascertain the effectiveness of management of the CDFs, the water quality monitoring plan

described in Section 7 of the EIS will be followed. Use of a hydraulic dredge with direct placement of excavated sediments in a confined disposal area would reduce ongoing adverse impacts stemming from agitation dredging of berths.

C.2.50 Contaminant Determinations. Two main questions focus this issue, the nature of the material to be dredged, and the nature of the material to be discharged. Three general types of material are proposed to be dredged, fines from slips outside the main channel, fines from within the main channel, and predominantly sands from within the main channel (inner channel and Bar Channel). Available information on sediments within slips shows that some slips do contain elevated levels of metals and organics (see discussion in the EIS). Averages of samples taken within the main channel show little concern for contaminants, although some metals such as chrome and zinc approach levels of lowest known effects (see discussion in the EIS). Bar Channel materials, consisting of predominantly sand, have been found suitable for ocean disposal. During normal harbor operations, sediments in the slips, with their potentially elevated levels of chemical compounds, are moved by agitation dredging from the berths and slips and are mixed with/diluted by the more natural river sediment levels before they redeposit in the main navigation channel. In addition, the nature of disposal operations in the CDFs tend to mix the deposited sediments to some degree.

C.2.51 The Section 404 guidelines require that a determination be made of the degree to which the material proposed for discharge will introduce, relocate, or increase contaminants. This determination is to consider the material to be discharged, the aquatic environment at the proposed disposal site, and the availability of contaminants. Seven general types of Section 404 discharges are proposed: (1) small miscellaneous fills associated with maintenance of weirs and construction of pipe access ramps, (2) small excavations, fill, and riprap associated with construction of the water control structure at the Savannah NWR, (3) excavation, fill, and riprap associated with installation of bank protection along the Savannah River shoreline of Jones/Oysterbed Island, (4) fill associated with construction of the dikes for Disposal Area 14A, (5) fill associated with construction of the access road to Disposal Area 2A, (6) CDF overflow effluent to the Savannah, Back, and Wright Rivers, (7) CDF underdrain effluent to the Savannah and Back Rivers, (8) open water discharges associated with construction of a bird island, nearshore submerged berms, nearshore feeder berm, Tybee Island nourishment, and Daufuskie Island nourishment, and (9) unconfined disposal on uplands at Jones/Oysterbed Island to maintain open bird nesting mounds.

C.2.52 (1) *Weir Replacements, Pipe Ramp Construction And Enlargements, Disposal Area 14A Dike Construction, And Disposal Area 2A Access Road Construction.* These fills would consist of predominantly sand material from within existing disposal areas. Sands are generally accepted to have little possibility for contamination.

C.2.53 (2) *CDF Overflow Effluent.* The normal harbor CDFs retain a very high percentage of heavy metals and other contaminants. A study of Disposal Area 12 (Palermo, 1988) found that 99.9 percent of solids and 99.6 percent of heavy metals were retained within the CDF. A recent study of CDF effluent (NMFS, 1994) found little concern for overflow effluent from the CDFs to the Wright River.

C.2.54 (3) *CDF Underdrain Effluent.* Underdrains were originally constructed in Disposal Areas 12B (weirs 1 and 2) and 13A (weirs 2 and 3). The 1994 NMFS study found that arsenic was being released to the Wright River through those underdrains at levels that violated water quality criteria. Arsenic levels in the Disposal Area 12B weir 1 underdrain effluent ranged from 117 to 147 micrograms/liter and in the Disposal Area 13A weir 2 effluent (which included both underdrain and overflow effluent) ranged from 14.9 to 298 micrograms/liter. The underdrain effluent was found to be toxic to test organisms. This toxicity was attributed primarily to arsenic, although other factors were also implicated (elevated manganese, low salinity, low dissolved oxygen and high turbidity). In agreement with the South Carolina Office of Ocean and Coastal Resource Management, the District has elected to close the underdrains to the Wright River. As of October 1994, the underdrains in Disposal Area 12B were sealed. The other underdrains were closed later in 1994. It is proposed that the underdrains be reinstalled to discharge to the Savannah or Back Rivers, where a suitable mixing zone would bring the arsenic levels within water quality criteria. Recent calculations predict that a 10- to 25-foot mixing zone would bring these levels within water quality criteria.

C.2.55 (4) *Open Water Discharges.* Predominantly sand materials from the Bar Channel and the Jones/Oysterbed Island portion of the inner harbor are proposed for open water discharge. Similar materials were sampled and tested in August 1992 (Skidaway, 1992) and found suitable for ocean disposal (Revised Deepening Project Section 103 Evaluation, November 1992).

C.2.56 (5) *Unconfined Disposal On Uplands At Jones/Oysterbed Island To Create/Maintain Bird Nesting Habitat.* These fills would consist of predominantly sand material from the navigation channel adjacent to the site. Sands are generally accepted to have little possibility for contamination.

C.2.57 (6) *Small excavations and fill for the water control structure at the Savannah NWR. Less than 0.1 acre of wetlands is expected to be excavated. Fill will consist primarily of riprap to protect the structure from subsequent erosion.*

C.2.58 (7) *Excavation, fill, and riprap associated with installation of bank protection along the Savannah River shoreline of Jones/Oysterbed Island. Approximately 2.63 acres of wetlands are expected to be impacted. Fill will consist primarily of riprap to protect the shoreline from ongoing and expected future erosion.*

C.2.59 Aquatic Ecosystem and Organism Determinations.

C.2.60 (1) *Effects On Plankton And Nekton.* Impacts from open water discharges would be primarily due to increases in turbidity during the discharge itself and subsequent erosion of any incompatibly sized material. Similar impacts could be produced by both the runoff during unconfined disposal events operations on Jones/Oysterbed Island and agitation dredging of berths by dock owners. Such impacts include a decrease in phytoplankton growth from decreased light availability due to absorption or reflection of light by suspended particulates. A decrease in feeding by nekton could result from reduced phytoplankton availability, limited visibility of prey or interference in feeding behavior from increased particulates. These impacts are expected to be temporary and subside following erosion of incompatibly sized material. No significant impacts on plankton or nekton are expected due to effluent from the CDFs.

C.2.61 (2) *Effects On Benthos.* The proposed dredging will result in a temporary disruption in benthic communities at the dredging sites. However, recolonization occurs relatively rapidly. There will be a temporary impact on benthic communities at the open water disposal sites as some organisms will be lost by covering. Some organisms which inhabit the underwater sites are capable of upward burrowing and should survive. Benthic organisms at the proposed nearshore and beach disposal sites are typically subject to changes associated with daily shifts in their habitat substrate. In addition, those organisms commonly recolonize nourished beaches. Turbidity effects may be produced by the proposed unconfined nearshore disposal, but they are expected to be temporary and minor. Fine-grained sediment will be washed off the proposed nearshore island, submerged berms, feeder berm, and nourished beaches and settle in adjacent subtidal areas, but this should not have more than a minor adverse effect on benthic populations because the fines are expected to accumulate in -- at most -- a very thin layer. Some benthic habitat will be lost from construction of the nearshore

island. However, it will be replaced by intertidal areas and valuable high ground nesting habitat. Placement of riprap along the Savannah River shoreline of Jones/Oysterbed Island would establish valuable stable rock intertidal habitat for benthos.

C.2.62 (3) *Effects On Aquatic Food Web.* No appreciable effects identified. Minor effects on benthic organisms should, for the most part, be temporary. Increased intertidal substrate at the island site should result in increased intertidal communities. It is hoped that the nearshore berms and feeder berm would provide a more stable environment on the shore of Tybee Island, extending the time between renourishments. This would allow further development of complex food webs between beach renourishment events.

C.2.63 (4) *Effects On Special Aquatic Sites (Including Wetlands).* The proposed bird island is adjacent to the Turtle Island Wildlife Management Area and near the Tybee Island National Wildlife Refuge. No other special aquatic sites have been identified at the proposed open water discharge sites. However, the actions listed below which are associated with the navigation project have been identified as having wetland impacts. The amount of wetland impact identified with each action is also listed.

- (a) Diking of Disposal Area 14A: 305 acres.
- (b) Construction of access road for Disposal Area 2A: 2.9 acres.
- (c) Construction of new pipe ramps: 1.70 acres.
- (d) Expansion of existing pipe ramps: 0.81 acres.
- (e) Installation of new weirs and discharge pipes: 0.10 acres.
- (f) Periodic maintenance and relocation of weirs and discharge pipes: 0.47 acres.
- (g) Construction of bank protection along Jones/Oysterbed Island Disposal Area: 2.63 acres.
- (h) Installation of underdrains: 0.21 acres.
- (i) Construction/maintenance of contractor lay down areas: less than 1 acre.
- (j) Less than 0.1 acre for the Savannah NWR water control structure (mitigation plan feature).

C.2.64 A Mitigation Plan was developed to offset the losses from the diking of Disposal Area 14A and miscellaneous disposal area operations in South Carolina. That Plan is included as Appendix G to the EIS. Separate mitigation would be performed to offset wetland losses in Georgia. That mitigation would consist of the restoration/creation of salt water wetlands within the Savannah Harbor area. The mitigation would be performed in conjunction with other projects conducted by Chatham County and/or the Georgia Department of Transportation at a 2:1 replacement level.

A detailed plan for that mitigation would be prepared by Savannah District and submitted to the US FWS and Coastal Resources Division of the Georgia Department of Natural Resources for approval.

C.2.65 (5) *Threatened And Endangered Species*. A Biological Assessment of Threatened and Endangered Species (BATES) has been prepared for continued operation and maintenance of the Savannah Harbor Navigation Project and is contained in Appendix B of the EIS. The BATES determined that the Project would not jeopardize any threatened or endangered species, provided the conditions outlined in that document are made a part of the dredging and construction contracts. The proposed increased management of the disposal areas for wildlife benefits should provide additional feeding opportunities for the endangered wood stork. Construction of the bird island should provide additional feeding and resting sites for the endangered piping plover, as well as nesting habitat for endangered sea turtles.

C.2.66 (6) *Other Wildlife*. Construction of the bird island, nesting islands within the disposal areas, and increased management of the disposal areas for wildlife benefits should provide additional benefits to a variety of shorebirds and other beach and intertidal area organisms. Nesting houses would be constructed at the CDFs for purple martins and bats as a biological control measure for mosquitoes originating from the CDFs.

C.2.67 (7) *Actions To Minimize Impacts*. Only material of compatible grain sizes is proposed for open water discharge. The size of the proposed diked area at Disposal Area 14A has been designed to minimize wetland impacts and still have an efficient area. A wetland mitigation plan to compensate for unavoidable impacts to South Carolina marsh vegetation is contained in Appendix G of the EIS. A separate wetland mitigation plan would be prepared to compensate for unavoidable impacts to Georgia marsh vegetation. The proposed hydraulic dredging of berths with direct placement of excavated sediments in confined disposal areas would reduce ongoing adverse impacts to the aquatic organisms and aquatic ecosystem resulting from agitation dredging.

C.2.68 Proposed Disposal Site Determinations.

C.2.69 (1) *Mixing Zone Determinations*. Proposed mixing zones are confined to the smallest practicable zone at each specified disposal site that are consistent with appropriate dispersion. The District believes that arsenic in the proposed underdrain effluent and low D.O. in both underdrain and overflow effluents mixes rapidly with receiving waters and has no impact on the aquatic environment. Calculations indicate that arsenic levels

in discharges from underdrains would reach acceptable levels within 10 to 25 feet of the discharge point when discharged into the Savannah River. Appropriate mixing zones will allow compliance with water quality criteria.

C.2.70 (2) *Determination Of Compliance With Applicable Water Quality Standards.* Water Quality Certifications are in place from both the State of Georgia and the State of South Carolina for operation and maintenance of the Savannah Harbor Navigation Project. The District requested each state evaluate the Project as currently proposed and determine if additional water quality certification is required. Certification was received from the State of Georgia in a letter dated September 5, 1995, with modifications dated February 6 and 28, 1996. Certification was received from the State of South Carolina in a letter dated May 10, 1996.

C.2.71 (3) *Stormwater Runoff Determinations.* No separate Stormwater Discharge Permits have been obtained for the dike improvement actions which are required for continued operation of the CDFs. During the 20-year period of analysis, multiple dike raising projects will need to be performed to increase the storage capacity of the CDFs. Those actions would each constitute a construction event covering more than 5 acres, which normally requires a state Stormwater Discharge Permit. However, since original construction and continued maintenance of a CDF in a wetland requires a Section 404 Evaluation, the evaluation requirements of Section 402 for a permit for the discharge from the site would be fulfilled. It is Corps policy to follow the evaluation procedures of the Section 402 permit process even though the Corps does not specifically request a Stormwater Discharge Permit from the state.

C.2.72 Guidance from Corps Headquarters titled "NPDES Storm Water Discharge Permit Requirements," contained in a memorandum dated June 23, 1992 states that discharges of dredged or fill material into waters of the US that are regulated under Section 404 are exempt from stormwater regulations. This guidance states "The construction, maintenance and operation of a CDF built in waters of the United States, and thus regulated under Section 404 of the Clean Water Act, would not require a permit under the storm water rule." Since all Project CDFs are built in wetlands, their operation and maintenance -- including stormwater runoff -- would be considered Section 404 discharges under that interpretation. Stormwater discharges from CDFs are, therefore, covered in this Evaluation. When stormwater has ponded behind the weirs and is released through a water control structure by removing weir boards, the District will monitor the discharge's water quality to ensure compliance with state water quality criteria. Where stormwater releases are intermittent and uncontrolled, water quality impacts are expected to be minimal and no monitoring is proposed.

C.2.73 Since dike construction and raising projects would occur in areas that were originally wetlands, the runoff which occurs during those construction events would also be considered under this Section 404 Evaluation. Erosion control plans would be implemented during those construction events to ensure maintenance of water quality. The location and size of the CDFs are described in the main EIS. With implementation of the proposed project, fill material for the dike improvement projects would typically be obtained onsite. Otherwise, offsite fill from other disposal areas would be required due to the limited period of time during which heavy equipment can work on the floor of a CDF before the next disposal operation occurs. The material used as fill for dike raising is typically comprised of sands, silty sands, and silts. The construction process which typically occurs when a dike is raised is described in Appendix H Local Sponsor's Work of the EIS. "Best Management Practices," as defined in the Manual For Erosion And Sediment Control In Georgia or the South Carolina Stormwater Management And Sediment Control Handbook For Land Disturbance Activities, are used for determining the appropriate erosion control measures which will be implemented during the dike raising process. Appendix N of the EIS, titled Erosion And Sediment Control Plan, describes the measures which are taken to control the potential for non-point source pollution stemming from the dike raising process. Those same procedures would effectively control stormwater runoff from the outside of the disposal area dikes during dike construction. No changes in a dike's runoff coefficient would occur as a result of a dike raising project. The raising would result in a decrease in a dike's impervious area since the total surface area of the dike would increase when it's height is increased. Stormwater runoff from the CDFs is discharged to either the Savannah, Middle, Back, or Wright Rivers, depending on the specific disposal site. Industrial chemicals are not stored at the CDFs, so suspended sediments would be the only pollutant expected in the stormwater runoff from the dikes. Washouts of the dikes are uncommon events, so the quality of the stormwater runoff is considered to be good.

C.2.74 (4) *Potential Effects Of Human Use Characteristic.*

C.2.75 (a) *Municipal And Private Water Supply.* No wells or other water supply inlets would be affected by the proposed discharges.

C.2.76 (b) *Recreational And Commercial Fisheries.* No more than very minor impacts are expected. No inner harbor dredging above River Mile 5 is conducted from March 16 to May 31 of each year to comply with conditions in state Water Quality Certifications intended to protect spawning Striped bass. If future research indicates that additional dredging may occur without threatening Striped bass, the District will follow

provisions contained in the state Water Quality Certifications. If possible, open water discharges would be scheduled to avoid the most critical time period for larval and estuarine fish and shellfish of March 1 to June 1. The nearshore submerged berms and feeder berm would interfere with large fishing boats as the berm crest would extend to a depth of 5 feet MLW.

C.2.77 (c) *Water Related Recreation / Aesthetics.* The proposed work would not impact the designated uses of area waters.

C.2.78 (d) *Parks, Etc.* Part of the Tybee Island National Wildlife Refuge is within the Jones/Oysterbed Island Disposal Area. Portions of Disposal Areas 1N, 1S, and 2A are within the Savannah National Wildlife Refuge. The District enters into agreements with the US FWS concerning disposal activities on their lands. Issuance by the FWS of a Special Use Permit would be required prior to construction occurring on FWS-managed sites. Construction of the bird island is expected to benefit the Tybee Island NWR through sheltering it from offshore waves. The bird island would also shelter the Turtle Island Wildlife Management Area, which is operated by the South Carolina Department of Wildlife And Marine Resources. As part of the Mitigation Plan, a water control structure would be constructed to increase water flow through an existing impoundment within the Savannah NWR, thereby increasing the value of that impoundment to fish. Unconfined disposal or clearing of the 26-acre upland nesting area on the Tybee Island NWR would increase the value of the site to colonial nesting birds.

C.2.79 Determination Of Cumulative Effects On The Aquatic Ecosystem. The original construction and continued operation of this project has resulted in the loss of considerable wetland acreage. This loss has taken place over many years. Recent impacts have been mitigated. Much of the wetland impacts occurred at the areas set aside for confined disposal facilities. Since construction of the diked disposal areas, impacts to wetlands have been minimized, with only minor accumulation of sediment directly adjacent to the CDF outfalls. Other historic impacts resulted from a widening of the trapezoidal channel prism as authorized depths were increased. In some areas, that widening resulted in the loss of wetlands located along the channel bank. Some loss of wetlands along the channel bank has occurred over time, even though their loss was predicted and mitigated during specific channel improvement projects. The proposed project would result in the loss of additional wetlands, but that loss is the minimum necessary to continue operation of the Navigation Project. Without the proposed project, the Project's CDFs would have a shorter life, requiring more wetlands to be lost to continue operation of the Navigation Project.

C.2.80 Determination Of Secondary Effects On The Aquatic Ecosystem. No more than minimal secondary impacts have been identified. Those impacts, stemming mainly from construction of landside facilities, receive separate environmental reviews prior to the projects receiving approval for construction. Implementation of the proposed hydraulic dredging of berths with direct deposition of sediments into CDFs would have a secondary benefit of reducing the number of agitation dredging events conducted in the harbor. The water control structure to be constructed within an existing impoundment in the Savannah NWR would increase tidal water exchange, thereby increasing the aquatic value of that impoundment.

C.2.81 Findings Of Compliance Or Non-Compliance With the Restrictions On Discharge.

C.2.82 Determinations.

C.2.83 (a) An ecological evaluation of discharges of dredged material associated with (1) the continued operation and maintenance, and (2) proposed changes to the Savannah Harbor Navigation Project, has been made following the evaluation guidance in 40 CFR 230.6, in conjunction with the evaluation considerations in 40 CFR 230.5.

C.2.84 (b) There are no less environmentally damaging practicable alternatives to the project that would accomplish project goals and objectives. Rotational use of the CDFs should maximize the useful life of those sites, thereby postponing environmental impacts which would result from the creation of new disposal areas in wetlands. Likewise, installation of underdrains at the CDFs would reduce adverse environmental impacts by extending the useful life of those sites. The maximum use of economically justified and environmentally acceptable advance maintenance sections minimizes the number of dredging events, thereby also minimizing adverse impacts from dredging and disposal operations. In the same manner, the proposed improvements to the Project's sediment control features would also minimize adverse impacts from dredging and disposal operations. The proposed hydraulic dredging of berths with direct deposition of sediments into CDFs would reduce the number of agitation dredging events conducted in the harbor, and the adverse impacts stemming from those events.

C.2.85 (c) The work will be conducted in accordance with state Water Quality Certifications to the extent practicable. A water quality monitoring program will be implemented to ensure the CDFs are functioning properly. Should it become apparent that operation of the project is resulting in a violation of state Water Quality Standards, coordination with the appropriate

state will be initiated to determine the appropriate course of action. The disposal operation will not violate the Toxic Effluent Standards of Section 307 of the Clean Water Act.

C.2.86 (d) Operation of the project will not jeopardize the continued existence of any Federally listed threatened or endangered species or its designated critical habitat. The Project will follow the provisions which the US FWS and NMFS state, through the Section 7 consultation process, are necessary.

C.2.87 (e) The project will be operated in accordance with the Marine Protection, Research, and Sanctuaries Act of 1972. A Section 103 Evaluation has been conducted and is contained in Appendix D to the EIS.

C.2.88 (f) The proposed discharges will not result in significant degradation of the Waters of the United States. There will be no significant adverse effects on human health and welfare, municipal and private water supplies, recreation and commercial fisheries, plankton, fish, shellfish, wildlife, special aquatic sites, life stages of aquatic life and other wildlife dependent on aquatic ecosystems, aquatic ecosystem diversity, productivity and stability, or recreational, aesthetic and economic values.

C.2.89 (g) The discharges will include all practicable and appropriate measures to minimize potential harm to the aquatic ecosystem, including mitigation for possible wetland losses as a result of the project.

C.2.90 Findings. Based on the determinations made in this Section 404 (b) (1) Evaluation, the finding is made that with the conditions enumerated in both the BATES for this project and this document, implementation of the Mitigation Plan for the loss of wetlands at Disposal Area 14A and through miscellaneous disposal area operations in South Carolina, and development and implementation of an acceptable mitigation plan for loss of wetlands in Georgia, the proposed discharges comply with the Section 404 (b) (1) Guidelines.

APPENDIX D

SECTION 103 EVALUATION
OF OCEAN DISPOSAL¹⁰

FOR THE
SAVANNAH HARBOR NAVIGATION PROJECT

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FOR THE
SAVANNAH HARBOR NAVIGATION PROJECT

D.1.00 PROJECT LOCATION. Savannah Harbor is a deep-draft harbor located on the South Atlantic U.S. coast 75 statute miles south of Charleston Harbor, South Carolina, and 120 miles north of Jacksonville Harbor, Florida. The harbor comprises the lower 21.3 miles of the Savannah River and 11.17 miles of channel across the ocean bar to the Atlantic Ocean. An ocean dredged material disposal site (ODMDS) is located south of the entrance channel and approximately 3.7 nautical miles offshore.

D.2.00 DESCRIPTION OF PROPOSED OCEAN DISPOSAL. Savannah District proposes to continue placing maintenance material excavated from the Savannah Harbor Bar Channel in the Environmental Protection Agency (EPA)-approved ODMDS.

D.3.00 NEED FOR EVALUATION. Federal projects involving the transportation of dredged material for the purpose of placing it in ocean waters for disposal must be evaluated to determine whether the proposed placement would unreasonably degrade or endanger human health, welfare or amenities, or the marine environment, ecological systems or economic potentialities. In making this evaluation, criteria established by the U.S. Environmental Protection Agency (EPA), pursuant to Section 102 of the Marine Protection, Research and Sanctuaries Act of 1972 (MPRSA), as amended (40 CFR Parts 220 to 228), are applied, including an evaluation of the need for the ocean disposal and the availability of alternatives to ocean disposal.

D.3.01 Transport for ocean disposal of materials excavated during Operations and Maintenance dredging of the Bar Channel for the Savannah Harbor Navigation Project has recently been reviewed under Section 103 of the MPRSA. Concurrence that the material is suitable for ocean disposal was received from EPA by letter dated October 22, 1992. That letter did not mention an expiration date, but EPA concurrences for ocean disposal are typically valid for three years.

D.3.02 This Evaluation was prepared as part of the Savannah Harbor Long Term Management Strategy. That study was intended to provide a long term assessment of the multi-faceted operation of the harbor. One component of that operation was the continued use of the Savannah ODMDS for placement of material dredged during maintenance of the Bar Channel. Therefore, a review of

the existing Section 103 Evaluation for Bar Channel maintenance was made to determine if any changes are warranted. The conclusions of this review resulted in an update of the Savannah Harbor Section 103 Evaluation for three (3) years from EPA's March 23, 1995 letter. During that time period, no further evaluation or coordination under Section 103 of the MPRSA would be necessary unless significant changes are observed in the harbor which would alter the findings of this Evaluation.

D.4.00 STATUS OF EXISTING OCEAN DISPOSAL SITE. The Savannah Ocean Dredged Material Disposal Site (ODMDS) was designated by EPA on August 3, 1987, as part of a Consent Decree. The offshore site is centered at 31 56'54"N and 80 45'34"W and is restricted to disposal of dredged material from the Savannah Harbor area. In the past, the site has been used for the disposal of both maintenance and new work material from the Bar Channel of the Savannah Harbor Navigation Project.

D.4.01 A Management Plan for the Savannah ODMDS is being developed jointly with Region IV of EPA. That document is included as Appendix I of the Savannah Harbor LTMS EIS. This Evaluation is also a component of that EIS.

D.5.00 DESCRIPTION OF SAVANNAH HARBOR NAVIGATION PROJECT. The Savannah Harbor Navigation Project consists primarily of a deep-draft navigation channel and associated dredged material disposal areas. The navigation channel has an authorized depth of -44 feet Mean Low Water (MLW) across the Bar Channel to Station -14+000B. The authorized depth from Stations 103+000 to -14+000B is -42 feet MLW. The Navigation Project was last improved to those depths in 1993/1994. Material from the outer portion of that improvement project (Savannah Harbor Deepening) was placed in the Savannah ODMDS.

D.6.00 PREVIOUS EVALUATIONS OF OCEAN DISPOSAL. As part of the Savannah Harbor Deepening Project, Savannah District completed a Section 103 Evaluation in 1991, of the disposal of new work and maintenance material to be excavated from the harbor's Bar Channel and placed in the Savannah ODMDS. EPA's review of the Evaluation resulted in their February 27, 1992, concurrence that the new work material to be dredged during that project was suitable for ocean disposal.

D.6.01 The District maintained in that evaluation and continues to maintain that Savannah Harbor Bar Channel maintenance material meets the exclusion at 40 CFR 227.13(b)(1). This position is based on the fact that the material normally averages about 15% fines and is found in areas of high current or wave energy (the nearshore ocean bar). The District also believes the material

meets the alternate criteria listed at 40 CFR 227.13(b)(3) since it is essentially similar to material found at the ocean disposal site, and is geographically removed from known existing and historic sources of pollution such that its location provides reasonable assurance that the material to be removed has not been contaminated by such sources. EPA's February 1992 position was that additional information, including comprehensive chemical and biological testing of the material, was necessary before they could concur in the suitability of maintenance material for ocean disposal.

D.6.02 Savannah District conducted the necessary chemical and biological testing of maintenance material, including Tier III testing, and in November 1992, completed a Section 103 Evaluation for the disposal of that material. The Evaluation addressed maintenance material to be excavated from the Bar Channel portion (Stations -60+000B to 0) of the Savannah Harbor Navigation Project. Through that Evaluation, the District found that maintenance material from the Bar Channel was suitable for ocean disposal and would not unduly degrade or endanger the marine environment. That conclusion received concurrence from EPA on October 22, 1992.

D.6.03 Savannah District performed an evaluation of the ocean disposal of new work and operations & maintenance material to be excavated from Stations 0 to 11+000 during the Savannah Harbor Deepening Project. After reviewing the sediment characteristics from that reach, the District determined that the material met the exemption set forth at 40 CFR 227.13(b) and was acceptable for ocean disposal without the need for further testing. EPA concurred with that determination in a letter dated February 25, 1994, for the Deepening Project only.

D.7.00 TIER 1 EVALUATION OVERVIEW. Savannah District conducted an in-house Tier I review in accordance with the Dredged Material Testing Manual to determine if any new conditions have occurred in the harbor that might alter the conclusions of the previous Section 103 Evaluation. The Evaluation included the following components, each of which will be described separately:

- * A review of the volume and channel stations of dredged material that would be placed at the ODMDS.
- * A reassessment of new and previously evaluated physical and chemical data relative to any regulatory changes.
- * A review of changes in sediment composition or deposition.
- * A review of information pertaining to chemicals which have been identified as potential contaminants of concern.
- * A review of spill records.

- * A review of new or revised NPDES permits from GA DNR for the potential contaminants of concern.
- * A determination whether water quality conditions have changed in the harbor that might indicate the need for further evaluation of plans to place Bar Channel maintenance material in the ocean.

D.7.01 Planned Ocean Disposal. Approximately 1 million cubic yards of material are removed each year from the Bar Channel with hopper dredges and deposited in the Savannah ODMDS. That estimated quantity and project area have not changed from that contained in the previously approved Section 103 Evaluation.

D.7.02 Changes In Physical Or Chemical Data. There are no known changes in the composition of the maintenance material which would be removed. No changes have been made to the length, width or orientation of the Bar Channel since the previous Evaluation. No significant changes are known to have occurred in the watershed which could markedly alter the composition of the material which shoals in the Bar Channel.

D.7.03 Information On Potential Contaminants Of Concern. When the Tier II and Tier III testing was performed in 1992, no contaminants of concern were identified. The results of that program were used in the 1992 Evaluation which concluded that Bar Channel maintenance material was suitable for ocean disposal.

D.7.04 Since that time, no additional information has become available which would indicate that the low dioxin levels which were previously identified in Bar Channel maintenance material would now be considered unsafe. In the 1992 study, two samples were found to contain no detectable levels of 2,3,7,8-TCDD or 2,3,7,8-TCDF (the most toxic dioxin congeners). Moreover, the TEQ (toxic equivalence), calculated using 1/2 detection limit values), was found to be 0.96 to 1.07 pptr. In addition, some additional degree of uncertainty has developed on the threshold for impacts as the U.S. Food and Drug Administration deleted its criteria of 25 pptr (parts per trillion) as the cutoff for acceptable levels of dioxin in fish for human consumption.

D.7.05 Improvements are being made in laboratory instrumentation, resulting in a lower detection limit for dioxins. However, uncertainties still remain on how to handle test results which do not reach the detection limits. A national EPA/Corps task force evaluated this issue and a standard protocol has been established whereby test results are evaluated using zero, half the detection limit and the full detection limit when

the test result is reported as "Non-Detect". That protocol had no impact on the previous decision concerning the acceptability of the level of dioxin found in the maintenance material.

D.7.06 Previous sediment investigations performed on inner harbor sediments contained individual samples where levels of the following metals approached or slightly exceeded concentrations where concern should be expressed: Chromium (Cr), Copper (Cu), Lead (Pb), Nickel (Ni), Silver (Ag), and Zinc (Zn). In recognition of the large variability which is common between sediment samples, analyses of the acceptability of dredging and disposal operations use an average of the individual test results as a better representation of the material to be removed by an entire dredging project. Those analyses have consistently determined that dredging and disposal of Savannah Harbor sediments could be conducted in an environmentally responsible manner. However, the metals which were previously found to be elevated in individual cases were considered in this analysis.

D.7.07 Spill Records. The District has no records of any large chemical or material spill comprised of compounds containing those heavy metals.

D.7.08 Georgia DNR NPDES Permits For Potential Contaminants Of Concern. The Environmental Protection Division (EPD) of Georgia Department of Natural Resources was consulted to determine if any changes had occurred since 1992 in the NPDES permits for dioxin and the identified heavy metals for Savannah industries. EPD indicated that since 1989/1990, it has made no changes in the permitted discharge of dioxins or the identified heavy metals in Savannah.

D.7.09 Changes In Water Quality Conditions. No significant changes are known to have occurred which would alter the water quality conditions upon which the previous Evaluation was made.

D.8.00 MONITORING. No information was found which would alter the previous position that monitoring of water quality and impacts to marine organisms due to the chemical properties of the sediments is not necessary. Since there is potential for mounding at the site, bathymetric surveys should continue to be conducted periodically to determine (1) the direction the deposited material is migrating, and (2) ensure that continued use of the Savannah QDMDS is not creating any hazards to navigation.

D.9.00 DETERMINATION AND FINDINGS. Based on the Tier I assessment performed for this Evaluation, no changes were identified which would alter the determination made in previous Section 103 Evaluations that the maintenance material to be excavated from the Savannah Harbor Bar Channel is suitable for ocean disposal and will not unduly degrade or endanger the marine environment.

D.10.00 EPA CONCURRENCE. This current evaluation was coordinated with EPA and concurrence for 3 years received in a letter dated March 23, 1995. The District's Savannah Harbor 103 Evaluation will expire on March 23, 1998.

APPENDIX E

RESULTS OF WRIGHT RIVER
WEIR EFFLUENT AND SEDIMENT TESTING

APPENDIX E

RESULTS OF WRIGHT RIVER
WEIR EFFLUENT AND SEDIMENT TESTING

E.1.00 In late 1993 and early 1994, tests were conducted to determine the environmental impacts of the release of effluent to Wright River from the confined dredged material disposal facilities which are operated for the Savannah Harbor Navigation Project. A testing program was jointly developed by Savannah District, the South Carolina Coastal Council, and the Southeast Fisheries Science Center of the National Marine Fisheries Service (NMFS). The plan was approved by Region IV of the U.S. Environmental Protection Agency prior to implementation. The NMFS Charleston Laboratory was responsible for performance of the testing program. The NMFS performed most of the work, with assistance from the Marine Resources Institute of the South Carolina Wildlife and Marine Resources Department and independent testing laboratories.

E.1.01 The following pages contain the Executive Summary, Discussion, and Conclusions sections of the July 1994 report prepared by the NMFS which documents the investigation. The report is entitled "Ecotoxicological Assessment Of Dredge Disposal Operations In The US Army Dredge Material Disposal Area In The Wright River Estuary Of South Carolina."

E.1.02 As a result of the findings obtained from this investigation, Chatham County has agreed to close the underdrains located in Disposal Areas 12B and 13A which discharge into the marshes adjacent to Wright River. One underdrain has been closed, while discharge from the others will be shut off by the end of 1994 to allow completion of ongoing engineering field investigations.

E.1.03 The study results found that discharges from the overflow weirs did not result in acute effects to aquatic life. It did note that discharges from overflow weirs sometimes exhibited low dissolved oxygen and high turbidity. The District will evaluate additional management measures to reduce possible adverse effects from those items. Based on the study findings, relocation of the overflow weirs does not appear to be warranted.

APPENDIX E

RESULTS OF WRIGHT RIVER
WEIR EFFLUENT AND SEDIMENT TESTING

E.1.00 In late 1993 and early 1994, tests were conducted to determine the environmental impacts of the release of effluent to Wright River from the confined dredged material disposal facilities which are operated for the Savannah Harbor Navigation Project. A testing program was jointly developed by Savannah District, the South Carolina Coastal Council, and the Southeast Fisheries Science Center of the National Marine Fisheries Service (NMFS). The plan was approved by Region IV of the U.S. Environmental Protection Agency prior to implementation. The NMFS Charleston Laboratory was responsible for performance of the testing program. The NMFS performed most of the work, with assistance from the Marine Resources Institute of the South Carolina Wildlife and Marine Resources Department and independent testing laboratories.

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EXECUTIVE SUMMARY

In May 1993, the U.S. Army Corp of Engineers (COE), Savannah District, began a major dredging project in the Savannah River to deepen the harbor near the port of Savannah, Georgia. Disposal of sediments for this project were designated for the state/county owned confined dredged material disposal facility on the Wright River estuary in South Carolina. To assess potential impacts of dredge disposal operations in the Wright River estuary, an integrated field and laboratory ecotoxicological study was undertaken by the U.S. National Marine Fisheries Service (NMFS), Southeast Fisheries Science Center, Charleston Laboratory and the South Carolina Wildlife and Marine Resources Department, Marine Resources Research Institute at the request of the COE and the South Carolina Coastal Council.

The purpose of this study was to determine the acute and chronic toxicity of effluents from and sediments outside the Wright River dredge disposal areas (Figures 1-2, pages 10 & 11) on sensitive estuarine juvenile fish (*Cyprinodon variegatus*), adult grass shrimp (*Palaemonetes pugio*), oyster embryos (*Crassostrea virginica*) and amphipods (*Ampelisca virrilli*) using established Environmental Protection Agency (EPA) and COE protocols. Additionally, adult oysters (*Crassostrea virginica*) were collected from a pristine reference site on Leadenwah Creek and deployed downstream of each disposal area (12-B, 13-A, 13-B, and 14-B) and monitored for bioconcentration of trace metals and polycyclic aromatic hydrocarbons (PAHs), adult survival, potential yield (grams of oyster meat/bushel of oysters) and larval spat settlement.

Sediments, deployed oysters, and effluent were analyzed for a variety of chemical contaminants including:

Contaminant Type	Contaminant	
Trace Metals	Aluminum (Al)	Lead (Pb)
	Arsenic (As)	Manganese (Mn)
	Cadmium (Cd)	Mercury (Hg)
	Chromium (Cr)	Nickel (Ni)
	Copper (Cu)	Silver (Ag)
	Iron (Fe)	Zinc (Zn)
Polycyclic Aromatic Hydrocarbons (PAHs)	Acenaphthene (Ace)	Indeno(1,2,3-Cd)perylene (I(1,2,3)P)
	Acenaphthylene (Acy)	Benzo(b)fluoranthene (BbF)
	Anthracene (Ant)	Naphthalene (Nphl)
	Benzo(a)anthracene (BaA)	Phenanthrene (Phe)
	Benzo(k)fluoranthene (BkF)	Pyrene (Pyr)
	Chrysene (Chy)	2-methyl Naphthalene (2mNphl)
	Dibenzo(a,h)anthracene (D(a,h)A)	1-methyl Naphthalene (1mNphl)
	Fluoranthene (Fla)	Fluorene (Fle)
Other Parameters	% Oil and Grease	% Moisture Content
	Total Organic Carbons (TOC)	Grain Size
	Turbidity	Total Lipids
	Total Suspended Solids (TSS)	
	Biological Oxygen Demand (TOD)	

The following established EPA protocols were used for the analyses: trace metals = graphite furnace atomic absorption, and intracoupled plasma spectroscopy; PAHs = high performance liquid chromatography (oysters and sediments) and gas chromatography-mass spectrometry (effluent only). Results are reported in mg/L or $\mu\text{g/L}$ -effluent, $\mu\text{g/Kg}$ -sediment and $\mu\text{g/Kg}$ oysters.

Monitoring of effluents indicated toxicologically significant (greater than Water Quality Criteria (WQC)) concentrations of As in effluent from areas 12-B Weir 1 and 13-A Weir 3 outfall underdrains. Elevated concentrations of Mn which were greater than WQC based on bioaccumulation but less than levels considered toxic in marine organisms were also observed, along with reduced salinities (< 15 ppt) and high turbidity. Significant toxicity to embryo oysters, grass shrimp, and sheepshead minnows was observed at area 12-B. At areas 13-A and 13-B toxicity was only observed in oyster embryos. High survival ($> 90\%$) was observed in all reference site and controls except low salinity oyster embryo controls ($< 2\%$ survival).

Monitoring of sediments indicated elevated [greater than Effects Range Low (ERL) and greater than Effects Range Median (ERM) described by Long and Morgan, 1989] concentrations of As at area 12-B and Acy at area 14-B. Toxicity tests with amphipods and grass shrimp resulted in high survival ($> 90\%$) at areas 13-A, 13-B, and 14-B. High survival ($> 90\%$) was also observed in all controls and reference site sediments. Sediments toxicity tests were not conducted at area 12-B, since sediment concentrations of As exceeded ERLs and ERMs and earlier effluent tests indicated toxicity in all species tested at this site.

High adult oyster mortality and reduced potential yield and spat settlement were observed in oysters deployed outside weirs for areas 12-B and 13-A and as a result, no uptake of chemical contaminants in oysters was measurable. The cause of death in oysters at these sites may have resulted from elevated As levels in sediments and effluent, low salinity, reduced dissolved oxygen concentrations and high turbidity levels measured at these sites. No significant uptake of chemical contaminants was observed in deployed oysters at any other sites (13-B and 14-B). Reduced spat settlement was also observed at area 13-B. High adult oyster survival, potential yield and spat settlement rates were observed at the New River reference site and the Leadenwah Creek collection site.

These results clearly indicated that the dredge disposal operations in areas 12-B and 13-A ([underdrains]) discharged effluent containing As which was toxic to a variety of estuarine organisms (fish, crustaceans, and mollusc). This has also resulted in toxicologically significant (greater than ERLs and ERMs) As concentration of sediments outside area 12-B. Other co-factors of As toxicity include Mn (which may enhance As precipitation into marine sediments),

low salinity (which favors arsenite [more toxic] over arsenate [less toxic] production) and high turbidity. Another factor which must be considered was low dissolved oxygen levels measured at these sites. Low dissolved oxygen concentrations ($<1\text{mg/L}$) have been routinely found during studies at the headwaters of small tidal creeks in South Carolina. Generally, these low dissolved oxygen conditions only occur naturally during early morning ebb tides due to high nocturnal respiration rates (Scott, et al, 1993). Results from daily monitoring of outfalls suggest sustained periods of low dissolved oxygen concentrations. Results of deployed oyster studies at areas 12-B and 13-A did not indicate evidence of hypoxia (i.e., oyster shell blackened due to hydrogen sulfide associated with hypoxia) among dead adult oysters at this site. Rather an orange discoloration similar to that of the effluent was observed among shells and internal tissues. Other species such as grass shrimp and sheepshead minnow can survive low dissolved oxygen levels indefinitely, as much of their ecology is predicated on survival of low dissolved oxygen conditions. Low dissolved oxygen and high turbidity conditions may also enhance potential exposure of oysters to As and other contaminants due to that species' increased ventilation/pumping response to these conditions.

Results for outfall 13-B only indicated toxicity to oyster embryos and larvae. Only elevated concentrations of Mn which were greater than WQC for bioaccumulation but less than levels considered toxic, low salinity and high turbidity conditions were observed. Much of the toxicity at this site may have been related to low salinity conditions, although the elevated turbidity and Mn concentrations may be co-factors of low salinity effects. The absence of toxicity in euryhaline fish, grass shrimp and adult oysters supports the conclusion that low salinity (which would be toxic to oyster larvae and embryos) was the primary cause of toxicity at area 13-B.

Results for area 14-B and Jones/Oysterbed Island did not indicate any significant impact from dredge disposal operations at these sites. Although elevated levels of acenaphthene (greater than ERL) were observed in sediments outside area 14-B, no sediment toxicity was observed in sediment toxicity tests.

Mitigation/environmental management options for reducing impacts from dredge disposal operations in areas 12-B and 13-A should be considered. Modification or the removal underdrains at these sites would be an obvious first step in reducing As levels and other observed water and sediment quality impacts at these sites. Additional monitoring of any mitigation/management steps would be useful in assessing the success of any mitigation strategy implemented.

DISCUSSION

Results for chemical analysis of sediments, effluent and oysters along with field bioaccumulation bioassays in oysters and laboratory toxicity tests with oysters larvae, grass shrimp, sheepshead minnow and amphipods exposed to effluent and sediments have indicated that several sites within the Wright River dredge disposal area may be potentially toxic to living marine resources. Table 32 summarizes the results of laboratory toxicity tests, field bioaccumulation bioassays, and contaminant chemistry results for each site by formulating a holistic ecotoxicological assessment for the Wright River estuary.

Results from **laboratory toxicity tests** indicated:

- 1) Significant ($p \leq 0.05$) toxicity (multiple species at multiple effluent dilutions) was only observed at area 12-B Weir 1.
- 2) Some toxicity (one species at one dilution) was also observed at areas 13-A Weir 3 and 13-B Weir 5.
- 3) In areas 13-A and 13-B, the lack of toxicity in multiple species at subsequent dilutions suggests that impacts would be confined to the area of the outfall specifically to oysters and possibly other mollusc species.

Results from **oyster field bioaccumulation studies** indicated:

- 1) No significant uptake of chemical contaminants in oysters at any site assayed.
- 2) Significant adult oyster mortality at areas 12-B Weir 1 - outfall and mid sites 13-A Weir 3 - outfall site.
- 3) Significant reductions in potential yield (g of meat/bushel) at areas 12-B Weir 1 - outfall and mid stations and 13-A Weir 3 - outfall and mid sites.
- 4) Significant reductions in larval settlement at areas 12-B Weir 1 - outfall and mid stations, 13-A Weir 3 - outfall, and 13-B Weir 5 -outfall sites.

Effluent contaminant chemistry results indicated:

- 1) Significant ($>$ water quality criteria) concentrations of As and Mn found in underdrains in areas 12-B Weir 1 and 13-A Weir 3.
- 2) Significant ($>$ water quality criteria) concentrations of Mn found at area 13-B Weir 5 - outfall.

Table 32. Summary of laboratory toxicity tests, oyster bioaccumulation assays, and chemical contaminant characterization of effluent, sediments, and oysters from the Wright River estuary.

Site	Laboratory Toxicity Tests: Effluent ¹			Laboratory Toxicity Test: Sediments		Field Oyster Bioaccumulation Assay				Contaminant Chemistry			Cumulative Ecotoxicological Assessment
	Sheeps-head	Grass Shrimp	Oyster Larvae	Amphipods	Grass Shrimp	Bioaccumulation Effects	Adult Mortality	Potential Yield	Larval Settlement	Effluent: Water Quality Criteria	Sediment: Quality Guidelines		
12-B Weir 1 Outfall Mid Outer	**	**	**	NM	NM	?	**	**	**	** (As, Mn > WQC)	* (As > ERL and ERN)	Evidence of significant As effects, and/or possible Mn effects. High turbidity and low salinity conditions were also observed at this site. Zone of impact from outfall to mid station. Low dissolved oxygen (<1 mg/L) observed at outfall.	
12-B Weir 3 Old-Outfall Outer	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	-	Sediment concentrations of trace metals and PAHs < ERL.	
12-B Weir 3 New Outfall Outer	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	-	Sediment concentrations of trace metals and PAHs < ERL.	
13-A Weir 3 Outfall Mid Outer	-	-	*	-	-	?	**	**	**	* (As, Mn > WQC)	-	Elevated concentrations of As found in underdrain. Mn concentrations > WQC (bioaccumulation effects) but < concentration considered toxic to marine organisms. High turbidity and low salinity conditions. Impact zone defined at outfall but may extend outward towards mid station. Low dissolved oxygen (<1 mg/L) observed at outfall.	
13-B Weir 5 Outfall Mid Outer	-	-	*	-	-	-	?	-	**	* (Mn > WQC)	-	Mn concentration > WQC (bioaccumulation effects) but < concentration considered relative to marine organisms. High turbidity and low salinity conditions. Impact zone confined to area around outfall.	
14-B Weir 5 Outfall Mid Outer	NM	NM	NM	-	-	-	-	-	-	-	* (Acy > ERL)	High PAHs concentration of Acy which was > ERL. Otherwise site was considered not impacted by dredging operations.	
Jones Island Mid Outer	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	-	No evidence of dredging impacts.	
Reference Site Inner Mid Outer	-	-	-	-	-	-	-	-	-	-	-	Reference site conditions were similar to other reference site conditions at North Inlet and Leadswath Creek. High survival rate in all bioassays.	

Legend follows on next page.

** = very significant toxic effect (> 90% mortality)

* = significant toxic effect (partial mortality < 90%)

? = results are uncertain as to toxic effect

- = No effect

! = In Laboratory toxicity test, the assumption was made that 50% effluent = mid station and 10% effluent = the river station.

NM = Not Measured

- 3) Low salinity (< 10 ppt) and high (> 400 NTU) turbidity levels were observed in area 12-B Weir 1 and 13-A Weir 3.

Results from **sediment contaminant chemistry** analysis indicated:

- 1) Potentially toxic (> ERL and ERM values) concentrations of As in sediments at area 12-B Weir 1 outfall stations; and
- 2) Potentially toxic (> ERL value < ERM) concentrations of Ace in sediments at area 14-B Weir 5 - mid site.

Laboratory sediment toxicity test results indicated that none of the sediments from areas 13-A, 13-B, and 14-B were toxic to amphipods and grass shrimp. These results suggest that only sediments from area 12-B outfall area would be potentially toxic to living marine resources.

These laboratory and field results generally indicated:

- 1) Sediments and effluents from area 12-B Weir 1 underdrain - outfall may be toxic to a variety of organisms in the estuarine ecosystem (fish, crustaceans, and mollusc);
- 2) Effluent from area 13-A Weir 3 underdrain and overflow may be toxic to oysters (adults and embryos);
- 3) Effluent from area 13-B Weir 5 overflow may be toxic to oysters (embryos only).

Table 33 summarizes ecotoxicological results at sites potentially impacted by dredging operations. Also listed are the possible stressors at each site which may adversely affect living marine resources. These include As, Mn, low salinity, prolonged periods of low (< 1 mg/L) dissolved oxygen concentrations and high turbidity.

Arsenic is a member of Group Vb of the periodic classification, which may undergo multiple electron transfer reactions to form a variety of inorganic and organic compounds of different toxicity to aquatic organisms. Arsenic may exist as As (+5), As (+3), As (0) and As (-3). In the marine environment the most abundant forms of As are arsenate (As +5) and arsenite (As +3). In surface waters As species include As (+5), As (+3) and methylated As (Moore and Ramamoorthy, 1984). It is now well understood that bioaccumulation and toxicity in marine species is a function of the chemical behavior and speciation of As in surface waters and sediments (Sadiq, 1992). Biological activity may also affect both the chemical speciation and cycling of As in marine ecosystems.

Table 33. Summary of sampling sites with evidence of ecological impact and possible stressors affecting living marine resources at each site.

Ecologically Impacted Area	Ecotoxciological Assessment	Possible Stressors
12-B Weir 1 Outfall-Mid	Impacts to fish, crustaceans and mollusc at the outfall extending to the mid station	As, Mn, high turbidity, low salinity, and prolonged periods of low dissolved oxygen concentrations
13-A Weir 3 Outfall	Impacts to adult and larval mollusc at the outfall possibly extending beyond towards the mid station	As, Mn, high turbidity, low salinity and prolonged period of low dissolved oxygen concentrations
13-B Weir 5 Outfall	Impacts to larval mollusc confined to the outfall	Mn and low salinity

The biogeochemical cycle of As in estuaries and marine waters include As uptake by plankton, conversion of As to organic arsenicals, release of arsenite and methylated forms of As, and oxidation and reduction of As to arsenate (Sadiq, 1992). The reduction of arsenite to arsenate in marine environments is generally considered a biological process (Andrae, 1983; Johnson, 1972; Wood, 1974; and Wrench and Addison, 1981) although Cherry et al. (1979) demonstrated that H_2S was very effective in converting arsenate to arsenite.

Salinity may also play a significant role in arsenite/arsenate kinetics. Klump and Peterson (1979) reported that in seawater arsenate predominates while in freshwater arsenite prevails. Generally, arsenite concentration decreased along an increasing estuarine salinity gradient. For example, in a 0.4 Km distance arsenite concentrations decreased by almost 50% (Klump and Peterson, 1979). Similar declines in As concentrations were observed downstream of effluent outfalls at areas 12-B Weir 1 and 13-A Weir 3. Penrose et al (1975) reported that removal (98%) of As from seawater into sediments downstream of a point source of pollution occurred within 100m of the point source. Klump and Peterson (1979) also reported that the ratio of arsenite to arsenate varied with tidal stage, as arsenite dominated at ebb tide and arsenate at flood tide. Pristine river waters generally have As concentration of $< 1 \mu g/L$ where as pristine marine waters have As concentrations ranging from 2-3 $\mu g/L$. In this study, As concentrations in area 13-B, the New River reference site and Leadenwah Creek had As concentrations $< 10 \mu g/L$. Arsenic water concentrations are much higher around point sources of pollution such as mine waste (500 - 5000 $\mu g/L$), agricultural runoff of arsenical pesticides (10 - 33 $\mu g/L$) and downstream of industrial point source pollution (1 -20 $\mu g/L$) (Aston et al., 1975; Richardson et al, 1978; Van der Veen and Huizenga, 1980; and Waslenchuk, 1979). Arsenic concentrations in areas 12-B Weir 1 (117 -147 $\mu g/L$) and 13-A Weir 3 (14.9 - 298 $\mu g/L$) outfalls were elevated relative to levels reported for pristine marine water ($< 3 \mu g/L$) and concentrations found in other sites during this study ($< 10 \mu g/L$).

Arsenic in seawater will combine with clay, organic matter, and Fe or Mn oxides to form precipitant solids, which settle out in sediments (Crecelius, 1975; Sadiq, 1992). The high Mn concentrations (19,800 $\mu g/L$) observed in effluent during this study would favor complexation with As to enhance sedimentation. Arsenic concentrations in pristine sediments are approximately 10 mg/Kg but concentrations as high as 10,000 mg/Kg have been reported around known sources of pollution (Crecelius, 1975; Sadiq, 1992). Elevated As concentrations ($> 10 - > 80 \text{ mg/Kg}$) were reported for area 12-B Weir 1 underdrain and mid stations and area 13-A Weir 3 underdrain and overflow site. Arsenic concentrations for all other stations were generally $< 10 \text{ mg/Kg}$. Penrose et al (1975) reported that removal of Arsenic from seawater

downstream of a point source of pollution occurred within 100m of the point source. Results from area 12-B Weir 1 (Figure 16) support these results as As sediment concentrations declined by > 70% within 0.5 Km of the effluent discharge outfall (mid station) and by > 90% at greater distances downstream (outer station).

Arsenic is generally considered an environmental pollutant associated with anthropogenic activities (Sadiq, 1992). Primary anthropogenic sources of As pollution include mine waste, pesticide formulations, industrial uses, chromated copper arsenate wood preservatives, cement production, poultry feed additives, pharmaceuticals, detergents, petroleum and coal combustion, metal ore smelters, and plant desiccants (Moore and Ramamoorthy, 1984; Sadiq, 1992). Erosion, weathering of bedrock and vulcanism are the primary natural biogenic sources of As. The total discharge of As from anthropogenic sources is 110,000 tons/year which is 2.5 times the contribution due to natural sources (Moore and Ramamoorthy 1984). Urban air may also be enriched in As, particularly in highly industrialized areas and resulting atmospheric deposition may occur.

The toxicity of As to living marine resources is dependent upon valence state and complexation with organic molecules (Sadiq, 1992). Arsenite is more toxic than arsenate; therefore, any factor or mechanism which increases arsenite production over arsenate will increase As toxicity. At the outfalls in areas 12-B Weir 1 and 13-A Weir 3, lower salinity conditions would favor arsenite production over arsenate. Thus greater toxicity would be expected at the outfall, where lowest salinities and highest As concentrations were observed. McLusky et al (1985) reviewed the effect of temperature and salinity on As toxicity and found that salinity had no significant effect in a limited study of three marine species.

Sadiq (1992) reports that As is acutely toxic to aquatic organism (fish and crustaceans) at concentrations ranging from 1,000 - 50,000 $\mu\text{g/L}$. The threshold toxicity of As in marine organisms is dependent upon species type and stage of development (Sadiq, 1992). Generally larval stage and benthic bottom feeders are more sensitive than fish. Scott et al (1984) in a review of heavy metal toxicity reported that the most sensitive species among edible shellfish species were crab larvae (*Cancer magister*) and oyster embryos (*Crassostrea gigas*) with 96h and 48 LC50s respectively of 232 and 326 $\mu\text{g/L}$ as arsenite (AsO_3) (Martin et al, 1981). Arsenic concentrations found as arsenite may be more toxic than arsenate. Total As concentrations of 117 - 147 $\mu\text{g/L}$ were measured in effluent from outfall 12-B Weir 1 and concentration of 14.9 - 298 $\mu\text{g/L}$ were measured in effluents from outfall 13-A Weir 3. Effluents from 12-B Weir 1 were toxic to all species tested (fish, crustaceans, and mollusc)

while effluents from 13-A Weir 3 were only toxic to oyster larvae. Generally oyster embryos appeared to be the ecotoxicological end point most affected by dredge effluent and oyster embryos are among the most sensitive species tested in terms of As toxicity. While toxicity was observed in outfall effluents at As concentration < levels reported toxic to oyster embryos, the apparent potential for arsenite production rather than arsenate due to low salinity conditions would favor greater toxicity at outfalls which would decrease dramatically with increasing distance from the source as salinities increase and arsenite/arsenate concentrations decrease. Sediment Arsenic results from area 12-B clearly support this hypothesis. Another factor to consider is that *Crassostrea virginica* may have different sensitivities than *Crassostrea gigas* to As exposure.

Arsenic is only moderately bioconcentrated by marine organisms with a bioconcentration factor (BCF) of 85.4 in *Crassostrea virginica* (Scott et al, 1984). Arsenic is not progressively bioaccumulated in food chains (EPA, 1976). Of particular interest is the fact that while arsenite is more toxic than arsenate, arsenate has greater bioaccumulation potential than arsenite (Sadiq, 1992). This suggests that the preferential uptake of arsenate provides a physiological protective mechanism to reduce potential arsenite toxicity when both compounds co-occur as would be the case in estuarine waters.

The salt water quality criteria for As (+5) is 69.0 µg/L for acute effects and 36 µg/L for chronic effects and for As (+3) the acute effects level is 2,319 µg/L and 13 µg/L for chronic effects. Effluent concentration in areas 12-B Weir 1 and 13-A Weir 3 exceeded these concentrations. The ERL and ERM values (Long and Morgan, 1989) for As sediment concentrations are 33 mg/Kg and 85 mg/Kg, respectively. MacDonald (1993) reported a No Observable Effects Level (NOEL) of 8 mg/Kg and a Probable Effects Level (PEL) of 64 mg/Kg for As in sediments. Only sediments from area 12-B Weir 1 outfall contained As concentrations > ERL and ERMs and > PEL. Sediment As concentrations at other sites were generally at or below the NOEL.

Arsenic is also considered a carcinogen (EPA, 1980). Fish action levels are lacking for the US but international standards range from 1 - 10 mg/Kg. No significant uptake of As was observed in field deployed oysters, although significant adult oysters mortality occurred at areas 12-B Weir 1 - outfall and 13-A Weir 3 - outfall.

Disturbance of sediments containing As may enhance the toxicity and bioaccumulation potential of As (Sadiq, 1992). Cherry and Guthrie (1977) studied the deposition of coal ash in

the Savannah River and found that dredging of As containing sediments resulted in a 3 fold increase in As bioaccumulation in marine invertebrates. Accumulated As is rapidly depurated with estimated half lives in marine mollusc of 4 - 13 days (Klamp, 1980). Low salinity may also decrease the bioconcentration of As from water exposure (Klamp, 1980; Moore and Ramamoorthy, 1984).

In addition to As, potential toxicity of Mn in effluents from outfalls in areas 12-B, 13-A, and 13-B must be considered. Manganese does not occur naturally as a pure metal but rather is found as a salt and mineral usually found in association with Fe (EPA, 1976). The primary forms of Mn are manganese dioxide (MnO_2), pyrolusite, manganese carbonate (rhodocrisite), and manganese silicate (rhodonite) (EPA, 1976). The oxides are the only mineral form of Mn mined, generally in iron ore used to form ferro-manganese alloys. Manganese is used in metal alloys, dry cell batteries, micro-nutrients in fertilizers, organic compounds in paint driers and chemical reagents (EPA, 1976). Manganese is a vital micro-nutrient for both plants and animals in micro quantities with an average daily intake in the diet of humans of 10 mg/day.

The average ambient concentration in surface waters is 2 $\mu\text{g/L}$ and concentration > 1,000 $\mu\text{g/L}$ are rare (EPA, 1976). Very little toxicity data exist on Mn. The EPA water quality criteria is 100 $\mu\text{g/L}$ which is based upon the potential for bioaccumulation as BCFs of > 12,000 have been reported (EPA, 1976; NAS, 1974). Scott et al (1984) reported that Eisler (1977) found a 96h LC50 value of 50,000 $\mu\text{g/L}$ for Mn in adult *Mya arenaria*, which were the most sensitive estuaries/marine species of edible shellfish.

The concentrations of Mn found in effluent from areas 12-B Weir 1 (18.3 - 19,800 $\mu\text{g/L}$), 13-A Weir 3 (13 - 2,300 $\mu\text{g/L}$), and 13-B (1,210 $\mu\text{g/L}$) exceeded the EPA saltwater WQC of 100 $\mu\text{g/L}$ based on bioaccumulation effects but were less than the 50,000 $\mu\text{g/L}$ 96h LC50 value reported for clams by Eisler (1977). Manganese concentration at the New River reference site and Leadenwah Creek control site range from <30 - 97.5 $\mu\text{g/L}$, well above the 2 $\mu\text{g/L}$ concentration reported by EPA (1976). These results suggest that while Mn occurred in high concentration in effluents in areas 12-B, 13-A, and 13-B, measured concentrations would not have been directly toxic *per se* to fish, crustaceans and molluscs.

The presence of elevated Mn concentrations may have potentially affected the toxicity of As in effluent by providing an oxide for complexation with As to enhance As deposition from the water column into marine sediments. This As-Mn interaction would probably reduce the As toxicity in effluent at these outfalls sites in the Wright River, but would do so by increasing the toxicity potential in sediments.

Reduced salinities (< 10 ppt) may be another factor which must be considered in evaluating toxicity results from effluent and sediment toxicity tests. Low salinity (< 10 ppt) would be toxic to embryo and larval oysters but would not be toxic to adult oysters, adult sheepshead minnows, and adult grass shrimp. The toxicity observed in larval and adult oysters and adult grass shrimp and mummichogs at area 12-B Weir 1 in effluents and field deployed oysters was primarily related to As exposure although effects from low salinity in part may have affected oyster embryos. Adult oysters can survive low salinity exposure indefinitely (> 60 days) (Scott et al, 1982) as can grass shrimp and sheepshead minnows (Scott et al, 1993). Survival of embryo oyster, low salinity (13 ppt) controls was $< 2\%$, suggesting oyster embryo toxicity may be related in a large part to low salinity. At outfall 13-A Weir 3, toxicity was confined to embryo and adult oysters in field and laboratory studies where salinities of 12.5-19 ppt were measured. This suggests that toxic factors other than low salinity would be responsible for observed effects, possibly elevated As concentrations. In area 13-B Weir 5 outfall, toxicity was confined to larval and embryo oyster, respectively, in both field and laboratory exposures where low salinity of 11-22 ppt were observed. Davis and Calabrese (1964) studied the survival of oysters eggs and larvae at a variety of temperature ($17.5 - 32.5^{\circ}\text{C}$) and salinity (7.5 - 27.0 ppt) conditions. Optimum embryo survival (58 - 98%) was at salinities of 20 - 27 ppt. Embryo survival at 17.5 ppt salinity ranged from 10 - 89% and at 15 ppt salinity from 0 - 39 % at different temperatures. Embryo survival at salinities of 12.5 ppt and below was 0%. Davis and Calabrese (1964) further reported oyster larvae were better able to survive low salinity. At 10 ppt salinity larval survival ranged from 49 - 71% at a variety of temperature conditions. Field studies of oyster larval settlement in North Carolina estuaries indicated that oyster recruitment was decreased at low salinity sites when compared to high salinity areas (Ortega and Sutherland, 1992). Davis (1958) also noted that the salinity tolerance of oyster embryos is in large part determined by the salinity adults are reared in, prior to spawning. These results suggest that the survival of oyster embryo and larvae (not adults) exposed to effluent at outfalls 12-B Weir 1, 13-A Weir 3, and 13-B Weir 5 may in part be influenced by low salinity conditions.

A final factor which must be considered is the high turbidity conditions in effluent discharges from outfalls in areas 12-B, 13-A, and 13-B. Galtsoff (1964) reported that rapid settlement of suspended material maybe highly destructive to any oyster bed community. If sedimentation rates exceed oyster growth rates, the oysters will perish due to siltation effects (Galtsoff, 1964). Oysters exposed to high sedimentation loads may be invaded by parasites, such as the mud worm *Polydora websteri*, which invade the oyster shell causing mud to accumulate. The oyster responds by calcification over the invading parasite to form a blister.

This diverts energy away from the adult oyster for growth and reproduction. In addition to adult oyster effects, heavy siltation may also affect the ability of larval oysters to settle on adult oyster shell (Galtsoff, 1964). A 1 - 2 mm deposit of sediments is sufficient to cause a failure of larval oysters to settle (Galtsoff, 1964). Ortega and Sutherland (1992) reported that increased sedimentation, greatly reduced oyster spat settlement in North Carolina estuaries and sounds. The combination of low salinity sediment characteristic and algal turfs was particularly inhibitory to larval settlement. Increased turbidity may also reduce photosynthetic activity of phytoplankton important to the diet of oysters.

LaSalle et al., (1991) reported that acceptable ranges of turbidity for survival of aquatic organisms was $\geq 500 - 1,000$ mg/L. Results from this present study indicated that turbidity levels > 400 mg/L may be harmful and/or potentially toxic to oysters, grass shrimp and sheepshead minnow. At the New River reference site, the Leadenwah Creek oyster collection site, and overflow weirs in areas 13-B and 14-B, turbidity levels were < 100 mg/L. Generally, no significant ecological effects were observed in these areas. LaSalle et al., (1991) reported that the most sensitive fish species (alewife) had reduced survival at turbidity levels of ≤ 100 mg/L and other fish species (striped bass, yellow perch) had significant effects on survival at ≤ 500 mg/L. Our results are in general agreement with these findings. Sites with turbidity levels > 400 mg/L (areas 12-B and 13-A) had high mortality, elevated contaminant levels of As and Mn, low salinity, and low dissolved oxygen levels. Turbidity levels $> 100 - \leq 500$ mg/L, would be stressful (i.e., reduced assimilation efficiencies, increased metabolic rates) to estuarine organisms as the energetic cost of maintenance metabolism would be increased.

Heavy turbidity loads adversely affect adult oysters by clogging gill mucous, requiring hypersecretion of mucous during feeding. Scott et al (1980) reported that increased mucous production in oysters induced by high levels of coliform bacteria, decreased oyster condition index due to hypersecretion of mucous thus reducing oyster assimilation efficiencies. Increased turbidity may also cause clogged gills in fish and invertebrates (EPA, 1976).

As this discussion suggests high turbidity may in part be a factor in observed toxicity in oyster larvae in the laboratory and the field. Turbidity effects on adult oysters, fish, and grass shrimp are less evident but certainly possible.

CONCLUSIONS

Based upon results from their study, the following conclusions were made:

- 1) Area 12-B Weir 1 underdrains contained effluent which had elevated ($>WQC$) concentrations of As and Mn and sediments with elevated levels of AS ($>ERL$ and $ERMs$) which were toxic to fish, crustaceans and mollusc in laboratory and field toxicity tests. Impacts were observed at the outfall extending to the mid-station. No impacts were observed at the outer (Wright River) station.
- 2) Toxicity observed in grass shrimp and sheepshead minnow at area 12B Weir 1 underdrains was attributed primarily to As, although elevated concentrations of Mn, low salinity conditions, prolonged period of low dissolved oxygen concentrations and high turbidity were potential co-factors of As toxicity.
- 3) Toxicity in field deployed adult oysters, reduced field spat settlement, and high mortality in laboratory, oyster embryo toxicity tests was observed at area 12-B Weir 1. While toxicity in the field, oyster larval settlement and laboratory oyster embryo bioassays may have in part been related to low salinity conditions, mortality in adult oysters was clearly related to other factors such as elevated As concentrations and high turbidity levels at this site.
- 4) At area 12B Weir 3 Old and New combined underdrain and overflow weir, no elevated concentrations of trace metals or PAHs were observed in sediments from that site. No sediment or effluent toxicity tests or oyster bioaccumulations studies were conducted at this site.
- 5) At area 13A Weir 3 underdrains, elevated concentrations of As and Mn ($>WQC$) were observed in effluent samples along with low salinity, low dissolved oxygen concentrations and high turbidity conditions which were acutely toxic to oyster embryos in laboratory toxicity tests and in the field, reduced oyster spat settlement, adult oyster potential yield and adult oyster survival was observed. Measured effects were observed at the outfall and extended outward to the mid-station.
- 6) Toxicity to embryo, larval, and adult oysters at area 13A was related in part to As toxicity. Elevated effluent concentrations of Mn, low salinity and high turbidity were potential co-factors of As toxicity. No toxicity was observed from sediments at this site in grass shrimp and amphipods.

- 7) At area 13B Weir 5 overflow weir, elevated concentrations of Mn (>WQC) were observed along with low salinity and high turbidity conditions which were acutely toxic to oyster embryos in the laboratory and oyster larvae in the field. No toxicity was observed in sediments at this site during exposures to grass shrimp and amphipods. Effects were confined to the areas around the outfall only.
- 8) The elevated levels of Mn at area 13B weir 5 were >WQC based upon bioaccumulation effects but were < concentrations considered acutely toxic to marine organisms. Low salinity and elevated turbidity concentrations may be co-factors of toxicity at this site.
- 9) At area 14B Weir 5 and 6 overflow weirs, only elevated (>ERL) concentrations of Ace were observed in sediments. No significant laboratory or field toxicity was observed in fish, grass shrimp, amphipods and oysters tested. Generally, this site was considered non-impacted by dredging operations.
- 10) At Jones/Oysterbed Island, there was no evidence of dredging impacts observed, based on chemical analysis of sediments at this site. No laboratory or field toxicity tests were conducted at this site.
- 11) At the New River reference site, no significant contaminants levels were observed in effluent or sediments nor was there evidence of contaminants uptake by oysters.
- 12) High survival (>90%) was observed in all laboratory toxicity tests with effluents and sediments at the New River reference site. Similarly high adult oyster survival, potential yield and larval settlement rates were observed in field deployments.
- 13) The role of other factors such as low dissolved oxygen should also be considered when reviewing results from this study. Periodic (< 6hr) low dissolved oxygen concentration (<1mg/L) are quite common in estuarine tidal creeks of South Carolina. Grass shrimp, oysters and sheepshead minnows have physiological adaptations which allow them to survive in the rigors of a dynamic estuarine environment which includes brief daily excursions of low dissolved oxygen, usually at early morning ebb tides during the summer. Prolonged periods of low dissolved oxygen concentrations may be acutely toxic to estuarine organisms and generally caused by the discharge of oxygen demanding waste into the ecosystem. Low dissolved oxygen conditions may also be a co-factor of toxicity as enhanced uptake of chemical contaminants would occur due to increased ventilation/pumping rates in marine organisms (fish, crustaceans, and mollusc).

- 14) Environmental mitigation to reduce toxicity outside areas 12-B Weir 1 and 13-A Weir 3 should be focused on the underdrains located at these sites. The removal of the underdrains there would certainly result in reduced contaminant levels in both effluent and sediments at this sites. This would result in the improvement of the environmental quality at these sites. Additionally, the impacts of materials discharged from the underdrains would be greatly reduced and minimized if the discharges were directed into a receiving water body with a larger volume and greater assimilative capacity where concentrations would be diluted faster than the Wright River. Discharge of effluents at other sites (areas 13-B and 14-B) with overflow weirs were clearly less toxic to living marine resources than underdrains.
- 15) Potential mitigation at area 13-B could be further studied since there was no clear cut, definitive cause identified which was related specifically to contaminants for the observed toxicity. Rather low salinity must be considered a potential major cause of observed oyster embryo toxicity at this site.

APPENDIX F

SEDIMENT QUALITY EVALUATION

SEDIMENT QUALITY EVALUATION
FOR THE
SAVANNAH HARBOR NAVIGATION PROJECT

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SEDIMENT QUALITY EVALUATION

F.1.00 OVERVIEW OF SEDIMENT QUALITY EVALUATION.

F.1.01 An extensive evaluation was made of past sediment quality tests and scientific literature pertaining to the field of sediment quality / sediment contamination. The information presented in this appendix pertains to the quality of sediments in the inner harbor. A review of the quality of sediments found at the Bar Channel are included in the Section 103 Evaluation for ocean disposal which is contained in Appendix D of the EIS. The evaluation described in this appendix is divided into two sections. The first examines the acute, or short term, impacts from exposure to the inner harbor sediments. The subsequent section examines the chronic, or long term, impacts from exposure to those sediments. The analysis of chronic impacts is much more difficult as the concern is for less visible, but equally critical, biological responses to chemical stimuli. Significantly less basic scientific research has been done on chronic impacts, and the examination of these impacts is often confounded by the presence of other adverse stimuli simultaneously affecting the organisms being evaluated.

F.2.00 ACUTE (SHORT TERM) CONTAMINANT IMPACTS.

F.2.01 Introduction. Savannah District is aware of no accepted standards of sediment quality or accepted method for conclusively determining sediment quality. There is a lack of national sediment quality criteria and biological assessment consists largely of acute bioassays (EPA, 1992). In addition, "Realistic prediction of the impact of trace metals in sediments upon aquatic organisms requires an understanding on how physical and chemical factors affect metal uptake by organisms. These factors are not completely understood, and simple relationships are seldom found in natural systems between trace metal levels in the organisms and total metal concentrations in either the sediment or the water to which the organisms are exposed (Luoma, 1989)" (cited in Bourgoin et al., 1991).

F.2.02 Numerous standards or thresholds have been reviewed during the conduct of this evaluation. The various levels are quoted throughout this document. No single reference contains conclusive and widely-accepted standards which can be directly applied to the analysis of harbor sediments. This analysis must include 3 aspects of the sediments: (1) their insitu concentrations, (2) potential impacts from the dredging operation, and (3) potential impacts from the disposal operation, including discharges from confined disposal facilities. The insitu concentrations also allow a direct assessment of

concentration in the sediment at the disposal site, since no chemicals are added to the material during the dredging or disposal processes and sediment constituents should be at equilibrium with the river water used to transport the sediment during hydraulic dredging.

F.2.03 One set of standards which may have a better application to insitu concentrations than most are those standards set by EPA for the land application of sewage sludge when the land is not used to grow crops for human consumption. Such a process is fairly similar to the Project's confined disposal facilities (CDFs) where material is applied to land that is not used to produce crops for human consumption. No edible crop is grown at the CDFs, and the growth of vegetation is actually discouraged within the CDF. As such, there are no direct avenues for chemicals within the deposited sediments to affect humans. Those particular EPA standards were established in recognition that wildlife may use the land application site, and the levels were set to protect such use. A somewhat higher set of standards set by EPA governs the land application of sewage sludge on gardens, where crops for human consumption are expected. These standards may be useful for those concerned about the potential for chemical uptake by wildlife which use the disposal areas. The District's evaluation of sediment quality also used this set of sediment criteria in the analysis.

F.2.04 There is some question as to how well sediment contaminant levels can be related to biological effects. "Previous efforts to relate sediment chemical concentrations to biological effects have been only partially successful (Giesy et al., 1988) because sediment contaminants are not generally bioavailable in the same sense that contaminants in water are" (Tatam, 1990). Analyzing the total concentrations of contaminants in sediments may well overstate the sediment's toxicity to biota. "Considerable published data indicate that total metal concentrations in sediments are not good estimators of the 'free' and bioavailable fraction of the total chemical present ... Different sediments can differ by a factor of 10 or more in toxicity for the same total metal concentration" (Burton, 1992). There have been two attempts to address possible acute toxicity of sediments, one by Long and Morgan (Long and Morgan, 1990), and one by MacDonald (MacDonald, 1993). The efforts of these investigators has since been merged into one evaluation (Long et al., 1993). These studies are part of an effort to identify contaminant levels that might constitute a concern for environmental impacts. It should be recognized that these studies do not address bioavailability nor do they consider changes that the sediments might undergo once they are placed in an upland disposal area. Neither of these studies were designed to be regulatory in nature, however they may be used to estimate whether or not a possible concern may exist, especially for inundated or saturated dredged material within a CDF. Known

information on the composition of Savannah Harbor sediments will be compared to these and other studies in the following discussions.

F.2.05 Ranking of Savannah Harbor on the EPA Region 4 Coastal Sediment Quality Inventory. Savannah Harbor's ranking on this inventory should be an overall indication of how it compares to other harbors in the southeast with respect to concern for contaminants. The EPA draft report lists Savannah Harbor as a site "with effects indices for metals exceeding one" (EPA, 1992). Savannah is not included on their list of harbors where organics may be of concern. That inventory shows Savannah Harbor as having a sediment "effects index for metals" of 2.4. This index value was derived by summing the ratios of all toxic metals to their TEL's (threshold effects level). Savannah had one of the lowest indices of all southeast harbors studied, ranking 12th out of 14 harbors studied. This study cited chromium as the primary contaminant. Since the 1992 EPA report was only a draft, it represented only EPA's contractor's evaluation of data which they obtained on the region's harbors and did not represent EPA's evaluation. EPA states that conclusions drawn from the contractor's evaluation are to be considered preliminary and subject to change. However, EPA has not finalized the 1992 report, so the District believes that document represents the best broad assessment and comparison of the harbor's sediment quality available.

F.2.06 Organic Contaminants.

F.2.07 Past sediment analyses have not found a concern for organic contaminants. The 1982 study by Environmental Protection Systems (EPS, 1982) of 30 sediment samples taken in the harbor area detected only one organic compound, the PAH naphthalene, and only at 3 of their stations in the harbor (two within the channel at 1.27 ppm and 1.96 ppm, and one in a slip at 1.65 ppm). They recommended that further sediment testing be restricted to heavy metals. A potential problem with most of the contaminant studies within the harbor is that the detection limits are higher than the ER-L's of Long and Morgan, 1990, and Long et al., 1993. Recent studies using detection limits in the range of the ER-Ls have had a specialized purpose and have investigated a particular set of chemicals. A selected group of chemicals, study source, and the detection limit used, are shown in Table 1. As can be seen from this table, some of the more recent studies have employed suitably low detection limits. These studies have been used in assessing the overall probability of environmental impacts from project dredged material. As is discussed below, available data show little concern for organic contaminants of project dredged material.

TABLE 1

DETECTION LIMITS (PPB)
FOR SELECTED ORGANIC CHEMICALS
FROM TESTS OF SAVANNAH HARBOR SEDIMENTS

	EPS*1	EMC*2	SKID*3	SL*4	NMFS *5	ER-L
	1982	1993	1993		1994	
<u>PAHs</u>						
Acenaphthene	500	500	80	480- 4200	25- 320	16
Benzo(a)an- thracene	500	750	130	480- 4200	5-64	261
Benzo(a)pyrene	500	1000	170	480- 4200	5-64	430
Flourene	500	1000	90	480- 4200	11- 160	19
Flouranthene	500	---	110	480- 4200	11- 160	600
Phenanthrene	500	1000	90	480- 4200	5-85	240
Naphthalene	500	1000	70	480- 4200	25- 320	160
<u>Pesticides</u>						
Chlordane	25	5000	.5	25-44	---	.5
Dieldren	25	2500	.1	4.8-8.5	---	.02
Endosulfan	25	5000	---	2.5-4.4	---	---
Endrin	25	5000	1.0	4.8-8.5	---	.02
Heptachlor- epoxide	25	1000	.1	2.5-8.4	---	---
4,4'DDD	25	1000	1.0	5.2-8.5	---	2
4,4'DDT	25	5000	.1	5.2-8.5	---	2

NOTE: The references for these evaluations are as follows:

*1 EPS. Environmental Protection Systems, Inc., 1982.

*2 EMC. EMC, 1993.

*3 SKID. Skidaway Institute of Oceanography, 1993.

*4 SL. Savannah Labs study for CITCO, May 1994.

*5 NMFS. National Marine Fisheries Service, 1994.

F.2.08 Polynuclear Aromatic Hydrocarbons (PAH's). Some studies have found organic contaminants in Savannah Harbor sediments, primarily PAH's. In the 1982 study cited above, naphthalene was detected in three samples (of 26) samples from the main river area. The levels (1.27, 1.96, and 1.65 ppm) were above the ER-L of 340 ppb but below the ER-M of 2.1 ppm. In a study of two berths in the harbor (Skidaway, 1993), Skidaway Institute detected the following PAH's at levels at or above the ER-L but below the ER-M, using detection limits ranging from 0.07 to 0.23 ppm: fluorene, phenanthrene, anthracene(sic, anthracene?), fluoranthene, pyrene, benz(a)anthracene, chrysene, benzo(b)(k)-fluor, benzo(e)-pyrene (no ER-L), benzo(a)-pyrene (no ER-L), perylene (no ER-L), Indo(1,2,3-Cd)pyrene, benzo(g,h,i)perylene (no ER-L), and dibenz(a,h)anthracene. A recent study by the NMFS (NMFS, 1994) looked at PAH concentrations in a large number of sediment samples taken below the CDF weir outfalls to the Wright River. Only one of three sediment samples taken midway out from 13B weir #5 had a PAH (acenaphthene) concentration greater than the ER-L. The study identified no impacts from PAH's due to dredging discharges. A recent study of the Stone Container berths using low detection limits (EMC, 1995), found only one PAH above reference values or ER-L's, acenaphthylene. In this case, three replicate samples showed <14 ppb and the two duplicates exhibited 46 and <14 ppb. Therefore, only one of five replicate samples showed a value above the ER-L of 44 ppb. This is not thought to be of concern. A study of Georgia Container Berth 7 by S&ME (S&ME, 1995) had detection limits too high to judge whether PAH's were present above reference levels or ER-L's. One of their four samples did find the following PAH's above the reference, ER-M or ER-L: acenaphthylene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, fluoranthene, indeno(1,2,3-cd)pyrene, and pyrene. These data show the possibility of increased PAH's and other organics in off channel sediments in parts of the harbor. Additional evaluation may be necessary where such sediments may predominate in a dredging operation.

F.2.09 Specific Polynuclear Aromatic Hydrocarbons (PAH's). Reference values cited below are from the Savannah Harbor reference in the 1994 Wright River Weir Study conducted by the NMFS. Sample values are from the Stone Container Study, where suitably low detection limits were employed.

F.2.10 Acenaphthene. The three replicate samples and two duplicates of <14 ppb. The reference values are all non-detect at <11 to <120 ppb. The reference values are all non-detect at <11 to <120 ppb. Alexander et al. (1994) studied sediments dated from the present to 1900 in three cores from Savannah Harbor and

did not detect this PAH in recent sediments (10 ppb detection limit). Earlier sediments contained up to 66 ppb (1962). Sediments from the last 10 years showed a high of 10 ppb. Since the ER-L is 16 ppb, there is no concern for this substance.

F.2.11 Acenaphthylene. The three replicate samples of <14 ppb and the two duplicates of 46 and <14 ppb. The reference values are non-detects at <38 to <120 ppb. The ER-L is 44 ppb and the ER-M is 640 ppb. Alexander et al. (1994) studied sediments dated from the present to 1900 in three cores from Savannah Harbor and detected some of this PAH in sediments of various ages. Highest concentrations (105 and 146 ppb) were found in sediments from the 1950's and 1960's. Sediments from the last 10 years showed no detection at 10 ppb. The overall low levels show there is no reason for concern.

F.2.12 Anthracene. The three replicate samples and two duplicates of <5.7 ppb. The reference values are all non-detect at <7.7 to <24 ppb. Alexander et al. (1994) studied sediments dated from the present to 1900 in three cores from Savannah Harbor and detected some of this PAH in sediments of various ages. Highest concentrations (172 to 189 ppb) were found in sediments from 1954 to 1962. Sediments from the last 10 years showed a high of 40 ppb. Since the ER-L is 85 ppb, there is no concern for this compound.

F.2.13 Benzo(a)anthracene. The three replicate values of 8.1, 7.0, and 6.0 ppb and the two duplicates of 7.6 and 6 ppb. All reference values < 22 ppb. Alexander et al. (1994) studied sediments dated from the present to 1900 in three cores from Savannah Harbor and detected some of this PAH in sediments of various ages. Highest concentrations (347 to 702 ppb) were found in sediments from 1900 and 1954 to 1962. Sediments from the last 10 years showed a high of 58 ppb. Since the ER-L value (Long and Morgan, 1990) is 230 ppb, there is no concern for this compound.

F.2.14 Benzo(a)pyrene. The three replicate values of 6.9, 6.2, and 7.3 ppb and the two duplicates of 6.0 and 6.1 ppb. The reference values are < 77 ppb. One sample from the GPA Berth 7 study showed 2200 ppb, above the ER-M of 1600 ppb. Alexander et al. (1994) studied sediments dated from the present to 1900 in three cores from Savannah Harbor and detected some of this PAH in sediments of various ages. Highest concentrations (154 to 464 ppb) were found in sediments from 1900 and 1954 to 1962. Sediments from the last 10 years showed a high of 36 ppb. Because the ER-L is 400 ppb, there is no reason for concern for channel sediments. Where sediments outside the channel predominate a dredging project, occurrence of this compound should be considered.

F.2.15 Benzo(b)fluoranthene. The three replicate values of 29, 26, and 34 ppb and the two duplicates of 29 and 30 ppb. The GPA Berth 7 study found one sample at 2400 ppb. The reference values are <41 ppb. Alexander et al. (1994) studied sediments dated from the present to 1900 in three cores from Savannah Harbor and detected some of this PAH in sediments of various ages. Highest concentrations (314 to 684 ppb) were found in sediments from 1900 and 1954 to 1962. Sediments from the last 10 years showed a range of 25 to 74 ppb. There is no ER-L for this compound. However, existing data for recent sediments indicate that there should be no concern for this compound in project O&M sediments. The possible occurrence of this compound should be investigated when evaluating other sediments.

F.2.16 Benzo(g,h,i)perylene. The three replicate values of <14, 21, 17 ppb and the two duplicate of 16 and <14 ppb. The reference values are < 63 ppb. Alexander et al. (1994) studied sediments dated from the present to 1900 in three cores from Savannah Harbor and detected some of this PAH in sediments of various ages. Highest concentrations (153 and 321 ppb) were found in sediments from 1900 and 1954. Sediments from the last 10 years showed a high of 39 ppb. These data indicate that in channel O&M sediments should be expected to occur in the range of the reference sediments. Therefore, there should be no concern for environmental impacts from this compound in project O&M sediments. The possible occurrence of this compound should be investigated when evaluating other sediments.

F.2.17 Benzo(k) Fluoranthene. The three replicate samples and two duplicates of <14 ppb. The reference values are all <19 to 170 ppb. One sample from the GPA Berth 7 study was found to contain a concentration of 2330. Alexander et al. (1994) studied sediments dated from the present to 1900 in three cores from Savannah Harbor and detected some of this PAH in sediments of various ages. Highest concentrations (207 to 426 ppb) were found in sediments from 1900 and 1954 to 1962. Sediments from the last 10 years showed a high of 47 ppb. Since the observed values for recent sediments are less than the reference, there is no reason for concern with respect to project O&M sediments. Other sediments may require additional evaluation.

F.2.18 Chrysene. The three replicate values are 14, 12, and 17 ppb and the two duplicates of 13 and 15 ppb. The GPA Berth 7 study found one sample with a concentration of 2970 ppb. Alexander et al. (1994) studied sediments dated from the present to 1900 in three cores from Savannah Harbor and detected some of this PAH in sediments of various ages. Highest concentrations (271 to 866 ppb) were found in sediments from 1900 and 1954 to

1962. Sediments from the last 10 years showed a range of 18 to 66 ppb. The reference values are <57 ppb. Since the ER-L is 384 ppb, there is no concern for recent project O&M sediments. Other sediments may require additional evaluation.

F.2.19 Dibenzo(a,h)anthracene. The three replicate samples and two reference samples of < 14 ppb. The reference values are <45 to <120 (with one observed value of 90 ppb). The ER-L is 63.4 ppb and the ER-M is 260 ppb, with an incidence of effect of 54.5 percent (12 of 22 studies showed effects where levels of this compound fell between the ER-L and ER-M. Alexander et al. (1994) studied sediments dated from the present to 1900 in three cores from Savannah Harbor and detected some of this PAH in sediments of various ages. Highest concentration (992 ppb) was found in sediments from 1954. Sediments from the last 10 years showed a high of 15 ppb. The data indicate no concern for recent project O&M sediments. However, other sediments may require additional evaluation.

F.2.20 2,6 dimethylnaphthalene. Alexander et al. (1994) studied sediments dated from the present to 1900 in three cores from Savannah Harbor and did not detect this PAH in recent sediments at a detection limit of 10 ppb. Earlier sediments contained up to 44 ppb. Sediments from the last 10 years showed no detection at 10 ppb. No reference values or ER-L/ER-M values exist for this compound. Existing data do not demonstrate a concern for this compound.

F.2.21 Flouranthene. The three replicate values are 43, 41, and 75 ppb and two duplicates of 46 and 35 ppb. The GPA Berth 7 study found 1770 ppb in one of their four samples. Alexander et al. (1994) studied sediments dated from the present to 1900 in three cores from Savannah Harbor and detected some of this PAH in sediments of various ages. Highest concentrations (340 to 1932 ppb) were found in sediments from 1900 and 1954 to 1967. Sediments from the last 10 years showed a range of 55 to 144 ppb. The reference values are 7 to <61 ppb, the ER-L is 600, and the ER-M is 3600 ppb. Existing data indicate no concern for recent project O&M sediments. However, other sediments may require additional evaluation.

F.2.22 Flourene. The three replicate samples and two duplicates of < 14 ppb. Reference samples are <11 to <61 ppb. The ER-L is 35 ppb and the ER-M is 640 ppb with an 36.5 percent incidence of effect for studies in which the fluorene concentration was between the ER-L and ER-M. Alexander et al. (1994) studied sediments dated from the present to 1900 in three cores from Savannah Harbor and detected some of this PAH in sediments of various ages. Highest concentrations (144 to 206 ppb) were found in sediments from 1954 to 1962 and 1993. Sediments from the last 10 years showed a high of 16 ppb except one sample with a high of 206 ppb. Observed highs, even though above the ER-L, are closer

to the ER-L than ER-M. Given the low probability that the observed highs would even cause effects, there is no concern for this compound.

F.2.23 Indeno(1,2,3-cd)pyrene. The three replicate values of <14, 22, <14 ppb and the two duplicates of <14 ppb. The GPA Berth 7 study found one sample with a concentration of 1070 ppb. The reference values are <61 ppb (there is no ER-L). Alexander et al. (1994) studied sediments dated from the present to 1900 in three cores from Savannah Harbor and detected some of this PAH in sediments of various ages. Highest concentrations (106 to 395 ppb) were found in sediments from 1900 and 1954 to 1962. Sediments from the last 10 years showed a high of 39 ppb. The concentration in recent sediments appears to be in the range of the reference levels, indicating no concern for recent project O&M sediments. Other sediments may have higher levels which may warrant further investigation.

F.2.24 2-methylnapthalene. No reference values or an ER-L are listed. Alexander et al. (1994) studied sediments dated from the present to 1900 in three cores from Savannah Harbor and detected small amounts of this PAH in sediments of various ages. Highest concentration (46 ppb) was found in sediment from 1962. Sediments from the last 10 years showed a high of 13 ppb. Available data do not indicate a concern for this compound.

F.2.25 1-methylnapthalene. Not tested, but no ER-L is listed, nor do any reference values exist. Alexander et al. (1994) studied sediments dated from the present to 1900 in three cores from Savannah Harbor and detected small amounts of this PAH in sediments scattered throughout this time period. Detection limit was 10 ppb. The highest concentration (30 ppb) was found in sediment from 1985. Sediments from the last 10 years thus showed a high of 30 ppb. Available data do not indicate a concern for this compound.

F.2.26 Naphthalene. The three replicate values are <14, 18, and <14 ppb and the two duplicates of 19 and 25 ppb. The reference values <120 ppb and the ER-L of 160 ppb. Alexander et al. (1994) studied sediments dated from the present to 1900 in three cores from Savannah Harbor and detected only small amounts of this PAH in sediments of various ages. Highest concentration (28 ppb) was found in sediments from 1962. Sediments from the last 10 years showed a high of 12 ppb. All available data show concentrations below the ER-L, indicating no concern for this compound.

F.2.27 Perylene. No ER-L/ER-M or reference data exist for this compound. Alexander et al. (1994) studied sediments dated from the present to 1900 in three cores from Savannah Harbor and detected some of this PAH in sediments of various ages. Highest concentrations (339 to 812 ppb) were found in sediments from 1900

to 1958. Sediments from the last 10 years showed a high of 165 ppb. No toxicity data are available to indicate that observed concentrations of this compound would cause environmental effects.

F.2.28 Phenanthrene. The three replicate samples of 21, 11, and 32 ppb and the two duplicates of 21 and 9.8 ppb. Alexander et al. (1994) studied sediments dated from the present to 1900 in three cores from Savannah Harbor and detected some of this PAH in sediments of various ages. Highest concentrations (180 to 518 ppb) were found in some sediments from 1954 to 1967. Sediments from the last 10 years showed a high of 59 ppb. The reference values are < 57 ppb, with an ER-L of 240 ppb and ER-M of 1500. Existing data do not indicate a concern for this compound.

F.2.29 Pyrene. The three replicate values of 43, 37, and 60 ppb and the two duplicates of 42 and 28 ppb. The GPA Berth 7 study found one sample to contain a concentration of 2200 ppb. Alexander et al. (1994) studied sediments dated from the present to 1900 in three cores from Savannah Harbor and detected some of this PAH in sediments of various ages. Highest concentrations (985 to 1701 ppb) were found in some sediments from 1954 to 1958. Sediments from the last 10 years showed a high of 163 ppb. The reference values are <60 ppb, the ER-L of 665 ppb, and the ER-M of 2600 ppb. Existing data for recent sediments do not indicate a concern for project O&M sediments. However, other sediments may require additional evaluation.

F.2.30 Pesticides. The CITCO study (Savannah Labs, 1994) reported no detects for surface sediments, with detection limits of 3.5 to 8.5 ppb for most pesticides except chlordane (35 to 44 ppb), methoxychlor (35 to 44 ppb) and Toxaphene (350 to 440 ppb). The Stone Container study (EMC, 1995) reported no detects, with detection limits of 4.8 to 12 ppb for most pesticides except chlordane (10 to 25 ppb), methoxychlor (10 to 26 ppb), and toxaphene (97 to 240 ppb). The GPA Berth 7 study reported no detects, with detection limits of 1.7 to 3.3 ppb for most pesticides except Toxaphene (167 ppb). However, two site specific studies of off-channel sediments did detect some

pesticides. These studies are the Skidaway Agitation Dredging study (SKID) (Skidaway, 1993) and the CITCO Study, where only the deeper sediments from the three cores showed detects (SL) (Savannah Laboratories, 1994). These results are shown below.

alpha-chlordane.	SKID: 2.3, 5.5, 8.9 ppb
4,4'DDD.	SKID: 1.5, 15.5 ppb; SL: 13 ppb.
2,4'DDE.	SKID: 4.4, 19.6 ppb
4,4'DDE.	SL: 12 ppb (ER-L = 2.2 ppb, ER-M = 27 ppb).
2,4'DDT.	SKID: 0.2, 4.2 ppb
4,4'DDT.	SKID: 3.2, 9.9, 29.6 ppb; SL: 40 ppb. (ER-L = 1.58 ppb, ER-M = 46.1 ppb).
dieldrin & 4,4'DDE.	SKID: 22.9, 3.7 ppb.
endosulfan sulfate.	SL: 100 ppb.
Endrin.	SKID: 2.0, 5.8, 11.4 ppb
heptachlor epoxide.	SKID: 0.3, 0.7 ppb
hexachlorobenzene.	SKID: 2.7, 3.9 ppb
methoxychlor.	SL: 44 ppb.
trans-nonachlor.	SKID: 0.7, 3.0, 3.7 ppb.

F.2.31 Pesticide Summary. Since detection limits are considered adequate, there is no concern for most pesticides in project O&M dredged material. For DDE and DDT, ER-L's are available, with some off channel samples approaching the ER-M. Detection was not widespread, indicating some question as to how widespread these substances are in the harbor. However, if off-channel sediments are to predominate in a dredging project, consideration should be given to further investigation of the levels of these pesticides.

F.2.32 Dioxins. The only available harbor data is from the Stone Container Study (EMC, 1993). TEQ for this data has been calculated, using 1/2 the detection limit for non-detects, as 2.08 ppb. Theoretical bioaccumulation potential (TBP) using 1.5 percent lipid content is 4.56 ppb. In comparison, mean TEQ for 13 Brunswick bar channel samples (I.T., 1992, USACOE, 1993) was 5.06 ppb and the TBP was 7.04 ppb. Since the Brunswick sediments were found suitable for ocean disposal with concurrence by EPA, dioxin levels in the Stone sediments show no reason for concern. The three dioxin congeners detected were at levels less than the mean Brunswick levels. The two detected furan congeners were at higher levels than found in Brunswick. The OCDF levels were significantly higher than in Brunswick, but are not at a level of concern.

F.2.33 Oil & Grease. The Stone Container study (EMC, 1993) found oil & grease in three replicate samples to equal 160, 110, and 89 ppm and in two duplicates to equal 140 and 100 ppm. These values are within the reference value range of 4.94 to 180 ppm, indicating no reason for concern.

F.2.34 Petroleum Hydrocarbons. The Stone Container study (EMC, 1993) found three replicate samples to contain 46, 73, and 210 ppm and the two duplicates were 53 and 70 ppm. The CITCO study (Savannah Labs, 1994) found surface values of 59, 20, and 73 ppm. These values are similar to the reference oil and grease values above, indicating no reason for concern.

F.2.35 Polychlorinated Biphenyls (PCB's). Most studies have detected no PCB's (as Aroclors). Detection limits in the Stone Container study ranged from 0.013 to 0.110 ppm. The sum of all the Aroclor detection limits in the Stone Container study equals 277 ppb. No PCB's were detected in the GPA Berth 7 Study, where detection limits of 0.033 ppm for all aroclors except 1221 which was 0.067 ppm. The sum of all the Aroclor detection limits in the GPA study of 267 ppb. Total PCB's would therefore be expected to be less than this number. Skidaway, using detection limits of 0.1 to 1.0 ppb, detected total PCB's ranging from 36.7 to 160.7 ppb. Since for total PCB's the ER-L is 50 ppb and the ER-M is 400 ppb, there is no real reason for concern.

F.2.36 Phenols and substituted phenols. The Stone Container and GPA Berth 7 studies had the lowest detection limits of recent harbor studies. None were detected, with detection limits in the GPA Berth 7 study ranging from 0.33 to 0.83 ppm and in the Stone study ranging from 0.470 to 2.4 ppm. These detection limits are considered adequate, therefore there is no reason for concern for these compounds.

F.2.37 Organotins. See discussion under metals, tin.

F.2.38 Other Organics.

F.2.39 The GPA Berth-7 study (S&ME, 1995) found trichloroethene in two of its four samples (16 (#1), 6 (#2), <5, and <5 ppb). No ER-L or reference values exist for this chemical. However, this is a volatile chemical which would not be expected to remain at detectable levels in the disposal area.

F.2.40 In a study of several harbor berths, EMC (EMC, 1993) found the following organic chemicals (for which no ER-Ls have been set) in an abandoned slip: acetone, carbon disulfide, 1,2 dichloroethane, o-dichlorobenzene, m-dichlorobenzene, and p-dichlorobenzene.

F.2.41 Organics Summary. It appears probable that a number of organic compounds exist at low levels in the sediments dredged from the Savannah River. However, a review of existing information reveals little overall concern for organic contaminants within the harbor. Winger and Lasier (1994) found that "concentrations of organic contaminants (polycyclic aromatic hydrocarbons (PAHs), PCBs, and DDT) were well below the ER-Ls provided by Long and Morgan (1990) for these compounds: ER-L for total PAHs of 4000 micrograms/gram, PCBs of 50 micrograms/g, and DDT of 1 microgram/gram." They also found that organic contaminants in the Savannah River were comparatively low, although elevated levels of PAH's and PCB's were found at a few sites. The Skidaway study of two Savannah Harbor berthing facilities (Skidaway, 1993) found several PAH's and pesticides at levels above the ER-Ls. They state that in only one of their samples, which contained 2 compounds that exceed the ER-Ms (DDE and dibenz(a,h)anthracene), did contaminants occur "where there is a significant probability of biological effects." They concluded "the organic contaminants observed in these sediments probably represent the general condition of Savannah Inner Harbor sediments" but made no conclusions as to the effect dredging these sediments has on possible organic contaminant impacts. Since this was a study of environmental impact, one must conclude that they viewed these possible impacts as inconsequential. As cited above, EPA does not show a concern for organic contaminants in the harbor. It is concluded from a review of available information, that organic contaminants do not pose a significant potential for detrimental environmental impacts due to project O&M dredging and disposal operations.

F.2.42 Heavy Metals.

F.2.43 The list below shows the chemical symbols for heavy metals which are included in this discussion of harbor sediments.

CHEMICAL	SYMBOL
Silver	Ag
Arsenic	As
Chromium	Cr
Copper	Cu
Nickel	Ni
Lead	Pb
Zinc	Zn

F.2.44 Results of heavy metal analyses are shown in Table 2. Table 3 displays the various guidance levels found for metal concentrations in sediment. The data show that some individual sediment samples from the channel and suspended in the river exceed ER-L's (Long et al., 1993) for Cr, Cd, Cu, Ni, Ag, As, and Zn. A few of the highest channel readings (Ag: 13 ppm, and Zn: 530 ppm) exceed ER-M values of 3.7 ppm for Ag and 410 ppm for Zn. Highest Sediment Basin samples (Ag: 33 ppm) exceed the ER-M values of 3.7 ppm for Ag. Some sediment samples from the Sediment Basin also exceed ER-L's for Cd, Cr, Cu, Pb, Ni, Ag, As, and Zn. However, as a 48-hour study of Disposal Area 12A influent metal levels showed (Savannah Lab., 1983), sediment samples from even the same area can provide widely varied values (26 to 183.3 ppm) for Cr, (20 to 196 ppm) for Cu, (4.1 to 86.7 ppm) for Pb, (1.8 to 32.8) for Ni, (0.1 to 4.97) for Ag, and (57.1 to 219.2) for Zn. Therefore, all channel and suspended river sample data have been averaged as a means of estimating the overall quality of material recently placed in the disposal areas. The average value is believed to provide a more realistic assessment of the composition of the harbor's sediments.

F.2.45 Inner Harbor Channel Sediments And Suspended River Sediments. Only two averages, those of Ag and Cd, are high enough to warrant further consideration here. As shown in Table 2, only the average data for Ag (channel of 2.0 ppm, Sediment Basin of 1.1 ppm and outside channel of 1.4 ppm) exceed, but only slightly, the Long et al. ER-L of 1 ppm. Only the channel average value of 2.0 ppm is above the Overall Apparent Effects Thresholds (Long and Morgan, 1990) of 1.7 ppm for Ag. None of the averages approach the ER-M of 3.7 ppm. In only 1/3 of the studies, were effects shown for sediments with a silver level between the ER-L and ER-M. The likelihood of silver causing the observed effects is therefore not high. The Ag level of 2 ppm does equal the cutoff value set by the Georgia DNR as posing no significant risk (GA DNR, 1995). However, this value does not exceed the natural range for Western U.S. soils (Conner and Shacklette, 1975). Those authors list naturally occurring levels of Ag as less than 0.5 to 5 ppm. The only other heavy metal to show an average above the ER-L is cadmium. The channel cadmium average of 1.5 ppm is above the ER-L of 1.2 ppm but not close to the ER-M of 9 ppm. Long et al. (1993) report that 32/87 studies showed sediment effects where the cadmium level was between the ER-L and ER-M (37 percent). Since the channel value is so close to the ER-L, it is not likely that cadmium would cause any contaminant effects. Although this value is above naturally occurring levels for the eastern U.S. (Conner & Shacklette, 1975), and slightly above the 99 percent for agricultural soils (Holmgren et al., 1993) it is below the level (2 ppm) set by the Georgia DNR as posing no significant risk (GA DNR, 1995). Available evidence, therefore, indicates there is no concern for the levels of heavy metals in the channel sediments and suspended river sediments.

TABLE 2
SAVANNAH HARBOR SEDIMENT DATA
(IN PPM)
(VARIOUS SOURCES)

	Site	Cr	Cd	Cu	Pb	Ni	Ag	Zn	As
Ave	Riv	42.3	1.5	13.4	14.3	13	2.0	77.8	4.1
"n"	Riv	27	27	27	33	23	23	33	45
Ave	SB	87.3	1.1	55.1	27.4	16.4	1.1	118	18.0
"n"	SB	56	8	56	57	56	53	57	5
Ave	Out	57.2	2.4	29.6	44.2	23.8	1.4	123	10.2
"n"	Out	73	73	73	73	73	51	73	54
High	Riv	100	4	56	46	36	13	530	24.3
High	SB	183	2.8	196	86.7	32.8	33	219	22.6
High	Out	130	7.5	141	189	89.6	14	424	33.3

NOTE:

- * "Riv" refers to samples from the main channel bottom sediment and suspended sediment
- * "SB" refers to Sediment Basin samples
- * "n" refers to the number of samples available
- * "out" refers to samples taken in the main river, but outside the navigation channel
- * Changes in "Riv" data from the Draft EIS version of this table are primarily due to removal of Agitation Dredging Study "plume" data, and use of 1/2 the detection limit for data below detection.
- * Changes in "Out" data from the Draft EIS version of this table are due primarily to additional data available from recent berth studies and use of 1/2 the detection limit for data below detection.

TABLE 3

GUIDANCE LEVELS FOR METAL CONCENTRATIONS IN SEDIMENTS

SOURCE		ELEM						
	Cr	Cd	Cu	Pb	Ni	Ag	Zn	As
HOL-95*7		.78	95	23	57		126	
HOL-99*7		1.3	216	36	154		170	
SF-Inner*8	561	.09	19	11	63	.1	59	5.1
SF-Outer*8	286	.31	37	27	93	.3	107	9
SF-Ref*8	195	.24	51	28	98	.6	118	11
ER-L*9	81	1.2	34	46.7	20.9	1	150	8.2
ER-M*9	370	9.6	270	218	51.6	3.7	410	70
OAET*1		5	300	300		1.7	260	50
EPA*2	1200	39	1500	300	420		2800	41
C&S,high*3a	100		100	70	70		100	
C&S,high*3b		1	150	300	700	5	400	73
C&S,mean*3c	36	<1	14	14	13	<.5	36	5.4
L&C*4			125		62		250	
Conner*5	230	1.3	87	87		1.2	280	
TEL*6	66	2	56	42		1	136	16
PEL*6	240	7.5	170	160		2.5	300	64
GA DNR*11	100	2	100	75	50	2	100	20
Ave.*9	100	.06	30	10	40	.05	50	5
com,high*10	1000	.7	100	200	500	5	300	50

TABLE 3 (CONT.)

GUIDANCE LEVELS FOR METAL CONCENTRATIONS IN SEDIMENTS

SOURCE:

- *1 Long & Morgan, 1990. ER-L: Effects-Range Low, ER-M: Effects-Range Median, OAET: Overall Apparent Effects Threshold
- *2 EPA concentration limits from sewage application to gardens (40 CFR 503.13). These standards are more stringent than those for application of sewage sludge to land where no food crops are grown. The potential toxicity and dispersal pathways for contaminants existing at the confined disposal areas would be most approximated by the application of sludge to land for non-food crop purposes.
- *3 Conner & Shacklette, 1975. Maximum level in GA and eastern U.S. soils (Ag data is from western U.S.)
 - a. High limit for range for Georgia uncultivated a horizon soils
 - b. High limit for range for Eastern U.S. (Western U.S. for Ag) uncultivated soils
 - c. Mean for Eastern U.S. uncultivated soils
- *4 Logan & Chaney, 1983. Minimum phytotoxicity levels.
- *5 O'Conner, T.P. 1990. High values for sediments that are 100% silt and clay.
- *6 MacDonald, 1993. TEL: threshold effects level, PEL: probable effects level.
- *7 Holmgren et al., 1993. Uncontaminated agricultural soil, 95th and 99th percentile.
- *8 McFarland et al., 1994. Mean metals concentrations in Oakland inner and outer sediments and Berkeley Flats reference sediment.
- *9 Long et al., 1993. Incidence of Adverse Biological Effects within Ranges of Chemical Concentrations in Marine and Estuarine Sediments. Submitted to Environmental Management.
- *10 Lindsay, W.L., 1979. Chemical Equilibria in Soils. John Wiley and Sons.
- *11 Georgia DNR, 1995. Rules of the Georgia Department of Natural Resources Environmental Protection Division. Chapter 391-3-19. Hazardous Site Response. 22 February, 1995. 82 pp.

F.2.46 Sediment Basin Sediments. Sediments which accumulate in the Sediment Basin typically have a finer grain size than do sediments which settle in the navigation channel. Since finer grained sediments have a greater potential for adsorption of chemical compounds, there is a higher likelihood of contamination of sediments which accumulate in that location. Therefore, higher concentrations of contaminants at that site would not necessarily indicate that a source of any observed contamination would be located nearby.

F.2.47 For the average values from samples of Sediment Basin sediments, ER-L's are exceeded for Cr (ave. of 87.3 ppm, ER-L of 81 ppm), Cu (ave. of 55 ppm, ER-L of 34 ppm), As (ave. of 18 ppm, ER-L of 8.2 ppm), and Ag (ave. of 1.1 ppm, ER-L of 1.0 ppm). These concentrations are within the lowest ranges at which effects have been observed in some sediments containing these concentrations metals (however, the observed effects were not directly attributable to a particular concentration of a particular metal). A large fraction of the sediment level of each of these elements is not expected to be bioavailable (see discussion in the conclusions section below). Furthermore, the incidence of effect (Long et al., 1993), which is the percentage of studies of sediment exhibiting concentrations between the ER-L and ER-M that showed effects, is not large. For the metals in question, the percentages are: As: 11.1 percent, Cr: 21.1 percent, Cu: 29.1 percent, and Ag: 32.3 percent. It is therefore not likely that sediment with levels of these metals between the ER-L and ER-M would exhibit environmental effects. It is even further unlikely that the identified concentration of a metal would cause an environmental effect. The As average of 18 ppm is approaching the Georgia DNR value (20 ppm) posing no significant risk (GA DNR, 1995). Furthermore, none of the average concentrations are above the range for uncultivated Georgia soils (Conner & Shacklette, 1975). Because the average copper concentration is much closer to the ER-L than the ER-M, and only 29.1 percent of studies with copper concentrations between the ER-L and ER-M showed effects, the likelihood of the observed copper concentrations causing environmental effects is not high. Furthermore, the average copper concentration (55 ppm) is below the level (100 ppm) set by the Georgia DNR as posing no significant risk (GA DNR, 1995). Therefore, no concern exists for metal concentrations in the Sediment Basin sediments.

F.2.48 Sediment Samples Taken Outside The Navigation Channel And Sediment Basin. The following metals exhibit averages requiring further evaluation here: Cd, Ni, Pb, Ag, As. The average Pb value of 44.2 ppm approaches the ER-L of 46.7 ppm. The average is also above the 99th percentile for agricultural soils of 36 ppm (Holmgren et al., 1993). However, it is far below the Georgia DNR ceiling value (75 ppm) posing no significant risk and within the range of naturally-occurring concentrations for

Georgia (High of 70 ppm, Conner & Shacklette, 1975). The averages for Ag and As are below those found for either in channel or Sediment Basin sediments. Therefore, the discussions above apply. The out-channel average shows a cadmium concentration (2.4 ppm) exceeding the cadmium ER-L of 1.2 ppm and a Ni concentration (23.8 ppm) exceeding the nickel ER-L of 20.9 ppm. With regards to Ni, the incidence of effects for sediments containing Ni concentrations between the ER-L and ER-M is only 16.7 percent. Furthermore, the average is well within the upper limit for uncultivated A horizon soils in Georgia of 70 ppm (Conner & Shacklette, 1975), below the 95th percentile for agricultural soils of 57 ppm (Holmgren et al., 1993), and below the Georgia DNR ceiling value posing no significant health risk, also 50 ppm (GA DNR, 1995). The cadmium average, although exceeding the ER-L, does not approach the ER-M. The incidence of effects for sediments containing cadmium concentrations between the ER-L and ER-M is 36.6 percent. It is, therefore, unlikely that the observed average would cause effects in an aquatic system. However, the average cadmium value is also above the Georgia DNR ceiling value posing no significant risk (GA DNR, 1995). It is also above the high end of the range for eastern U.S. soils of 1 ppm (Conner & Shacklette, 1975) and above the 99th percentile of U.S. agricultural soils of 1.3 ppm (Holmgren et al., 1993). Cadmium values in off-channel sediments are, therefore, of some concern. However, this concern does not extend to project O&M sediments, for two reasons. The first is that these materials are normally relocated to the channel through agitation dredging, and their effect is already accounted for in the sediment samples taken from the main channel and Sediment Basin. The second factor is that these values represent only a fraction of material annually dredged from the harbor and placed in the disposal areas. The vast majority of the sediments annually removed by dredging are in the navigation channel and Sediment Basin. Where off-channel sediments would predominate in a dredging project, further investigation of cadmium concentrations in the sediments should be made.

F.2.49 Summary Of Metal Concentrations By Element.

F.2.50 Chromium (Cr). Alexander et al. (1994) found evidence of enrichment in the upper parts of most of their cores from the Savannah Harbor. Their data indicate a potential concern for this metal. The highest recorded value for Savannah Harbor is from the Sediment Basin (183.3 ppm). This value exceeds the maximum recorded value for A horizon Georgia soils (100 ppm, Conner & Shacklette, 1975), but is below the ER-M (370 ppm, Long et al., 1993). The highest main channel value exceeds the ER-L (81 ppm, Long et al., 1993) and the maximum recorded value for GA/eastern U.S. soils. However, the average main channel value (42.3 ppm) is below the ER-L. In addition, the only average value that exceeds the ER-L of 81 ppm is the Sediment Basin

average of 87.3 ppm. Moreover, all observed values do not approach EPA's acceptable concentration level for sewage sludge application to gardens (1200 ppm). Naturally-occurring levels in uncultivated soils in Georgia range from 3 to 100 ppm (Conner and Shacklette, 1975). Table 2 of the February, 1995, GA DNR Hazardous Site Response document lists a soil concentration that poses no significant risk of 100 ppm (GA DNR, 1995). Savannah Harbor reference values range from 9.0 to 17.6 ppm. Observed levels are compatible with expected naturally-occurring values.

F.2.51 Cadmium (Cd). Alexander et al. (1994) found evidence in two of their cores from the Savannah Harbor of enrichment towards the surface. All average and highest observed sediment values are greater than the concentrations recorded for A horizon eastern U.S. soils (1 ppm, Conner & Shacklette, 1975). The inner channel average value of 1.5 ppm exceeds the ER-L. However, none of the within channel sediment values or any of the average sediment values exceed the ER-M of 9.6 ppm (Long et al., 1993), and none approach EPA's acceptable level for sewage sludge application to gardens. The expected overall concentration of sediments deposited within the disposal area would be expected to be slightly above the channel and Sediment Basin averages of 1.5 and 1.1 ppm. The expectation of a slightly higher average level is due to the outside channel average of 2.4 ppm and the fact that the highest recorded value for a sediment sample taken outside the channel is 7.5 ppm (equal to the probable effects level of MacDonald (1990)). It should be noted that the average value for sediments outside the channel is much closer to the ER-L than the ER-M. As stated above, Long et al. (1993) report that 32/87 studies showed sediment effects where the cadmium level was between the ER-L and ER-M (37 percent). The likelihood of these effects being caused by the silver concentration is not high. This again indicates that there is no real cause for concern for project O&M sediments. The highest harbor value does not approach the EPA acceptable level for sewage sludge application to gardens (39 ppm). These data indicate that one could expect isolated pockets of sediment from outside the channel, if they could be isolated, to pose a possible concern for aquatic disposal. Lee (1995) reviewed a preliminary compilation of Savannah Harbor sediment data and concluded there should be some reason for concern for the potential bioaccumulation of arsenic and to a lesser extent, lead and cadmium in foodchains associated with waterfowl or shorebirds. The District believes these sediments would be mixed in the dredging process so that concentrations within the disposal areas would be expected to more closely approximate the average sample levels. Naturally-occurring levels in the eastern U.S. range up to 1 ppm (Conner and Shacklette, 1975; Korte, 1983). Table 2 of the February, 1995, GA DNR Hazardous Site Response document lists a soil concentration that poses no significant risk of 2 ppm (GA DNR, 1995). Since we expect the overall sediment average to be about 1.5 ppm, a level below DNR concerns, project dredged material

should pose no cause for concern. Since the off channel average (2.4 ppm) is above the DNR level and is well above the 99th percentile for agricultural soils (1.3 ppm, Holmgren et al., 1993), there is some concern for cadmium levels in outside channel sediments. Large amounts of outside channel materials, where they might be expected to predominate in a disposal operation, would require further evaluation (see discussion under out-channel sediments, above).

F.2.52 Copper (Cu). The highest recorded value from the Sediment Basin exceeds the ER-L and the level observed to cause phytotoxicity. The highest values recorded from main channel sediments and the Sediment Basin, as well as the average Sediment Basin value, exceed the ER-L and the maximum level recorded for Georgia soils. However, neither the average values for the main channel or outside channel exceed the ER-L, nor do any of the recorded values equal the ER-M of 270 ppm (Long et al., 1993). The average of available channel sediment test data (13.4 ppm) is below the ER-L (34 ppm). Although the average of Sediment Basin data is slightly above the ER-L at 55.1, the incidence of effects for copper values between the ER-L and ER-M was found to be 28 percent (32/110). Since the Sediment Basin average is only slightly above the ER-L, the likelihood of this level causing environmental effects is considered small. In addition, because of the mixing of sediments during dredge disposal operations, the overall average of sediment deposited in the disposal areas, including sediment from outside the channel, would be expected to be less than the ER-L. Moreover, none of the recorded sediment values approach EPA's concentration level for sewage sludge application to gardens. Naturally-occurring levels in Georgia soils range from 3 to 100 ppm (Conner and Shacklette, 1975). Table 2 of the February, 1995, GA DNR Hazardous Site Response document lists a soil concentration that poses no significant risk of 100 ppm (GA DNR, 1995). All averages are also well below the 95th percentile for agricultural soils of 95 ppm (Holmgren et al., 1993). Savannah Harbor reference values are much lower and range from 1.90 to 4.34 ppm. However, Alexander et al. (1994) found no evidence of anthropogenic enrichment in the harbor. Expected average copper levels in project dredged material are compatible with expected naturally-occurring values.

F.2.53 Lead (Pb). Alexander et al. (1994) found evidence of anthropogenic enrichment in the upper portions of all cores taken in Savannah Harbor. This finding indicates the potential for concern for this metal. The highest value recorded for sediments outside the main channel is 188.9 ppm, above the maximum recorded level for GA/eastern U.S. soils, and approaching the ER-M of 218 ppm. The highest recorded value for the Sediment Basin (86.7 ppm) exceeds the ER-L (46.7 ppm, Long et al., 1993) and the maximum level recorded for the A horizon in Georgia (70 ppm, Conner & Shacklette, 1975). The highest value recorded for the main channel (46.0 ppm) approaches (but is less than) the ER-L.

However, the only average value that exceeds the ER-L is that for sediments outside the channel (188.9 ppm). Since the vast majority of material dredged at one time would come from the channel itself, the average level in sediments deposited in the disposal area is not expected to exceed the ER-L. Moreover, none of the observed sediment values exceed the ER-M (218 ppm, Long et al., 1993) or EPA's acceptable concentration level for sewage sludge application to gardens (300 ppm). In addition, the observed levels are also much smaller than the maximum allowable soil content (511 ppm of Pb) calculated in a study of contaminant mobility at the Naval Weapons Air Station, Concord California (Lee et al., 1986). Lee (1995) reviewed a preliminary compilation of Savannah Harbor sediment data and concluded there should be some reason for concern for the potential bioaccumulation of arsenic and to a lesser extent, lead and cadmium in foodchains associated with waterfowl or shorebirds. We believe these sediments would be mixed in the dredging process so that concentrations within the disposal areas would be expected to more closely approximate the average sample levels. Naturally-occurring levels in Georgia and the eastern U.S. soils range from <10 to 70 ppm (Conner and Shacklette, 1975). Savannah Harbor reference values fall on the low end of that scale and range from 4.34 to 9.31 ppm. Lead in deep ocean sediments can vary from <10 to more than 80 ppm dry weight, with near shore sediments averaging 20 ppm (Demayo et al., 1982) and lead concentrations have been recorded at 110 ppm dry weight in a reference lake in Sweden (Haux et al., 1986). Table 2 of the February, 1995, GA DNR Hazardous Site Response document lists a soil concentration that poses no significant risk of 75 ppm (GA DNR, 1995). Since average lead concentrations in project dredged material are expected to be below 46.7 ppm (the ER-L), no impacts are expected. Since the out-channel average (44.2 ppm approaches the ER-L and is well above the 98th percentile for agricultural soils (36 ppm), there is some concern for lead levels within out-channel sediments. Large amounts of outside channel materials, where they might be expected to predominate in a disposal operation, may require further evaluation.

F.2.54 Mercury (Hg). Alexander et al. (1994) found evidence of anthropogenic enrichment in the upper portions of two cores (of six) taken in the Savannah River. This finding indicates the possibility of concern for this metal. The ER-M is 0.71 ppm and the ER-L is 0.15 ppm (Long et al., 1993). Naturally-occurring levels in the B horizon of soils in the eastern U.S. range from 10 to 3,400 ppb (Conner and Shacklette, 1975). As reported by NAS (1978), uncontaminated sediment usually had concentrations of <1,000 ppb. Table 2 of the February, 1995, GA DNR Hazardous Site Response document lists a soil concentration that poses no significant risk of 0.5 ppm (GA DNR, 1995). Average observed

mercury levels for 28 samples of in channel sediments is 0.35 ppm. The average of four Sediment Basin samples is 0.4 ppm (400 ppb) and the average for 20 samples taken outside the channel is 0.22 ppm (220 ppb). Observed levels are compatible with expected naturally-occurring values.

F.2.55 Nickel (Ni). Alexander et al. (1994) found evidence of anthropogenic enrichment in the upper portions of two cores (of six) taken in the Savannah River. This evidence indicates possible concern for concentrations of this metal in the harbor. The highest recorded values for the main channel (36 ppm), outside main channel (89.6 ppm), and Sediment Basin sediments (32.8 ppm) exceed the ER-L (20.90 ppm, Long et al., 1993), but only the outside channel highest value exceeds the ER-M (51.6 ppm, Long et al., 1993). Moreover, none of the average values (13.0 ppm in channel, 23.8 ppm out channel, 16.4 ppm Sediment Basin) exceed the ER-L. In addition, none of the recorded values exceeds the maximum level recorded for GA/eastern U.S. soils or observed levels of phytotoxicity. Only the highest recorded sample for sediments outside the channel (89.6 ppm) exceeded the maximum allowable soil content (MASC) (82 ppm of Ni) calculated by Lee (Lee et al., 1986). Moreover, none of the recorded levels approach EPA's acceptable concentration level for sewage sludge application to gardens. Lindsay ((1979) reported the average natural abundance of nickel to be 40 ppm with a common range of 5 to 500 ppm. Naturally-occurring levels in soils in Georgia range from <3 to 70 ppm (Conner and Shacklette, 1975). As reported by NAS (1978) uncontaminated sediment usually had concentrations of <1,000 ppb. Table 2 of the February, 1995, GA DNR Hazardous Site Response document lists a soil concentration that poses no significant risk of 50 ppm (GA DNR, 1994). Furthermore, the 95th percentile for agricultural soils is 57 ppm. Observed levels are compatible with expected naturally-occurring values.

F.2.56 Selenium (Se). Alexander et al. (1994) found evidence of anthropogenic enrichment in the surface portions of three cores, although concentrations were found to be less than 1 ppm. Other available sediment data shows all measurements <1 ppm. Concentrations in the B horizon uncultivated eastern U.S. soils range from <0.1 to 1.4 ppm (Conner & Shacklette, 1975). Table 2 of the February, 1995, GA DNR Hazardous Site Response document lists a soil concentration that poses no significant risk of 2 ppm (GA DNR, 1994). Therefore, there should be no concern for this metal.

F.2.57 Silver (Ag). Alexander et al. (1994) studied six cores from the Savannah Harbor and found they showed evidence of anthropogenic enrichment from 1900 to the present. The highest recorded main channel, outside channel, and Sediment Basin sediments exceed the ER-M (3.7 ppm, Long et al., 1993). Average data from both the main channel (2.0 ppm), outside channel river data (1.4 ppm), and the Sediment Basin (1.1 ppm) exceed the ER-L

(1.0 ppm, Long et al., 1993). None of the average values exceed the ER-M of 3.7 ppm. The incidence of observed effects for data between the ER-L and ER-M is 32.3 percent. Since the average data are all closer to the ER-L than the ER-M, the probability of environmental effects due to silver in the project dredged material is not high. In addition, the average values do not exceed the highest recorded values for western U.S. soils (no eastern U.S. values). Naturally-occurring levels in B horizon of western U.S. soils range from <0.5 to 5 ppm (Conner and Shacklette, 1975). Table 2 of the February, 1995, GA DNR Hazardous Site Response document lists a soil concentration that poses no significant risk of 2 ppm (GA DNR, 1995). Observed levels are compatible with expected naturally-occurring values.

F.2.58 Tin (Sn). Alexander et al. (1994) found evidence of anthropogenic enrichment in the upper portions of most of the six cores they studied from Savannah Harbor (0.1 to 6.04 ppm). In the B horizon of eastern U.S. soils, concentrations range from <10 to 15 ppm (Conner & Shacklette, 1975). No toxicity data for metallic tin was located during this study. In addition, tin is not listed in the GA DNR Hazardous Response document (GA DNR, 1995). However, organotins are known to be toxic to some organisms.

F.2.59 Harbor organotin data is available only from the Stone Container Study (EMC, 1995). Four measurements for monobutyltin (MBT) were 2.9, 2.3, 2.7, and 6.0 ppb. Four measurements for dibutyltin (DBT) were 11, 17, 21, and 26 ppb. Four measurements for tributyltin (TBT) were 11, 26, 80, and 90 ppb.

F.2.60 TBT compounds have a broad range of applications, including use as fungicides, bactericides, insecticides and wood preservatives, but TBT degrades into less toxic DBT and MBT (Dowson et al., 1993). TBT has been reported to be acutely toxic to aquatic organisms at water concentrations of 1 ppb (Dowson et al., 1993). In 1988, an environmental quality standard for TBT of 2 ng/l in seawater was set in Great Britain (Dowson et al., 1993). Organotin concentrations in 22 sites in Great Britain were followed for 6 seasons. This study considered 3 to 20 ppb TBT to be light contamination and 20 to 100 ppb TBT to be moderate contamination. Sediment concentrations in Great Britain were found to range from <3 ppb to 4207 ppb (Dowson et al., 1993). Since the dredged material would be placed in a high ground disposal area retaining most fines, and in which this material should decompose, dredging this material is not expected to impact aquatic resources.

F.2.61 Manganese (Mn). The normal range of values shown by the reference stations is 63.6 to 240 ppm (1994 Savannah Harbor Disposal Area Wright River Weir Effluent Study), with one value of 3430 ppm. Manganese levels in overflow weir effluent have been found to be of no concern (Scott et al., 1994). Manganese

levels in the A horizon of uncultivated Georgia soils were found to range from 50 to 700 ppm and eastern U.S. B horizon soils from <2 to 7000 ppm (mean 290 ppm) (Conner & Shacklette, 1975). Moreover, manganese is not listed in the GA DNR Hazardous Response document (GA DNR, 1995). There is no reason to believe that project dredged material manganese levels would be of concern.

F.2.62 Iron (Fe). Savannah Harbor reference values range from 7500 to 16400 ppm. B horizon eastern U.S. soils were found to have much lower ranges, from <0.01 to >10 ppm, with a mean of 2.76 ppm. Alexander et al. (1994) found no evidence of anthropogenic enrichment in Savannah Harbor. Moreover, iron is not listed in the GA DNR Hazardous Response document (GA DNR, 1995).

F.2.63 Zinc (Zn). Alexander et al. (1994) found evidence of anthropogenic enrichment in most of their cores taken in Savannah Harbor. This finding indicates the possibility of concern for this metal. The highest main channel sediment value (530 ppm) and the highest outside channel sediment value (424.5 ppm) exceed the ER-M (410 ppm, Long et al., 1993), observed phytotoxicity level, and the MASC value (Lee et al., 1986) of 304 ppm, the highest values recorded for uncultivated A horizon soils in Georgia (100 ppm, Conner & Shacklette), and the 98th percentile (170 ppm) for U.S. agricultural soils (Holmgren et al., 1993). However, all average values (in channel: 77.8 ppm, out channel: 123.5 ppm, Sediment Basin: 118.5 ppm) are below, although approaching, the ER-L (150 ppm, Long et al., 1993). No recorded sediment value exceeds EPA's acceptable concentration level for sewage sludge application to gardens. All average values are below the ER-L of 150 ppm, and the 95th percentile for agricultural soils (126 ppm). In addition, the in channel sediment average is within the recorded range for A horizon uncultivated Georgia soils of <25 to 100 ppm (Conner and Shacklette, 1975). Table 2 of the February, 1995, GA DNR Hazardous Site Response document lists a soil concentration that poses no significant risk of 100 ppm (GA DNR, 1995). Although sediment and out channel averages are above the DNR value, they are within the 95th percentile for agricultural soils and below the ER-L for zinc. Expected levels are, therefore, below that at which environmental impacts would be expected.

F.2.64 Arsenic (As). No recorded sediment values exceed ER-M of 70 ppm, although they do exceed the ER-L value of 8.2 ppm. The in channel sediment average is 4.1 ppm, well below the ER-L. However, the Sediment Basin average (18 ppm) and the out channel average (10.2 ppm) do exceed the ER-L. The incidence of effects of 11.1 percent (8/73 studies) for concentrations between the ER-L and ER-M indicates that the likelihood of effects for the observed averages is low. Lee (1995) reviewed a preliminary compilation of Savannah Harbor sediment data and concluded there

should be some reason for concern for the potential bioaccumulation of arsenic in foodchains associated with waterfowl or shorebirds. However, the data he reviewed erroneously showed average in-channel sediment levels of 9 ppm (rather than the corrected 4.1 ppm). The District believes the sediments with higher levels in spots would be mixed in the dredging process so that concentrations within the disposal areas would be expected to closely approximate the levels shown by the average sample data (4 to 18 ppm). Alexander et al. (1994) found in some cores possible small anthropogenic inputs into Savannah harbor (no sediment concentrations given). Levels found in B horizon eastern U.S. soils range from 0.2 to 73 ppm with a mean of 5.4 ppm (Conner and Shacklette, 1975). Table 2 of the February, 1995, GA DNR Hazardous Site Response document lists a soil concentration that poses no significant risk of 20 ppm (GA DNR, 1995). All average values are below this figure. Savannah Harbor reference values range from 3.18 to 17.8 ppm. Average project sediment values all also fall within the range of naturally-occurring values. The District believes this indicates no concern for arsenic levels within project dredged material. Elevated levels of arsenic have been observed in disposal area underdrain effluent (NMFS, 1994). This is thought to be a product of leaching processes. The District agreed to have the underdrains to the Wright River closed. New underdrains are to be directed to the Savannah River, where released arsenic is expected to have no impacts.

F.2.65 Summary Of Acute Effects. Average values of samples from Savannah Harbor channel sediments, outside channel sediments and Sediment Basin sediments show that ER-L's are exceeded in at least one of those cases for chrome, cadmium, copper, nickel, silver, and arsenic. However, only the cadmium, copper, and zinc averages exceed recorded naturally-occurring levels for Georgia and eastern U.S. soils. Finally, only the cadmium average for out channel sediments is above the Georgia DNR ceiling for no significant risk. As discussed above, the cadmium out-channel average is not expected to significantly affect environmental impacts of project O&M dredging. There are no minimum sediment contaminant concentrations for dredged material. However, EPA has set maximum allowable contaminant concentrations for sewage sludge application to gardens. None of the average values or even any maximum single sample concentration observed in Savannah Harbor sediments approach those concentrations. Maximum concentrations observed in the harbor as a percentage of the maximum allowable garden soil concentrations for sewage sludge application range from 13.1 percent (Cu) to 21 percent (Ni) for all but lead (63 percent), arsenic (81.2 percent), and silver (no standard).

F.3.00 CHRONIC (LONG TERM) CONTAMINANT IMPACTS.

F.3.01 "Heavy metals and organic contaminants added to water containing sediments will rapidly become associated with the sediment" (references in Brannon et al., 1990). This is the result of the adsorption of those compounds to the fine-grained (silt, clay, and organic) components of a sediment. Available data indicate no concern for any organics in Savannah Harbor sediments since these components are not found in significant concentrations in the sediments. The metal contaminants that have the highest likelihood of posing a possible problem are silver, lead, chrome, and zinc. These elements have sediment average concentrations all near the ER-L's and TEL's, indicating that although they are below levels which produce acute toxicity, an evaluation of their chronic toxicity should be considered.

F.3.02 A large series of tests were run on sediments from San Francisco Bay to determine their suitability for open water disposal (McFarland et al, 1994). It was concluded that the results of the bioaccumulation study suggest that disposal of the "inner" and "outer" sediments "is unlikely to increase contaminant bioaccumulation above that which already occurs from naturally resuspended sediments" (at the reference area). The average metals concentrations from this work are shown in Table 3. As can be seen, the concentrations of chrome and nickel greatly exceed the averages of Savannah Harbor data. Average concentrations of copper, lead, and zinc are similar for both areas, with averages for cadmium, silver, and arsenic being somewhat lower in San Francisco. Overall, results of the San Francisco study indicate there should be little concern for Savannah Harbor sediments.

F.3.03 The extent of movement of contaminants within a CDF depends on the extent of drying and oxidation that the sediments undergo. Brannon (1978) concluded that most naturally-occurring metals in aquatic sediments are tightly bound to sediment particles and are relatively immobile and unavailable (Tatem, 1990). Brannon also concluded that contaminants associated with sediments containing silt and clay and organic carbon are generally not readily available to aquatic organisms. He further found that the most mobile and potentially available sediment contaminants are those found in the sediment interstitial water, those adsorbed to the cation exchange complex, or those associated with amorphous iron and manganese oxides. In seawater and most estuarine environments, soluble sulfate ions are reduced to sulfides in sediments under anaerobic conditions; metals in the sediments will thus be in the form of highly insoluble metallic sulfides (Tatem, 1990).

F.3.04 When these anaerobic sediments are dredged and deposited at a site with aerobic (oxidizing) conditions, more soluble oxidized metallic compounds such as carbonates and hydroxides may be formed (Tatem, 1990). The extent of mobilization of potentially toxic contaminants through changes in physicochemical conditions at the disposal site may depend on the disposal method and properties of the dredged sediments (Gambrell, Khalid, and Patrick, 1978, cited in Tatem, 1990). Whether a particular contaminant is released or held in a sediment also depends on its state of drying and what oxidation/reduction reactions are taking place. It should be noted that a particular contaminant may be present in a sediment but not be bioavailable.

F.3.05 CDF sediments are expected to exist as either (1) anaerobic saturated sediments which are exposed or under ponded water, or as (2) oxidized drying sediments. The same sediment is likely to exist in each state over various times in its existence at the CDF. Movement and bioavailability of metals would be expected to differ in the two cases. In the saturated state, the sediments would be expected to resemble other aquatic sediments. As discussed above, the harbor sediment metal concentrations are not of concern because they are at levels which, in the worst cases, are only at the lowest levels where effects have been found under certain prescribed conditions. The expected lack of bioavailability is expected to preclude impacts from these metals in saturated sediments. As the sediments dry and oxidize, they would be expected to take on the characteristics of normal upland soils. The expected metal levels have thus been compared to levels of metals found in naturally-occurring soils of Georgia and the southeast. Since the expected sediment levels fall within the range of naturally-occurring soils, no impact from metals is expected.

F.3.06 Contaminant Pathways Within The Disposal Areas. Even though it appears that sediment metals levels are at low levels which preclude either acute or chronic impacts, some movement of metals could take place. Once placed within the disposal area, contaminants could remain within the site or move offsite through one of the following pathways (Lee et al., 1986): effluent during the disposal operation, dust, volatilization, soil invertebrate uptake, plant uptake, leachate to groundwater, and surface runoff. Tidal inundation could also occur in the lower end of Disposal Area 14B. Each of these theoretical pathways is discussed separately in the following sections.

F.3.07 Effluent (movement off-site through effluent during disposal operations). Previous studies at Savannah Harbor (Palermo, 1988) have shown that the disposal areas retain 99.93 percent of suspended solids and 99.67 percent of total metals. In addition, a recent study of Savannah Harbor CDF weir effluent by the NMFS (NMFS, 1994), revealed no concerns for possible contaminants discharged through the weir effluents.

F.3.08 In two of the Savannah Harbor CDF's, effluent has also come from underdrains designed to drain water from deep within the disposal sites. These underdrains have been closed in Disposal Area 12B and plans are in place to close those in Area 13A. The underdrains have produced the only Savannah Harbor effluent which has violated water quality criteria for a contaminant. Arsenic concentrations of up to 298 micrograms/liter have been observed (NMFS, 1994). Arsenic can be found in forms of different toxicity, and the percentage occurrence of the different forms in the underdrain effluent is unknown, although some conditions at the weirs are said to favor the formation of the more toxic arsenite ($As(+3)$) form (NMFS, 1994). A discussion of arsenic toxicity can be found in NMFS (1994). Measured levels of underdrain arsenic concentrations exceed the acute level for $As(+5)$ of 69 micrograms/liter (but not the acute level for $As(+3)$ of 2,319 micrograms/liter). The measured levels also exceed the chronic salt water criteria concentrations of 36 micrograms/liter for $As(+5)$ and 13 micrograms/liter for $As(+3)$. It is expected that with an appropriate mixing zone, discharge of underdrain effluent to the Savannah River would meet water quality criteria.

F.3.09 Using arsenic as the critical chemical parameter, mixing zone calculations were made using standard engineering procedures which are generally followed by state water quality authorities. Those calculations revealed that a maximum mixing zone of 10 feet would be required before the discharge from the new underdrains would meet acceptable water quality standards for all parameters. The 10-foot mixing distance is judged to be acceptable, as it is much less than the mixing zones of hundreds of feet which are typical for permitted industrial point discharges along the Savannah River.

F.3.10 Additional calculations were made using the procedures contained in the June 1994 draft EPA/Corps Inland Testing Manual. Appendix C to that document contains a section (C4) which describes formulas to use for mixing zones from confined disposal facilities which discharge in riverine conditions. Using those procedures, a discharge of 0.7 CFS into the shallow waters along the channel bank (average depth of 5 feet and a flow of 1 FPS) which contains 298 ug/l of arsenic would take 24 feet to reduce to a level of 13 ug/l. Section C6 of that Appendix describes other formulas to use for mixing zones from confined disposal

facilities. Using those procedures and parameter values for discharge in estuarine conditions, the same discharge and receiving water conditions would require a 13-foot mixing zone to reduce the arsenic level to 13 ug/l. Those calculations reveal that mixing of underdrain effluents would occur within very short distances, much shorter than that typically given for industrial point source discharges.

F.3.11 Dust. Since all metal concentrations have been found to be within levels observed in natural soils found in Georgia or below risk criteria, no increased impact from this pathway is expected.

F.3.12 Volatilization. Modeling of this pathway has not been perfected, but previous research has not considered volatilization of metals to be important (Brannon et al., 1990).

F.3.13 Plant and Soil Invertebrate Uptake. Lead (Pb) (and other heavy metals such as cadmium and mercury) may occur in ionized forms that are soluble in water, but they can also bind with organism tissues and, thus, are actively bioaccumulated (Clarke and McFarland, 1991). Zinc, chrome, lead, and cadmium, among others, seem to be effectively immobilized in CDF's during early stages of filling, thereby reducing the transfer of these metals to vegetation (Brannon et al, 1990, p. 40). However, their bioavailability may be changed as the sediment oxidizes (Brannon et al., 1990, p. 40). Mobility of Zn, Cd, and Pb is generally observed to be greater under drier upland soil conditions than under flooded wet soil conditions (Lee et al., 1986). Zinc, copper, and lead pose much less risk to water quality, even though they are mobilized by plants, than cadmium and mercury, and studies of plant uptake of chrome are limited (Brannon et al., 1990, p. 40). A study of the response of contaminated sediment from a brackish marsh in New Jersey to changes in pH and redox potential found that Ni, Cd, and Zn were released. A possible release of Cu was found, but no release of Cr or Pb was observed (Gambrell et al., 1991). These studies indicate that zinc is the most likely element to become available during drying. Lead is less likely to be released during the drying of a soil substrate, but may be expected to exceed chromium. No studies are known that predicted the fate of silver.

F.3.14 Plant uptake. Plants may serve as an avenue for contamination of higher organisms through the passing of compounds up the food chain. They may also make a significant contribution to other contaminant mobility pathways within a CDF, such as surface runoff, volatilization, and microbial degradation. For example, some metals such as cadmium and zinc may concentrate in the surface litter layer (from studies cited in Brannon et al., 1990, p. 46). Zinc might be expected to

accumulate in plant matter within the disposal area. However, zinc is not considered very toxic and, because of the low average levels found in Savannah sediments, is not expected to pose a problem.

F.3.15 Some research has been done on the long term effects of contaminants, including metals, and the potential for their bioaccumulation. Brandon et al. (1991), performed a long term evaluation of the potential for mobility of metals in plants and animals which colonize contaminated estuarine dredged material placed in both wetland and upland environments (Brandon, et al., 1991). As the tested material placed on an upland site oxidized it became more acidic and did not support vegetation after 6 years. Laboratory tests with the same sediments found that plants growing in these sediments had elevated zinc, cadmium, chromium, nickel, and lead. Earthworms were not able to survive in the sediments under upland conditions. Sediments placed in a wetland environment contained possibly elevated levels of only copper and chromium. Plants grown in the sediment under upland conditions showed metal concentrations up to the following: Zn:66.0 ppm, Cr: 8.64 ppm, and Pb: 1.56 ppm. Observed zinc levels in plants were within the normal range for agricultural crops of 15-150 ppm. The concentrations of metals in the sediments studied were as follows: Zn:1,307 ppm, Cr: 1,651 ppm, and Pb: 397.8 ppm. These levels are approximately 10 times higher than observed average concentrations of the metals in Savannah Harbor sediments. Using that relationship, one could predict metal concentrations in plant tissue from the Savannah Harbor disposal areas to be the following: Zn: 6.6 ppm, Cr: 0.86 ppm, and Pb: 0.16 ppm. These levels are all at or below normal levels (Chaney (1983) cited in Brandon et al. (1991)).

F.3.16 Soil lead can be absorbed and accumulated by plants and invertebrates (Lee et al., 1986). In a study of minespoil reclaimed with sewage sludge, sludge was applied with a mean Pb loading rate of 5.5 grams per square meter. After 1 to 2 years, surface soils (0 to 15 cm) generally had a Pb concentration of less than 10 ppm. Ninety-six percent of vegetation samples had less than 10 ppm of Pb. It was concluded that metals in forage species grown with the sludge for reclamation posed no threat to the food chain or animal health (Sneaker, 1991). Lead uptake has also been investigated by studies more closely resembling the Savannah Harbor situation. A study of sewage application to a dredge spoil site along the Chesapeake and Delaware Canal in Delaware near Chesapeake City, MD, found surface (0 to 20 cm) soil total Pb levels of 129 ppm after 2 years and 61 ppm after 4 years. At the same time, vegetation levels were found to be 0.2 ppm after 2 years and 5.7 ppm after 4 years (Palazzo and Reynolds, 1991). Lee et al. (1986) also looked at uptake of lead by *Typha* (cattails). Their data (Figures 2-83 and 2-86) indicate the following relationship: lead concentration in *Typha* (ppm) = (soil lead concentration/1220 + 1.4) ppm. Using their data and a

Savannah Harbor estimate of 32 ppm soil lead concentration, it can be predicted that plants would have a tissue level of 1.4 ppm (dry wt). This level is the same as would be predicted by the Palazzo study (5.7 ppm/4=1.4 ppm) since it investigated soil levels four times higher than estimated for Savannah and found a plant tissue level of 5.7 ppm. Green-winged teal weights range from about 275 g to 375 g (Baldassarre, 1986). They would be expected to consume about 10 percent of their body weight per day (Fredrickson, 1994, personal communication). For a 325 g (11.4 oz) green-winged teal consuming vegetation with a Pb concentration of about 1.42 micrograms/g dry weight (0.142 micrograms Pb/g wet weight, assuming plants are 90 percent water), this would mean 32.5 grams of plant matter containing 4.6 micrograms of lead would be consumed daily (the estimated intake corresponds well with Baldassarre (1986), where it was found that teal in Texas consumed about 30 g of corn per day). This equates to a body burden of 0.01 micrograms Pb/g body weight/day. Japanese quail reduce egg production with a dietary intake of 10 micrograms/g body weight (Edens et al., 1976, cited in Lee et al. 1986). Predicted body burdens in birds consuming plant material in the Savannah disposal areas would be much less than this.

F.3.17 Plants grown in contaminated sediments (Zn: 1307 ppm, Cr: 1651 ppm, and Pb: 398 ppm) under flooded conditions showed levels up to the following: Zn: 21.1 ppm, Cr: 10.4 ppm, and Pb: 3.8 ppm and under upland conditions : Zn:6.3 ppm, Cr: 8.64 ppm, and Pb: 1.56 ppm (Brannon et al., 1991). Since the original sediment contaminant levels in that study were 10 times higher than have been found in Savannah Harbor sediments, expected plant tissue chrome levels for Savannah CDFs should be in the 1 ppm range, at the upper bound of the normal range cited by Lee et al. (Table 7, Lee et al., 1991).

F.3.18 Animal uptake. Studies of the Times Beach CDF (Buffalo, NY) found that carnivores and detritivores accumulated greater concentrations of heavy metals than herbivores. They also found that lead, nickel and chromium moved through the food web within the upland ecosystem more than zinc, copper, and cadmium (Brannon et al., 1990, p.48). Operating conditions at the CDF are extremely important variables affecting contaminant migration, cycling, and mobilization pathways (Brannon et al, 1990, p. 6). More information is needed to precisely determine the importance of animal uptake to internal cycling of contaminants within CDFs (Brannon et al., 1990). Lead and chromium might be expected to accumulate in the food web of the disposal areas and are discussed further below. As stated above, little information exists discussing impacts of silver on higher organisms.

F.3.19 Animal Uptake of Lead. A study of oxic sediments along the shore near a lead smelter in New Brunswick, Canada, found that the Pb content of mussel tissue correlates best with certain Pb extraction fractions. The sulfur content of the sediments was found to play an important role in Pb accumulation in mussel tissue, with Pb bound to sulfur appearing to be less available. For the most part, an appreciable rise in tissue levels occurred when total sediment Pb levels were near or above 400 ppm (Bourgoin et al., 1991). Savannah Harbor sediment lead levels are much lower than this, averaging 20 to 60 ppm in different parts of the harbor. Lee et al. (1986) also found that elevated soil concentrations of Pb would result in increased lead in earthworm tissue. They compared soil and earthworm tissue lead levels and found a significant correlation. An estimate of the equation of the regression line shown in their figure 2-83 is: tissue Pb (ppm) = $(3.5 + \text{Soil Pb}/500)\text{ppm}$. Using the predicted average Savannah Harbor average sediment lead content of 32 ppm, this equation would predict invertebrate tissue levels of about 3.6 ppm (dry weight). Shovelers, a species that winters in the disposal areas, weigh about 1.5 lbs (3.3 kg) (US FWS, 1978) and black ducks, similar to Mottled ducks, weigh about 2.75 lb (US FWS, 1978). Lee et al., state that the dunlin (110 g) and black rail (100 g) eat 8.5 percent and 8 percent of their body weight per day. Ducks are thought to consume about 10 percent of their body weight per day (Frederickson, 1994, personal comment). Assuming animal prey are 77 percent water (earthworms, Lee et al., 1986), ducks would be expected to consume prey with a concentration of about 3.6 ppm lead dry weight or 0.83 ppm wet weight. This would be 0.83 micrograms Pb per gram of worm tissue. A 1.5 lb shoveler weighs about 3300 grams and consumes about 330 grams of food per day. This would equate to 0.08 micrograms Pb/gram body weight/day body burden. A 110 g dunlin, a species of shorebird that sometimes winters in the disposal areas, would be expected to eat 9.35 g of animal matter containing 7.76 micrograms of lead. This would equate to 0.07 micrograms Pb/gram body weight/day body burden.

F.3.20 Other studies have shown bioconcentration factors (BCFs) for lead in organisms exposed to marine sediments of 0.014 to 0.58 using wet tissue weights (Scott et al., 1994). Using these ranges, organisms feeding in Savannah Harbor sediments would be expected to have wet weight lead concentrations ranging from 0.45 to 18.6 ppm lead. Lead body burdens of shovelers feeding on these organisms would be expected to range from 0.045 to 1.86 micrograms Pb/gram body weight/day body burden. Dunlin body burdens would be expected to range from 0.038 to 1.58 micrograms Pb/gram body weight/day.

F.3.21 The effect of lead body burdens has been studied in the Japanese quail (*Coturnix coturnix*) where egg production was reduced with an intake of 10 micrograms/g dietary lead daily (Edens et al., 1976, cited in Lee et al., 1986, p. 454). This was calculated to be a daily body burden of 0.75 micrograms Pb exposure/gram body weight. Scanlon (1979) reported that carnivorous short-tailed shrews trapped along roadsides with lead concentrations of 19.9 to 109.7 ppm lead (a control area had 7.8 ppm Pb) had mean Pb body concentrations up to 34.8 ppm (dry wt.) (Lee et al., 1986). That would equate to approximately 11 micrograms/gram wet body weight. Lee et al. (1986) cite reports that Pb body levels in rats of 0.4 to 1.0 microgram/gram can cause physiological changes in rats. The high end of the calculated range of Pb exposure levels from Savannah Harbor sediments falls within the lower range of possible effects to birds and mammals. If most of the sediment lead were bioavailable, and the higher observed bioaccumulation factors were at work here, then one could expect some degree of physiological impact to birds feeding within the disposal areas from lead ingestion. However, as discussed elsewhere, the majority of lead in those sediments is not believed to be bioavailable, so lead exposure to birds feeding within the disposal areas is not believed to be of sufficient concern to take further action. As stated elsewhere in this analysis, no vegetation or wildlife have been observed in a stressed condition at or surrounding the disposal areas which would indicate a potential toxicity problem within the disposal areas.

F.3.22 Animal Uptake of Chromium. The degree of toxicity of Cr is related to its chemical form. Cr (VI) is the predominant species in sea water, and is readily taken up by marine organisms and is more toxic than Cr(III) (Sanders & Riedel, 1987, cited in Weiss et al., 1993). Mussels (*Mytilus edulis*) exposed to sediment concentrations of 195 to 561 ppm for 28 days have been shown to bioaccumulate Cr to tissue levels of 0.615 to 4.02 ppm (dry wt.) (McFarland et al., 1994). Clams (*Macoma nasuta*) exposed to the same sediments for 28 days have been shown to bioaccumulate chrome to 3.82 to 16 ppm (dry wt.). Areas of the Arabian Sea with sediments averaging 24.3 to 39.1 ppm Cr (dry wt.) were found to contain a fish with 8.51 ppm Cr (wet wt.), a shrimp with 5.9 ppm Cr (wet wt.) and a seaweed with 9.1 ppm Cr (wet wt.) (Tariq et al., 1993). These reports show a wide range in expected tissue levels that do not correlate well with sediment levels, possibly due to differences in bioavailability (which could be due to the chemical form the substance is in or other environmental factors). A literature review of studies on organisms feeding in marine sediments found bioconcentration factors for chromium to range from 0.04 to 0.35 (Scott et al., 1994, draft). Using a predicted average Savannah Harbor sediment concentration of 69 ppm chrome, organisms feeding in those sediments would be

expected to have tissue chrome levels of 2.8 to 24 ppm wet weight. The District was unable to locate any study on the effect of low levels of chrome body burdens on birds.

F.3.23 Animal Uptake of Silver. A literature review of studies on organisms feeding in marine sediments found bioconcentration factors for silver to range from 0.18 to 19.7 (Scott et al., draft). Using the predicted average Savannah Harbor sediment concentration for silver of 1.3 ppm, organisms feeding in those sediments would be expected to have wet weight body concentrations of 0.2 to 26 ppm silver. The District was unable to locate any study on the effect of low levels of silver body burdens on birds.

F.3.24 Leachate to groundwater. A recent weir study (NMFS, 1994) found underdrain arsenic concentrations of up to 298 micrograms/l. District monitoring of underdrain effluent has found the pH mostly in the 6.4 to 6.8 range, but a pH of 12 has been recorded. These are underdrain weir effluent releases that would not impact wildlife within the disposal areas. The underdrains are being closed, but it is proposed that new underdrains be constructed to outfall to the Savannah and Back Rivers. Underdrain releases would divert water that would be expected to enter groundwater.

F.3.25 Surface runoff. Once disposal has ceased, drying and oxidation of the sediments will take place. Salt accumulates on the surface of the dredged material where rainfall can dissolve and mobilize the salts in surface runoff. If the dredged material is high in sulfide and low in carbonate, oxidation may result in formation of highly acidic conditions in surficial sediments (Brannon et al. 1990). Modeling of suspended solids within ponded waters, such as occur within a CDF (looking at pathways such as resuspension of deposited sediments and surface runoff from emergent sediment) may be important in predicting contaminant impacts within a CDF; however, predicting such pathways through modeling of suspended solids with ponded water has not been well refined (Brannon et al., 1990). Due to the correspondence of predicted overall metal levels to those occurring in natural soils, no significant impacts are expected. Further prediction beyond the discussions above are not possible.

F.4.00 CONCLUSIONS.

F.4.01 As discussed above, the only contaminants identified to be of possible concern in the confined disposal areas are heavy metals. Metals may exert direct acute effects on organisms by affecting their growth and survivability. When looking at the overall composition of Savannah Harbor sediments, no contaminants have been identified which exist at levels that would indicate a concern for probable acute impacts. The average of cadmium in the in-channel sediments, the average levels of chrome, copper, and arsenic in sediments within the Sediment Basin, and average levels of silver within both in-channel and Sediment Basin sediments are above the ER-L's of Long and Morgan (1993). Average levels of cadmium, silver, and arsenic in sediments outside the channel are also above the ER-L's. The ER-L is the lowest 10 percentile of data or predictions associated with biological effects under some set of conditions. None of the average values approach the ER-M's. As discussed above, some concern remains for metal concentrations in out-channel sediments, especially cadmium. Since sediments outside the channel constitute only a small fraction of total O&M sediment that would be placed in the disposal areas, any possible effects by cadmium would be diluted below any level of concern. Moreover, since agitation dredging has been taking place throughout the time in which the sediment data discussed here was taken, the channel and Sediment Basin sediment data should include the effects of agitation dredging and sediments outside the channel. In addition, this discussion does not take into account the extent to which the observed bulk total concentrations of metals in the Savannah Harbor sediments may not be bioavailable.

F.4.02 The likelihood that a significant proportion of these metals would be bioavailable or exert chronic effects through bioconcentration is small. An earlier investigation of Savannah Harbor sediments (Savannah Labs, 1983) found that most (66 to 90 percent) of the chrome, lead, and silver occurred in the moderately-reducible or residual fractions that tend to be immobile. The District believes that sufficiently high metals concentrations are not bioavailable in concentrations that would exert chronic effects on organisms that accumulate metals in their tissues or feed on organisms that have accumulated metals.

F.5.00 RECOMMENDATIONS. Adequate data are available to conclude that current O&M sediments from the Navigation Project do not contain either metals or organic compounds at levels of concern. There is evidence that sediments outside the main channel may contain PAH's at levels of concern. There is also evidence that the sediments outside the main channel may contain metals at levels of concern. Non-O&M dredging projects should, therefore, include a sediment evaluation for metals and PAH's.

APPENDIX G

MITIGATION PLAN
FOR THE DIKING AND USE OF
DISPOSAL AREA 14A
AND MISCELLANEOUS DISPOSAL OPERATIONS
IN SOUTH CAROLINA

MITIGATION PLAN
FOR THE DIKING AND USE OF
DISPOSAL AREA 14A
AND MISCELLANEOUS DISPOSAL OPERATIONS
IN SOUTH CAROLINA

G.1.00 ACTIONS REQUIRING MITIGATION.

G.1.01 Alternatives 2, 3, and the Selected Plan (Alternative 8) have a component that would lead to the loss of significant wetlands -- that being the diking and use of Disposal Area 14A. Miscellaneous operations at the confined disposal facilities (CDFs) would also result in the loss of wetlands. Federal policy requires mitigation for the loss of wetlands.

G.2.00 OVERVIEW OF MITIGATION PROCESS.

G.2.01 Several steps were followed in the development of a mitigation plan. Those steps consist of the following:

- A) Selection of the dike alignment which would minimize wetland impacts yet serve the purposes of the project. This action would define the extent of the site which would be impacted.
- B) Identification of the types of vegetation present at the site.
- C) Identification of the wetland jurisdiction line.
- D) Identification of the functional values provided by the wetland existing at the site.
- E) Identification of alternate means of replacing those functional values at other sites.
- F) Selection of the best action to replace the lost functional values and the scope of the replacement necessary.
- G) Detailed design of the mitigation plan.

The following paragraphs describe the rationale supporting each of the decisions which were made as the District followed the steps listed above.

G.2.02 Selection Of The Dike Alignment. Dikes exist of two sides and part of a third side (road) of Disposal Area 14A as a result of previous construction of a road and dikes for adjacent CDFs. Only the north side of the site remains undiked. The selected alignment for the north dike was approved by the South Carolina Coastal Council in July 1984. That alignment was based on a review of vegetation at the site and the location of areas which had previously been impacted by unconfined deposition of dredged material. Such deposition increased the ground elevation

of some areas to the point that they are no longer considered wetlands. At other areas, the ground elevation was raised to the point that only vegetation that is generally considered lower quality wetland species exists. The approved dike alignment minimizes the acreage of high quality wetlands that would be destroyed, while still allowing construction of a technically viable settlement basin. Approximately 815 acres would be enclosed by the approved alignment.

G.2.03 Identification Of Vegetation Present. A two-step process was followed to identify the vegetation existing at the site of the proposed CDF; (1) delineation of vegetation from aerial photography, and (2) field verification of vegetation types.

G.2.04 Using 1991 aerial photographs taken for the Georgia Department of Transportation (GA DOT), vegetation types in the area to be impacted were delineated by a Biologist from the District's Planning Division. The vegetation and wetland delineations were field verified from March to May 1994 by that Biologist and another Biologist from the District's Regulatory Branch. Figure 1 shows the locations and extent of the various vegetation types existing at the site. A summary of the habitat which would be impacted by development of the 815-acre site as a CDF is shown below. A detailed description of the habitat types is included in Table 1.

<u>HABITAT TYPE</u>	<u># ACRES</u>
Wetland	
Low/moderate value within old dike	33
Low/moderate value outside old dike	85
High value outside old dike	<u>187</u>
Subtotal	305
Upland	
High value wildlife	43
Low value wildlife	<u>467</u>
Subtotal	510
Total	<u>815</u>

G.2.05 High functional value wetlands at the site consist primarily of (1) Distichilis spp. and Juncus roemerianus marsh, which primarily functions as wildlife habitat, (2) Spartina cynosuroides marsh, which primarily functions as wildlife habitat and a source of detritus, and (3) Scirpus spp. marsh, which primarily functions as wildlife habitat and as a wildlife food source. Savannah District developed a Mitigation Plan to replace the functional value of the wetlands which would be lost.

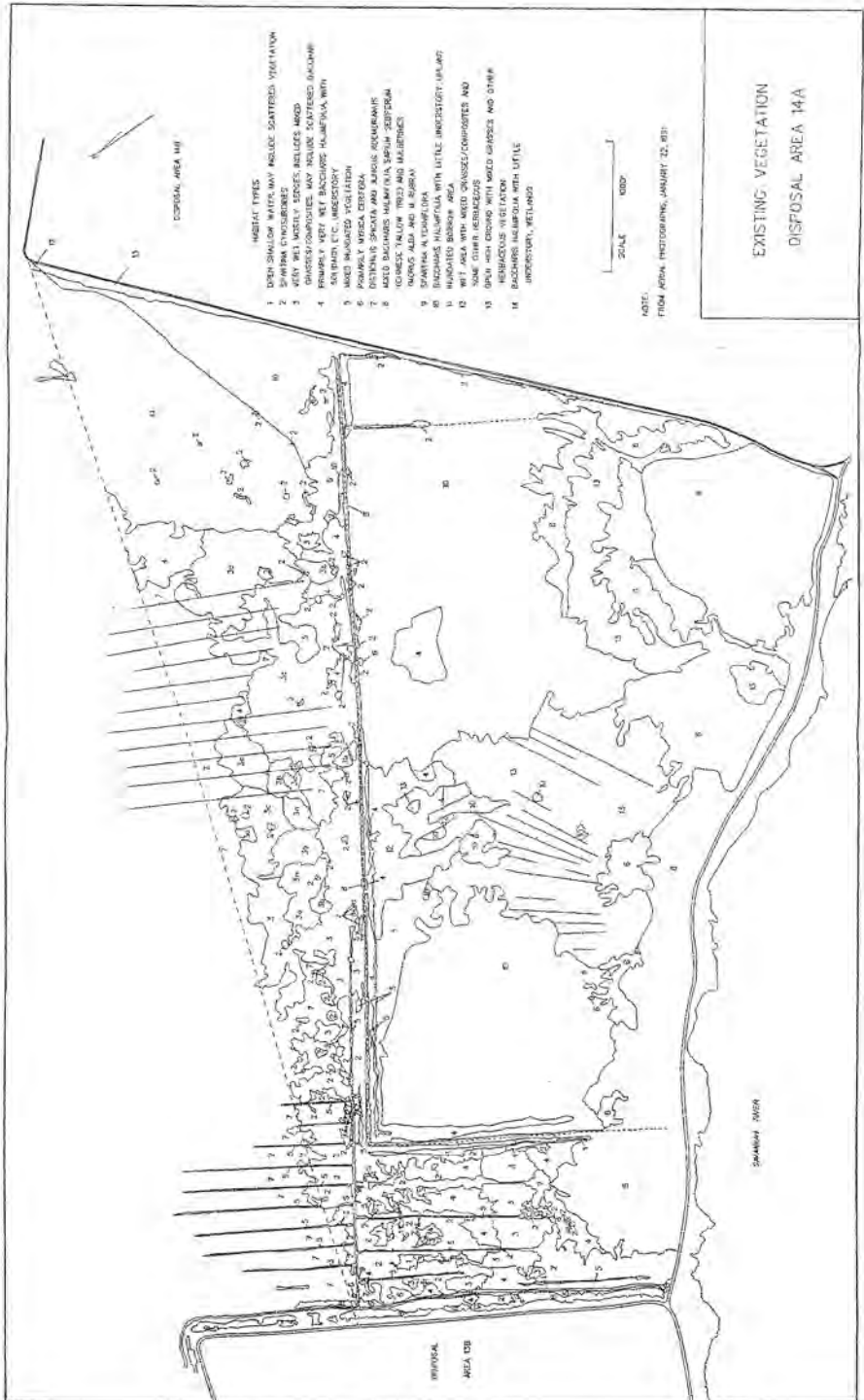


TABLE 1

VEGETATION TYPES
CURRENTLY AT
DISPOSAL AREA 14A

<u>VEGETATIVE TYPE</u>	<u>VEGETATIVE CLASSIFICATION</u>	<u>ACREAGE</u>
<u>WETLANDS</u>		
High value outside the old dike		
Open water	1	2.3
<u>Spartina alterniflora</u>	9	1.0
<u>Spartina cynosuroides</u>	2	49.9
<u>Distichilis/Juncus</u>	7	86.1
Sedges (<u>Scirpus spp.</u>)	3	10.6
Mixed inundated vegetation	5	<u>36.6</u>
SUBTOTAL		186.7
Moderate value outside the old dike		
Primarily <u>Baccharis spp.</u>	4	24.4
Low value outside the old dike		
<u>Baccharis spp.</u> (wet)	14	60.5
Mixed grasses/herbs	12	<u>0.1</u>
SUBTOTAL		60.6
Low/moderate value inside the old dike		
<u>Spartina cynosuroides</u>	2	1.6
Sedges (<u>Scirpus spp.</u>)	3	2.0
Mixed grasses/herbs	12	10.6
Primarily <u>Baccharis spp.</u>	4	<u>19.0</u>
SUBTOTAL		33.2
TOTAL WETLANDS ACREAGE		304.7
<u>UPLANDS</u>		
High value inundated borrow area	11	42.9
Moderate value mixed trees	8	76.1
Moderate value <u>Myrica cerifera</u>	6	71.5
Low value <u>Baccharis spp.</u>	10	228.7
Low value mixed grasses/herbs	13	<u>91.1</u>
TOTAL UPLANDS ACREAGE		510.3
TOTAL ACREAGE OF SITE		815.0

G.2.06 Identification Of The Wetland Jurisdiction Line. The wetland jurisdiction line was delineated by a Biologist in the District's Planning Division at the same time as he described the site's vegetation types. The jurisdiction line was field verified from March to May 1994 by that Biologist and another Biologist from the District's Regulatory Branch.

G.2.07 Identification Of The Functional Values Provided By The Site's Wetlands. The proposed site of this CDF has been impacted by previous dredged material disposal operations. Those historic disposal events impacted the existing wetland vegetation and raised the elevation of a significant portion of the site. The extent of the impacted marsh is approximately 815 acres. Within that area, 510 acres have been raised to the extent that they now fall outside the wetland jurisdictional line and are considered uplands. The disposal operations were located along the Savannah River side of the site, so that portion of the site experienced the most impact and contains the highest ground elevations. Part of that high ground has since been used as a source of borrow material for the construction of dikes for nearby disposal areas. The entire portion of the site along the river is now high ground. Therefore, no tidal exchange occurs at the site from the Savannah River. In addition, dikes which define CDFs located adjacent to Area 14A further restrict tidal exchange. Disposal Area 14A presently has three sides which are either diked or high ground. Tidal exchange for the remaining wetlands at the site must occur through the length of the rectangular-shaped site. This lack of good tidal exchange, coupled with the increase in marsh elevation stemming from previous unconfined disposal operations, has resulted in significantly reducing the traditional functional values of the salt marsh at this site.

G.2.08 The District attempted to follow the traditional approach to mitigating for lost or damaged wetlands; replacing the lost wetland vegetation with similar vegetation at another site. However, most high ground around the harbor is already developed and would be very expensive to purchase and then excavate to create a wetland. No single high ground tract or combination of smaller tracts could be identified where sufficient acreage of wetlands could be created. The District queried staff of resource agencies and environmental groups about potential wetland restoration sites; none were identified. Since a site or combination of sites could not be identified, excavation of high ground property was deleted from consideration as a method of wetland creation. Shallow water estuarine areas often contain features which have significant environmental value. Since suitable shallow areas are not extensive in the harbor area and deposition of material to fill the site could produce significant adverse impacts to benthic and aquatic resources, filling those areas to build up the elevation of the site so that marsh

vegetation could flourish was judged to be unacceptable. Therefore, the filling of shallow areas was deleted from consideration as a method of wetland creation. The infeasibility of these two approaches to wetland creation led to a conclusion that creation of a similar wetland within the immediate project vicinity to replace the functional values which would be lost at Disposal Area 14A was an unimplementable alternative for this project.

G.2.09 Identification Of Alternatives To Replace The Lost Functional Values. Early coordination with resource agencies revealed a degree of agreement on the functional values which would be lost and that should be replaced. Although salt marsh has many values and serves many functions, the value of the wetlands at this site is somewhat unusual, as described in the previous paragraphs. The site's location in a tidal estuary effectively eliminates any flood control function. The high ground at the site on the Savannah River side eliminates any water purification function which a site downriver of an industrialized city would normally possess. The restricted tidal exchange and raised elevations greatly reduced the value of the salt marsh located on the site. Therefore, the Distichlis spp. and Juncus roemerianus vegetation was judged to primarily function as wildlife habitat. The Spartina cynosuroides vegetation primarily functions as wildlife habitat and a source of detritus, while the Scirpus spp. marsh primarily functions as wildlife habitat and as a wildlife food source. The resource agencies recognized that traditional wetland mitigation procedures should be pursued first to attempt to replace the functional values which would be lost at a site, but they agreed that the traditional wetland mitigation procedures had not worked effectively for the proposed impact.

G.2.10 The next step was a review of what resources were most important in the function of the Disposal Area 14A site within the harbor. This was an attempt to view development of Disposal Area 14A in the larger context of the harbor's estuarine ecosystem. Agreement was reached between the agencies on the value of the site for wildlife habitat and the critical importance which the Project's adjacent CDFs provide shorebird and waterfowl populations in the harbor area. The District then developed the concept for mitigating wetland functional values lost at Disposal Area 14A through the creation of critically needed wildlife habitats; particularly habitats for migratory and endemic waterfowl and shorebirds. Mitigation efforts would be prioritized toward increasing wildlife values at the Project's confined disposal facilities. If sufficient habitat values could not be created at those disposal sites, off-site actions would then be investigated, but at sites within the Project area.

G.2.11 Selection Of The Best Replacement Method And Scope Of The Replacement Needed. Migratory birds were identified as the target group of wildlife species which could most benefit from increases in habitat availability in the Project area. These birds include least terns, Wilson's plovers, black-necked stilts, and mottled ducks, as well as large numbers of other migratory shorebird and waterfowl species. Many land bird species also use the areas at times, especially the shrub habitat found along and adjacent to the dikes. The confined disposal areas provide valuable habitat for those species due to the availability of food and the isolated and open nature of the sites. Although a number of bird species reside in the project area throughout the year, habitat for migratory shorebird species appears to be especially critical since those species regularly occur in the spring and fall in the CDFs in large numbers. Ten basic management techniques were identified which would benefit those migratory birds which rely on the Project area for an important period of their lives. Those techniques are described in paragraphs G.2.12 through G.2.21.

G.2.12 Creating Nesting Islands. Nesting islands could be provided within each disposal area. These areas would be covered with sand and scattered wood debris and have a gentle slope to make them suitable for least terns and Wilson's plovers. Other criteria for proper nesting habitat may be developed. These areas should be available and undisturbed from April 14 to August 6 (unless Wilson's plovers are present, in which case the areas should remain undisturbed until August 28). Areas could be disturbed earlier, if nesting species are not present. At least two 1- to 3-acre nesting islands could be provided within each disposal area. These islands could be located in each disposal area so that they would be surrounded by water or mud. Each island would be covered with coarse sand if the construction materials were not suitably sandy. This would result in 42 acres of wildlife benefit (two 3-acre islands in each of seven disposal areas). Vegetation would be controlled annually. Islands would also serve as year round roosting areas (would be similar to the natural high marsh panne roosting sites cited by Howe, 1989).

G.2.13 Creating Upland Nesting Areas. Bare ground nesting areas could be provided on high ground outside the diked perimeter of a confined disposal area. These areas would be cleared of existing vegetation and possibly covered with dredged material to provide a sandy nesting substrate. As in the previous paragraph, the site would be graded to produce a gentle slope to make them suitable for least terns and Wilson's

plovers. Other criteria for proper nesting habitat may be developed. These areas would generally remain undisturbed from April 14 to August 6 (unless Wilson's plovers are present, in which case the areas should remain undisturbed until August 28). These areas would not provide as high a quality nesting habitat as the islands described in the previous paragraph since the nests would be accessible to terrestrial predators.

- G.2.14 Holding Poned Water. At least 50 acres of water could be held in one of the disposal areas (Area 12A, 12B, 13A, 13B, 14A, 14B or Jones/Oysterbed Island) so that at least one 50-acre wet area would be present at any time during the year. This would result in at least 50 acres of wildlife benefit. Only a minimal depth of water would be needed, as the ponded area would primarily serve as a resting site for migratory waterfowl. For Disposal Area 14B, this would be in addition to the area currently inundated by tidal flow into the weirs. Maintenance of a constant water level would depend on rainfall to counter the effects of evaporation and infiltration, which lower the water surface.

- G.2.15 Slow Release of Poned Water. If sufficient rainfall is obtained, a constant water level could be maintained in the summer and winter and then slowly lowered through the spring and fall. The wet area would result in 50 to 100 acres of beneficial wildlife habitat.

- G.2.16 Mowing of Dike Slopes. Mowing of dike slopes could be halted during the nesting season (March 1 to July 14) to provide additional vegetated upland habitat. The dike crest could continue to be mowed to allow needed access around the Disposal Areas.

- G.2.17 Construction of an Offshore Bird Island. Construction and maintenance of a bird island north of the north harbor entrance jetty was identified as a valuable habitat enhancement feature. The island should be 3 to 10 feet above highest water level to prevent wave overtopping and should be at least 0.3 km from mainland to prevent predators from swimming to the site. A 1-acre island at 14' above MLW would produce an 11-acre surface area above MLW (assuming a 1:35 slope). A 5-acre island with the same side slope would produce a 14-acre surface area above MLW.

G.2.18 Monitoring of Bird Nesting. Monitoring of bird nesting at the confined disposal areas could be performed on a regular basis by District Biologists. This would provide information on bird use of the sites which could be used for future management decisions.

G.2.19 Manage Existing Areas for Optimum Bird Habitat After Each Disposal Operation. Ideal beneficial management strategies were identified for the following four different groups of birds:

(a) For spring migrants, there should be fall flooding (1 month before heavy freeze) and a spring draw down at a rate of 2 to 3 cm per week (Helmers, 1992). The draw down should begin in late March to provide optimal foraging opportunities for late migratory dabbling ducks (Howe, 1989).

(b) For fall migrants, two schemes are available. A disposal area could remain flooded through the spring and early summer, with either slow draw down or natural evaporation during the fall. For areas that are dry, shallow disking followed by shallow flooding 2 to 3 weeks before summer/fall migration begins (Helmers, 1992) would optimize the site's habitat value. Howe (1989) suggests reflooding to 5 to 76 cm.

(c) For waterfowl, the ponded water in the disposal area would be drawn down in the spring to firm the substrate and initiate germination of widgeon grass. Pool levels would then be drawn down in April through early June. After plants germinate, the area would be gradually reflooded to 35 to 45 cm to allow plants to grow. During late fall and early winter, water depths would be decreased approximately 10 cm per month (Helmers, 1992). Irrigation at 10 cm per month would increase plant growth, but would be quite expensive.

(d) For nesting birds, a constant water level in the late spring and early summer would be maintained. This would be followed by a slowly dropping water level in the late summer. The wet area would be expected to cover a minimum of 50 to 100 acres.

G.2.20 Maintaining High Marsh Pannes. Natural high marsh pannes could be maintained to provide roosting and feeding sites (Howe, 1989).

results of that study are contained in Appendix E of this EIS. In summary, the District evaluates the sediments prior to their excavation from the riverbed and evaluates the discharges leaving the CDFs.

G.2.25 However, the District does not typically evaluate the quality of sediments once they are placed inside the CDFs. Up to this point, technical justification for such expenditures did not exist since those sites were only used for dredged material disposal purposes. With the advent of managing the CDFs for the production of wildlife habitat as a component of overall CDF operations, it is prudent to ensure that the habitat being created is not harmful to wildlife. Therefore, the District will conduct chemical testing of sediments in the CDFs.

G.2.26 Sampling will be performed of soil material within the first 1 foot of the surface. It is within this 1-foot zone that invertebrates exist which are available to wildlife and most plant roots exist (annuals and pioneer species). Since fluctuating water levels within the areas greatly change the type of habitat which a specific location provides over time -- sometimes inundated and other times dry -- samples from within each CDF will be combined. The testing protocol to be followed on the soil samples would be coordinated with the South Carolina Department of Natural Resources and approved by the US Fish and Wildlife Service prior to the sampling being conducted. The District could participate with other interests to expand the scope of this sediment testing, but the testing strategy outlined in this paragraph would be the minimum effort that would be performed.

G.2.27 Selection of Specific Management Strategy. The specific management strategies were evaluated for both their expected benefits for birds, their impacts on expected disposal operations and their impacts on disposal site management activities. Strategy 1 reflects present operational practices. Certain disposal areas provide no suitable nesting habitat during some years. Other years, the areas may contain little or no water during the winter months when waterfowl often use the sites. Depredation Permits are sometimes required from the US FWS to allow contracted dredging operations to proceed without expensive delay costs (up to \$25,000 per day). The ability to obtain those permits is not guaranteed, so uncertainty exists about the ability to perform disposal or disposal area improvement actions during the nesting season. The large uncertainty which arises concerning the availability of a specific disposal site for either disposal or regular management activities greatly hinders effective management of all the confined disposal facilities. Strategies 2 and 3 would provide significant improvements of the confined disposal facilities for bird habitat over that which is presently available. Strategy 2 maximizes bird use of the areas

G.2.21 Creating Roosting Islands. Islands could be created in managed non-tidal wetlands for use by birds as roosting sites. Vegetation at the sites would be controlled to optimize the suitability of the vegetation for roosting.

G.2.22 Development of Specific Management Strategies. Using the ten basic management techniques just described, three potential specific management strategies were identified to increase wildlife (migratory bird) habitat in the CDFs. These strategies were analyzed for both their impacts to dredged material disposal operations and the benefits they are likely to produce when applied at these CDF sites. Before describing the strategies and their impacts, the issue of dredged material testing should be addressed.

G.2.23 Dredged Material Testing. Although the CDFs currently provide valuable habitat for migratory birds, this use of the sites is a byproduct of conditions resulting from dredged material disposal operations conducted at those sites. These CDFs are not specifically managed to produce wildlife habitat. The management strategies described in the previous paragraphs would change that situation. If those strategies are implemented, a component of the Savannah Harbor Navigation Project would be the creation and maintenance of wildlife habitat with the intention of increasing wildlife usage of the CDFs. With such a purpose, it is prudent to ensure that the habitat being created is beneficial to wildlife. As with nearly all dredged material disposal areas across the world, the toxicity of the deposited sediments is questioned.

G.2.24 Savannah District regularly evaluates sediments in the Savannah Harbor prior to dredging operations to ensure that the excavation and disposal activities can be conducted in an environmentally acceptable manner. This review has included chemical testing of the river sediments. (Appendix F of this EIS contains a summary of the sediment testing data which is available for Savannah Harbor.) The District also considers spills which are reported to have occurred along the river to determine if those new inputs are likely to have significantly altered the quality of the sediments since they were last analyzed in detail. The District also monitors the effluent from the CDFs to ensure (1) its compliance with the state Water Quality Certification, and (2) that the discharges are not causing any unexpected and unacceptable environmental impact. In addition, the District recently conducted a study of the impacts of the CDF discharges into the marshes along Wright River. The

at the expense of disposal and regular disposal site maintenance activities. The procedure would result in repeated choices having to be made between using a site for disposal operations and having sufficient drying time of that site to conduct necessary disposal site management activities. This was judged to be unacceptable and causes that strategy to be infeasible since sufficient times are needed to both conduct necessary disposal activities and perform required disposal site maintenance activities. Therefore, Strategy 3 (2-year rotational use of disposal areas with modifications for bird use) was selected for use. That strategy maximizes the benefits of the confined disposal facilities to birds while allowing sufficient periods for disposal operations and drying time through the rotational use of the sites.

G.2.28 Scope of The Replacement Needed. With traditional wetland mitigation actions consisting of the creation or restoration of similar vegetation at another site, there is a degree of uncertainty on the true success of the action in replacing the functional values of the original wetland vegetation. Although the same vegetation species can be made to grow at another site, there is still the question of whether all the original site's functional values are replaced at the new site. Therefore, some multiplier, typically 2:1, is applied to the wetland acreage to be created to provide more assurance that the true value of the original wetland site has been replaced.

G.2.29 With the mitigation scheme to be used for this site, a higher degree of certainty can be obtained in actually producing the agreed upon product. The view of the Corps and resource agencies' staffs is that the present value of Disposal Area 14A is primarily reflected in the site's provision of wildlife habitat. Based on that position, an agreement on the target species, and an analysis of the value of that habitat for the agreed upon target species, a mitigation plan can be developed which would result in similar levels of habitat for those species. Since the mitigation goal is then defined as habitat for specific wildlife species, a mitigation plan can be developed to produce the required amount of habitat. The bulk of the mitigation plan which the District developed uses adjacent CDFs under management control of the Corps and the sponsor (Chatham County). With the goal being a specific amount of habitat production on land which is under one's direct management control, a high degree of certainty can be obtained that the mitigation goal will actually be met. Because of that degree of certainty, this mitigation plan will require only an overall 1:1 replacement of the site's identified functional values.

G.2.30 One component of the Mitigation Plan is the restoration or creation of wetlands as in-kind mitigation. During the course of the study, neither the Corps nor regulatory agencies were able to identify specific sites where a significant amount of wetlands could be created in the harbor area in a reasonable manner. Never-the-less, during public review of the Draft EIS, the SC Department of Health and Environmental Control, Office of Ocean and Coastal Resource Management (SC DHEC-OCRM) stated that some form of in-kind mitigation would be required as part of an acceptable comprehensive mitigation package for this proposed Project. After reviewing Table 1 with its detailed information on vegetative types which would be impacted, the SC DHEC-OCRM stated that a minimum of 25 acres of in-kind mitigation would be necessary. The District and local sponsor agreed to include such a component in the final Mitigation Plan. During subsequent discussions with the SC DHEC-OCRM, they stated that they periodically become aware of sites where opportunity exists to restore or create wetlands, or purchase valuable habitats to protect them from development. The SC DHEC-OCRM indicated it would be willing to select sites for future wetland mitigation actions and oversee accomplishment of necessary mitigation actions. To accomplish this, Chatham County as the project sponsor -- or GA DOT as its designee -- will establish an escrow account which the SC DHEC-OCRM will administer to perform wetland restoration/creation or protection measures as it deems most appropriate as sites become available in the future.

G.2.31 Another component of the Mitigation Plan is the enhancement of fishery habitat within existing impoundments in the harbor area. Upon review of the Draft EIS, the NMFS stated it felt that wetland functional values which are beneficial to fishery resources were not being adequately compensated. The revised Mitigation Plan was still approximately 200 Habitat Units short of compensating for Project-induced wetland impacts. Various methods were considered to benefit fishery habitat in the project vicinity. These included deposition of shell on the intertidal banks of tidal creeks, deposition of shell on the ocean face of the nearshore bird island, construction and placement of concrete pads with PVC-pipes extending outward to create habitat for fish and shellfish, placement of concrete shells with holes in them for fish to use as shelter, and increasing fishery access or fish habitat quality at existing confined sites. Savannah District consulted the resource agencies to identify potential sites for these measures and assist in estimating the cost of construction. The final method, increasing fishery access or fish habitat quality at existing confined sites, proved to be the most cost-effective way of producing the needed 200 HUs of fishery habitat. Biologists with the Savannah National Wildlife Refuge identified an existing 228-acre impoundment at the Refuge where fishery habitat could be greatly increased. Other impoundments were identified, but the

228-acre site best matched the Habitat Unit need the proposed Project was facing. The impoundment selected is presently operated without having a daily connection with adjacent tidal waters. The impoundment currently has one water control structure with stop logs which maintain a constant water surface elevation. Once tidal flows enter the impoundment through the control structure, stop logs are placed across the opening to block further daily flows. This procedure traps the water --and any fish present -- within the impoundment until a decision is made sometime later to drain the impoundment either partially or completely. The proposed action consists of installation of a second water control structure which would generally be open to all tidal flows. This would provide a constant connection between the impounded water and adjacent tidal waters. Establishing this connection would result in a daily flushing of the impoundment, thereby substantially improving its water quality and making available the shallow areas to fish for feeding and spawning. The entire aquatic ecosystem at the impoundment would benefit from the increased flow and the action would directly benefit fishery resources.

G.3.00 DEVELOPMENT OF THE MITIGATION PLAN.

G.3.01 Summary of the Mitigation Plan. The Plan consists primarily of constructing additional wildlife habitat within existing diked disposal areas used by the Savannah Harbor Navigation Project and operating those areas for increased use by wildlife. As rainfall permits, water levels would be maintained in one area over the Winter and Spring each year to provide resting and feeding habitat for migrating waterfowl. Water levels would also be managed in one area with a slowly dropping surface during the Summer, rainfall permitting, for the benefit of resident shorebirds. One disposal area from each rotational pair would be available throughout the approximately 2-year rotation period for disposal/wildlife management purposes. Drying and construction activities would be occurring in the other disposal area in the rotational pair, so that second area would provide no wildlife habitat during that period. Nesting mounds would be created within the areas for migratory shorebirds. An offshore island would be established for use by bare ground nesting migratory birds. The island would be located in the nearshore area east of the Turtle Island Wildlife Management Area. An upland nesting area outside the dikes at the eastern end of the Jones/Oysterbed Island disposal area would also be established for use by bare ground nesting migratory birds. Restoration or protection of 25 acres of tidal wetlands

would be performed in South Carolina at sites identified by the SC DHEC-OCRM. Construction of a water control structure at an existing 228-acre impoundment within the Savannah National Wildlife Refuge would allow tidal flows to be established in the impoundment, thereby benefitting fishery resources.

G.3.02 The proposed Mitigation Plan replaces the habitat values which would be lost through the diking and use of Disposal Area 14A, and through miscellaneous disposal area operations in South Carolina. Loss of 3.2 acres of wetlands would also occur in Georgia as a result of miscellaneous disposal area operations at existing CDFs (Disposal Areas 1N and 2A) located in that state. Mitigation for those wetland impacts would occur at a 2:1 rate through actions which have yet to be determined, but which would be implemented prior to use of the improvement causing the wetland impact. Savannah District would submit a plan to mitigate the losses of Georgia wetlands to both the Coastal Resources Division of the Georgia Department of Natural Resources and the US Fish and Wildlife Service for approval. Those two agencies would need to approve the Mitigation Plan prior to its implementation.

G.3.03 Development of the Mitigation Plan. Habitat benefits were quantified for four general areas: (1) those presently produced at Disposal Area 14A, (2) those currently produced at CDFs in the middle and lower harbor (Management Strategy #1), (3) those impacted by management operations conducted outside the CDFs, and (4) those which would be produced inside the CDFs through the use of Management Strategy #3. A number of steps were necessary to quantify the habitat value of each site. Four categories were used to describe bird habitats; bare ground nesting, wetland nesting, shorebird feeding and wintering waterfowl. An additional category was included to address the detrital export function of wetlands. A final category was established to address the wetland functional values which directly benefit fishery resources.

G.3.04 Savannah District applied a variety of factors to calculate the value of sites for specific wildlife purposes. Based on past operational experience, the percentage of each area was identified that is normally inundated during a disposal operation. That factor led to a determination of the maximum acreage within each site which would be available at some period of the year for various wildlife uses. The sites were then examined to determine what wildlife habitat functions would exist at each tract (acres of disposal area floor). The normal duration of a disposal operation and subsequent drying period was then taken into account. The addition of that factor introduced the duration over which a tract would be available for use by wildlife for a given habitat function. The calculations were performed for those functional values which would be produced

both (1) during and immediately subsequent to disposal operations, and (2) after the initial draw-down of the area is complete. The following factors were then used to recognize the quality of a habitat or the scarcity of that habitat within the region:

- * A factor of 1.0 was applied for typical bare ground nesting, wetland nesting, shorebird feeding and waterfowl feeding habitats.
- * A factor of 2.0 was applied to the detrital function of Spartina marshes to reflect the importance of that function as the base of the estuarine and nearshore food webs. The sites affected are those in Disposal Area 14A and those adjacent to the existing confined disposal facilities.
- * A factor of 0.5 was applied in recognition of the lower quality of 78 acres of existing previously impacted (lower value) wetlands (Baccharis halimifolia dominated) at Disposal Area 14A. This habitat provides a variety of minor benefits such as shorebird feeding, waterfowl nesting and waterfowl feeding. To simplify calculations, these functions were combined and expressed as shorebird feeding.
- * A factor of 1.0 was applied to Spartina and other high value wetlands to reflect the importance of that vegetation to fishery resources.
- * A factor of 0.5 was applied to moderate and low value wetlands to reflect the reduced value of that vegetation to fishery resources.

G.3.05 Table 2 shows a sample calculation. The culmination of these analyses are numbers which express the value of a particular disposal site for a certain wildlife function. That number is called a Habitat Unit (HU) since it represents the amount of a certain habitat which a site produces. The different categories of functional values can be combined into a single number to represent all wildlife values of that disposal area. Table 3 displays the functional habitat values which the various disposal areas have under the Without Project Condition.

G.3.06 The analysis of habitat units revealed that the diking and use of Disposal Area 14A would result in a decrease in the site's wildlife functional value from a level of 1018 HUs to a level of 177 HUs, for a loss of 841 HUs. Miscellaneous disposal area management operations would result in an additional loss of 18 HUs in South Carolina and 9 HUs in Georgia. Replacement of

TABLE 2

SAMPLE CALCULATION OF HABITAT VALUE

AREA 12B
WITHOUT PROJECT CONDITIONS
SHOREBIRD FEEDING HABITAT

<u>ITEM</u>	<u>GIVEN/ FACTOR</u>	<u>CALCULATED VALUE</u>
DISPOSAL AREA	12B	
TOTAL SIZE (ACRES)	710	
AREA WITHIN DIKES (ACRES)	692	
PERCENTAGE INUNDATED	90	
AVAILABLE ACRES ($692 * 0.90$)		623
ACRES USED FOR SHOREBIRD		
FEEDING - DRYING	98	
ACRES USED FOR WATERFOWL		
FEEDING - DRYING	0	
ACRES USED FOR SHOREBIRD FEEDING		
DURING DREDGING ($623 - 98 - 0$)		525
AVAILABILITY OF FEEDING HABITAT		
DURING DREDGING EVENTS (MONTHS)	1	
ACRES USED FOR SHOREBIRD		
FEEDING - DREDGING ($525 * 1/12$)		44
AVAILABILITY OF FEEDING HABITAT		
DURING DRYING (MONTHS)	2	
ACRES USED FOR SHOREBIRD		
FEEDING - DRYING ($98 * 2/12$)		16
DISPOSAL EVENTS/YEAR	1.5	
ACRES USED FOR SHOREBIRD		
FEEDING/YEAR ($(44 + 16) * 1.5$)		90
DURATION OF SHOREBIRD FEEDING		
NON-DREDGING (MONTHS)	3	
ACRES USED FOR SHOREBIRD		
FEEDING - NON-DREDGING ($98 * 3/12$)		25
TOTAL ACRES OF SHOREBIRD		
FEEDING HABITAT ($90 + 25$)		115
HABITAT SUITABILITY FACTOR	1.0	
TOTAL SHOREBIRD FEEDING		
HABITAT UNITS ($115 * 1.0$)		115

TABLE 3

EVALUATION OF HABITAT FUNCTIONAL VALUES
 AT
 SOUTH CAROLINA
 CONFINED DISPOSAL FACILITIES
 UNDER WITHOUT PROJECT CONDITIONS
 (IN HABITAT UNITS)

DISPOSAL AREA	BARE GROUND NESTING	WETLAND NESTING	SHOREBIRD FEEDING	WATERFOWL FEEDING	DETRITAL EXPORT/ FISHERIES	TOTAL
12A	13	59	150	47	---	268
12B	2	24	115	12	---	154
13A	--	--	75	6	---	81
13B	--	68	72	65	---	205
14A	--	153	127	263	229/246	1,018
14B	--	26	68	27	---	121
J/O	--	53	96	18	---	166
TOTAL	15	383	702	438	229/246	2,012

those losses (865 HUs in South Carolina comprised of 197 acres of high value wetlands and 118 acres of low/moderate value wetlands; and 9 HUs in Georgia comprised of 3 acres of high value wetlands) is, therefore, the mitigation goal.

G.3.07 Strategy 3 alone was found to produce insufficient environmental benefits to adequately restore the habitat values which would be lost by diking Disposal Area 14A and the miscellaneous disposal area operations, as a total of only 1,614 HUs would be produced from the entire middle harbor disposal area complex. That amount is 422 HUs below that experienced in the Without Project Conditions. Designs were then developed using the most highly valuable general management options for inclusion as additional mitigation features. Various design options were evaluated for those general management options and those designs are described elsewhere in this EIS. The best designs consisted of the following features:

- a. Clearing of upland areas adjacent to diked disposal sites for use by bare ground nesting species. A 26-acre site located oceanward of the dikes at the Jones/Oysterbed Island Disposal Area was selected. Maintenance of the site may include unconfined disposal of dredged material to ensure suitable material for nesting exists on the surface of the site.
- b. Construction and maintenance of isolated nesting mounds within the confined disposal areas. A design was selected for two islands in each of the following CDFs: Disposal Area 12A, 12B, 13A, 13B, 14A, 14B, and Jones/Oysterbed Island. The islands would have a 1-acre crest, which would be located at the same elevation as the surrounding dikes. The islands would be located near, but separated from the disposal area dikes. The exact location of the mounds would be determined by the Corps.
- c. Construction and maintenance of a nearshore island located oceanward of the Turtle Island Wildlife Management Area. The area would be constructed using open water placement of dredged material obtained from or adjacent to the alignment of the navigation channel. The island would have at least a 2.0 acre crest located at +14 feet MLW. Due to the island's sloping sides, at elevation +10 feet MLW the island would be 6.8 acres.
- d. Restoration/creation or protection of 25 acres of tidal wetlands in South Carolina. The SC DHEC-OCRM would select feasible sites in the future and identify either (1) construction actions necessary to improve/create wetlands at the site, or (2) measures which would be necessary to adequately protect the site from future development. The SC DHEC-OCRM would administer an escrow account established by the local sponsor or its designee to accomplish the necessary construction and acquisition.

e. Construction of a second water control structure at an existing 228-acre impoundment within the Savannah National Wildlife Refuge. The second structure would generally be open to all tidal flows, thereby providing a constant connection between the impounded water and the adjacent tidal waters. Establishing this connection would result in a continual flushing of the impoundment, thereby substantially improving its water quality and making available the shallow areas to fish for feeding and spawning. The entire aquatic ecosystem at the impoundment would benefit from the increased flow and the action would directly benefit fishery resources.

G.3.08 The following factors were applied in the development of those new management options to recognize the quality of the habitat produced and/or the scarcity of that habitat within the region:

- * A factor of 1.0 was applied to bare upland areas connected to diked disposal areas for their value to bare ground nesting species. A site would produce valuable habitat, but their accessibility to terrestrial predators would keep such an area from being considered "prime" nesting habitat.
- * A factor of 2.5 was applied to small isolated islands within the disposal areas for bare ground nesting in recognition of their scarcity and high habitat value due to their traditionally high nesting success ratios. These islands would produce prime nesting habitat for those migratory species, something not readily found in this region.
- * A factor of 4.0 was applied to high areas at offshore bird islands for use in shorebird (bare ground) nesting. This factor is in recognition of the scarcity and high habitat value of such areas due to the isolated nature of the sites, which traditionally lead to high nesting success ratios. These islands would provide prime nesting habitat - which is rarely found in this region -- for a number of migratory bird species.
- * A factor of 3.0 was applied to intertidal portions of offshore bird islands for shorebird feeding in recognition of the scarcity and high value of such habitat due to the isolated nature of the sites.

* A factor of 4.0 was applied to intertidal portions of offshore bird islands for shorebird feeding in recognition of the expected winter use of such areas by the endangered piping plover. That species winters in the area, and such isolated feeding and resting sites have become increasingly rare. Suitable habitat is one of the factors identified as limiting the recovery of that species.

* A factor of 1.0 was applied to wetlands restored/created or protected to account for the detrital function of those marshes and to reflect the importance of that function as the base of the estuarine and nearshore food webs.

* A factor of 1.0 was applied to wetlands restored/created or protected to account for wetland functions which would directly benefit fishery resources.

* A factor of 0.95 was applied to impounded waters where tidal flushing and daily access with adjacent water bodies would be established for their value to fishery resources. These improvements would significantly enhance the site's value for fisheries. However, the factor was set at <1 to reflect the unavailability of a small portion of the site to fishery resources.

G.3.09 When Strategy 3 is combined with the five most valuable general management options, a Mitigation Plan is produced which adequately replaces the habitat values which would be lost through the diking of Disposal Area 14A and miscellaneous disposal area operations in South Carolina. Table 4 shows the habitat values at Disposal Area 14A and those which would be lost in South Carolina. Table 5 shows the habitat values which would be produced by the various components of the Mitigation Plan.

G.4.00 DETAILS OF MITIGATION PLAN.

G.4.01 Plan Description. The plan is based on Strategy 3; employing rotating disposal area use schedules of 2 years, with modifications for bird use. In this scenario, each disposal area would be available for use in disposal operations for two years, followed by two years of drying. A 26-acre bare ground nesting area would be cleared and maintained on high ground outside the dike at the Jones/Oysterbed Island Disposal Area for use by colonial nesting birds (Figure 2). Maintenance activities would include devegetation and possible additional placement of dredged material through unconfined disposal on the upland site. Two

TABLE 4

HABITAT VALUES AT DISPOSAL AREA 14A
AND
LOSSES AT OTHER SC DISPOSAL AREAS
(IN HABITAT UNITS)

OPTION	BARE GROUND NESTING	WETLAND NESTING	SHOREBIRD FEEDING	WATERFOWL FEEDING	DETRITAL EXPORT/ FISHERIES	TOTAL
CURRENT IN AREA 14A	--	153	127	263	229/246	1018
AREA 14A DIKED	--	43	106	27	---	177
LOSS AT AREA 14A	--	110	21	236	229/246	841
OTHER LOSSES AT SC AREAS	--	---	---	---	12/6	18

NOTE: The habitat functional values currently in Disposal Area 14A (1018 HUs) and the losses at other Project disposal areas in South Carolina (18 HUs) are included in Strategy 1: Without Project Condition at CDF's.

TABLE 5

ENVIRONMENTAL BENEFITS
FOR ALTERNATE MITIGATION ACTIONS
IN SOUTH CAROLINA
(IN HABITAT UNITS)

OPTION	BARE GROUND NESTING	WETLAND NESTING	SHOREBIRD FEEDING	WATERFOWL FEEDING	DETRITAL EXPORT/ FISHERY	TOTAL
STRATEGY 1 W/O PROJECT AT CDF'S	15	383	702	438	229/246 12/6	2,031
STRATEGY 3	--	450	659	505	---	1,614
UPLAND NESTING SITE	26	---	---	---	---	26
NESTING ISLANDS	28	---	---	---	---	28
NEARSHORE BIRD ISLAND	20	---	81	---	---	101
RESTORATION /CREATION	--	---	---	---	25/25	50
FISHERIES ENHANCEMENT	--	---	---	---	0/217	217
MITIGATION TOTAL	74	450	740	505	25/242	2,036
TOTAL HABITAT CHANGES	59	67	38	67	-216/-10	5

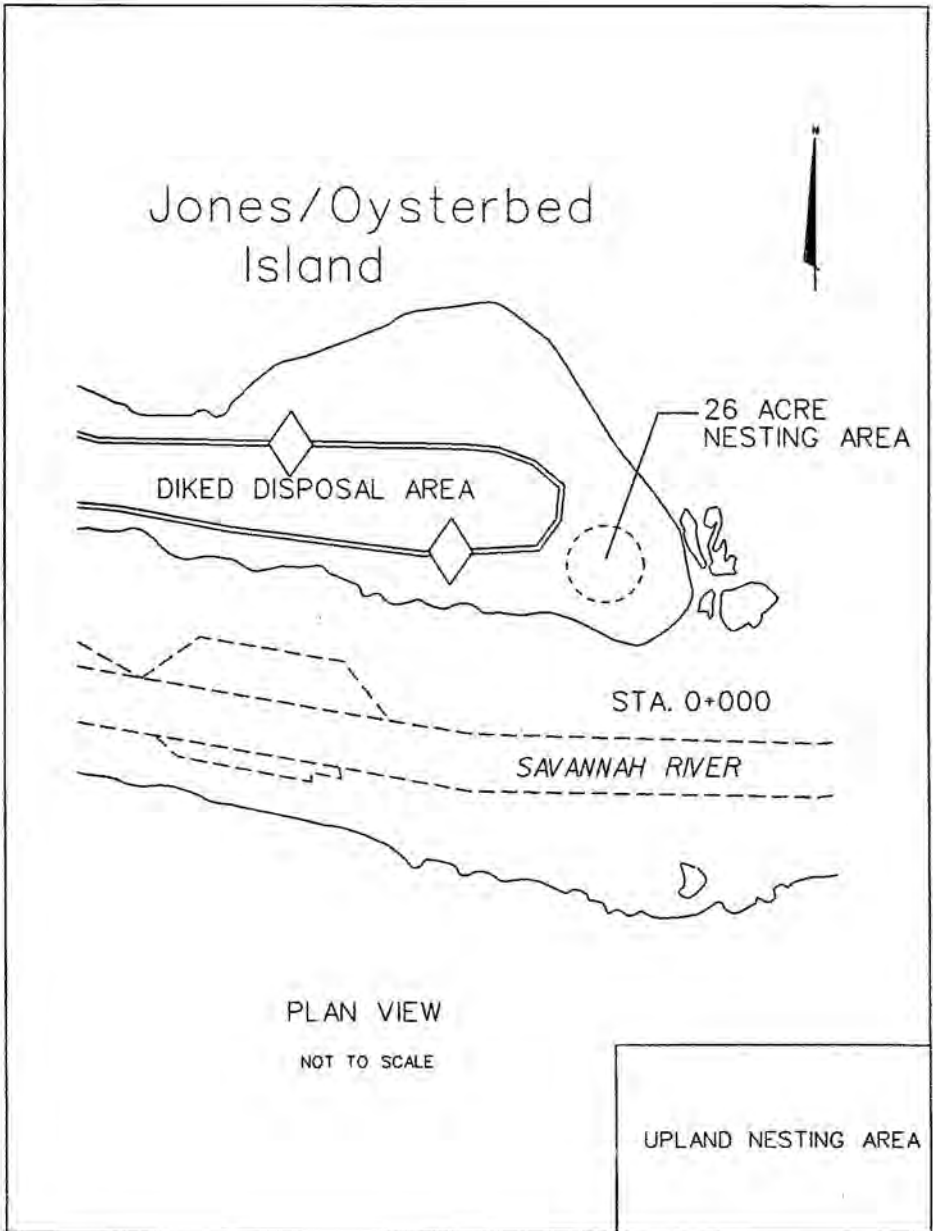


FIGURE 2

1.0-acre isolated nesting islands would be constructed and maintained in each disposal area in the rotation program for use by nesting migratory shorebirds (Figure 3). The islands would be constructed at the height of the surrounding dikes. The island crest would be raised when the adjacent dikes are raised to ensure the nesting area cannot be flooded during disposal operations. An island would be constructed and maintained offshore of the Turtle Island Wildlife Management Area (Figure 4). Benthic surveys would be performed during the final design to ensure that no rare benthic communities exist at the proposed site. The island would be maintained in a manner so that it continued isolated from Turtle Island and the north jetty. This bare ground bird nesting area would be constructed using open water placement of dredged material obtained from within, below, or adjacent to the navigation channel. The island's crown would be located at Elevation +14 feet MLW +/- 1 foot and have a minimum size of 2.0 acres at that elevation. Additional dredged material would be placed on the island when the area above EL 10 MLW has been reduced in size by 50 percent. Twenty-five acres of tidal wetlands would be restored/created/ protected in South Carolina. The SC DHEC-OCRM would select feasible sites in the future and identify either (1) construction actions necessary to improve/create wetlands at the site, and/or (2) measures which would be necessary to adequately protect the site from future development. The SC DHEC-OCRM would administer an escrow account established by the local sponsor or its designee to accomplish the necessary construction and acquisition. A second water control structure would be constructed at an existing 228-acre impoundment within the Savannah National Wildlife Refuge. The second structure would allow water exchange generally throughout the tidal cycle, thereby providing a constant connection between the impounded water and the adjacent tidal waters.

G.4.02 Confined disposal areas would be managed during each scheduled 2-year use period for the most environmentally appropriate outcome following each disposal operation. Dredging needs would have top priority concerning the scheduling of disposal events, while management of the disposal areas for wildlife would be a secondary consideration. The goal would be to have at least one disposal area each year functioning for each of the following four major categories of bird use: (1) spring migrants, (2) summer nesting shorebirds, (3) fall migrants, and (4) wintering shorebirds and waterfowl. Note that a disposal area may provide more than one function within a given year. For example, an area held wet for wintering shorebirds and waterfowl could be slowly dried during the spring for spring migrants.

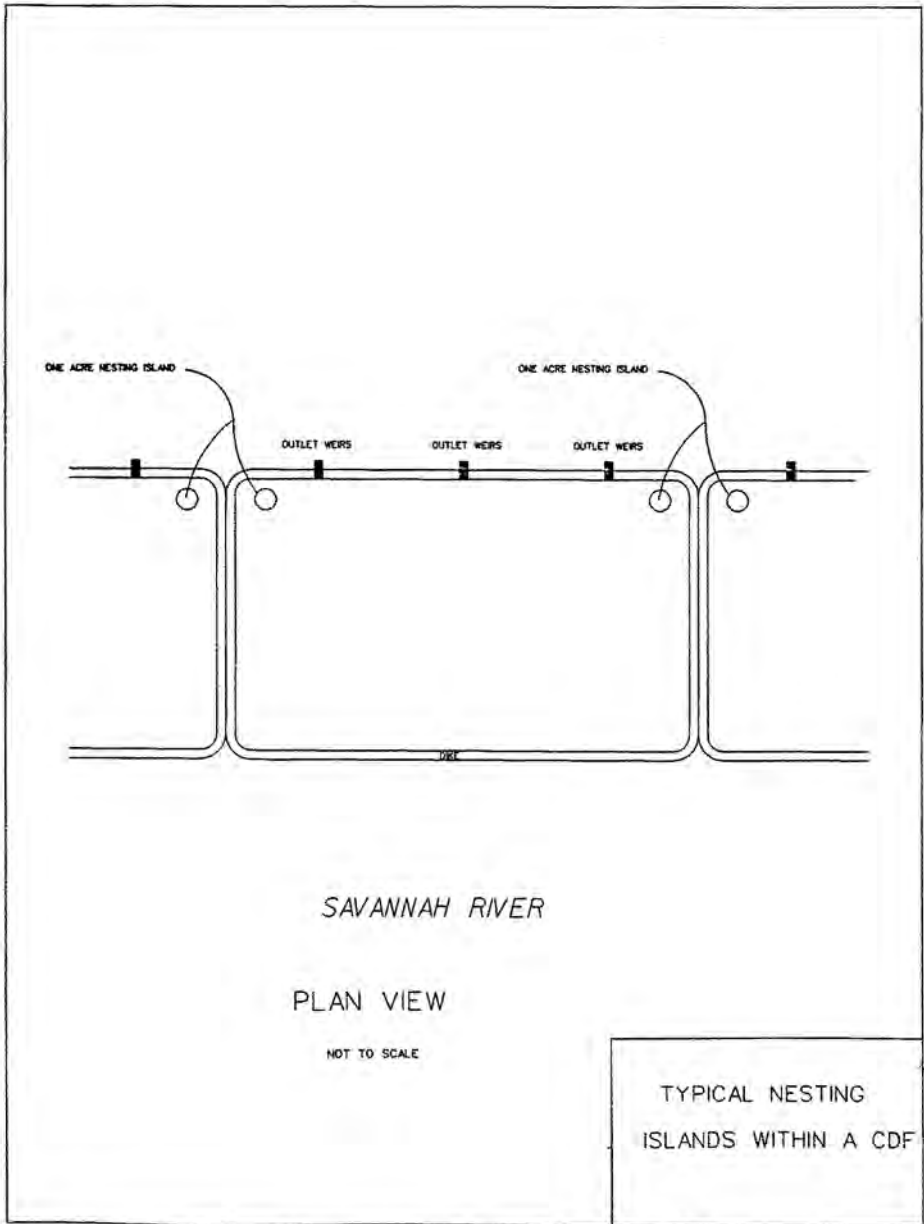


FIGURE 3

G.4.03 Nesting season constraints. Special considerations would apply to disposal operations taking place during the nesting season. Sand mounds would be constructed inside confined disposal areas for use by nesting birds such as least terns, Wilson's plovers, killdeer and nighthawks. Portions of these or other mounds would be constructed for use by black-necked stilts. Two bird nesting mounds would be constructed and maintained in the following CDFs in the rotational program: Disposal Areas 12A, 12B, 13A, 13B, 14A, and 14B. Each mound would have an area above the potential flood height of 1 acre. The crest of the mounds would be constructed above the height of the flooded pool to avoid inundation during disposal operations. Once these mounds are in place, it would be judged beneficial to flood the surrounding areas in the spring and early summer for both protection of the mounds from predators and stimulation of invertebrate prey populations.

G.4.04 Compliance with the Migratory Bird Treaty Act (MBTA). The middle and lower harbor (South Carolina) CDFs would be managed to produce habitat for endemic and migratory waterfowl and shorebirds. Development and maintenance of wildlife habitat at the CDFs, including interior nesting mounds, would be integrated into normal use of the sites for disposal of dredged materials. This integration would occur throughout the year to include the spring nesting season, the summer rearing season, and the fall and winter migratory periods. Additional habitat would be created through the establishment of a nearshore island off Turtle Island. This habitat would be maintained through the periodic placement of additional dredged materials on the island. Wildlife habitat would also result from the creation and maintenance of an upland nesting area outside the dike at the Jones/Oysterbed Disposal Area.

G.4.05 Multiple use of the sites (dredged material disposal and wildlife habitat purposes) could result in both beneficial and adverse impacts to migratory birds. The flooding of a disposal site as part of disposal operations would provide isolation to the internal nesting mounds, while also possibly destroying nests, eggs, or young that have nested on the floor and lower portions of the disposal site. The loss of these birds may occur incidental to the disposal operations which increase the site's overall wildlife habitat value. The "take" provisions of the MBTA are based on the "net" impact for a given action. Since the purpose of the wildlife habitat production component of the Mitigation Plan is to create habitat for endemic and migratory waterfowl and shorebirds, the beneficial aspects of the integrated use and management of the CDFs far outweigh the adverse impacts on possible nesting migratory bird species. Implementation of the Mitigation Plan as described in this EIS -- and concurrence in the Plan by the South Carolina Department of

Natural Resources and the US Fish and Wildlife Service -- would be deemed compliance with the MBTA and similar South Carolina laws, and no further clearances related to migratory birds would be necessary to implement the actions described in this EIS.

G.4.06 Application of the Plan. Management of a disposal area for birds would depend on the month in which the disposal operation is scheduled to end. Management options available after a disposal operation ended would be chosen based on the situation in other disposal areas and the availability of habitat for each major category of bird use (spring migrants, summer nesting shorebirds, fall migrants, and wintering shorebirds and waterfowl). Maintenance of a constant water level within a disposal area may not be possible for extended periods due to the natural effects of evaporation and infiltration. However, discharges from the site through the weirs and underdrains could be stopped to retain as much water as possible. The disposal operation would be managed to ensure the successful attainment of the scheduled management scenario. This would include management of weir discharges to ensure a full pool upon completion of the disposal operation. Since water would be held in the disposal areas for longer periods than presently occurs, there is a potential for increased mosquito breeding. To address that possibility, purple martin nesting houses and bat houses would be installed at each of the disposal areas included in the rotation program to provide a biological control for that situation. Table 6 displays the actions which would be taken after completion of disposal operations. The critical factor used to decide which management technique would be implemented is the date when disposal operations are complete. If District biologists believe it would be beneficial to use a management technique which is different than that prescribed in Table 6, approval from the US FWS would be required prior to implementation.

TABLE 6

MIDDLE AND LOWER HARBOR
(SOUTH CAROLINA)
CONFINED DISPOSAL FACILITY
MANAGEMENT TECHNIQUE

Date Disposal Operation Ends	Proposed Management Technique
1 Jan - 15 Mar	Hold water level as high as possible. Beneficial to waterfowl and wintering shorebirds. Draw down in the spring for migrating shorebirds.
15 Mar - 15 Jul	<u>Option 1.</u> Hold water as protection for nesting terns, plovers, nighthawks, and in preparation for fall draw down for fall migrating shorebirds. <u>Option 2.</u> Draw water down slowly for spring migrating shorebirds and nesting black-necked stilts and vegetation growth if flooded later for wintering waterfowl.
15 Jul - 15 Nov	<u>Option 1.</u> Draw down slowly for fall migrating shorebirds. <u>Option 2.</u> Hold for wintering waterfowl and shorebirds.
15 Nov - 31 Dec	Hold water level as high as possible for wintering waterfowl and shorebirds, and in preparation for spring draw down for spring migrating shorebirds.

APPENDIX H

DESCRIPTION OF WORK PERFORMED
AT THE CONFINED DISPOSAL FACILITIES
BY THE LOCAL SPONSOR
FOR THE
SAVANNAH HARBOR NAVIGATION PROJECT

DESCRIPTION OF WORK PERFORMED
AT THE CONFINED DISPOSAL FACILITIES
BY THE LOCAL SPONSOR
FOR THE
SAVANNAH HARBOR NAVIGATION PROJECT

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DESCRIPTION OF WORK PERFORMED
AT THE CONFINED DISPOSAL FACILITIES
BY THE LOCAL SPONSOR
FOR THE
SAVANNAH HARBOR NAVIGATION PROJECT

H.1.00 INTRODUCTION.

H.1.01 The laws which govern the establishment and continued operation of Federally authorized navigation projects require a non-Federal sponsor to share in the responsibilities of those projects. Cost sharing is required during the evaluation of the feasibility of those projects and in their construction. The non-Federal sponsor also has responsibilities during the operational phase of those projects. One of the sponsor's major responsibilities during that period is the provision of adequate disposal areas for the deposition of material dredged from the navigation channel. Many non-Federal sponsors across the country have the Corps to perform the local sponsor work on a reimbursable basis. Chatham County, the local sponsor for the Savannah Harbor Navigation Project, currently performs all local sponsor responsibilities itself and views its relationship with the Corps as a partnership. The Georgia Department of Transportation (GA DOT) assists Chatham County as they fulfill their responsibilities.

H.2.00 DIKE RAISING.

H.2.01 Design. The dikes surrounding the Savannah Harbor disposal areas periodically require raising to higher elevations to continue to contain dredged materials. The top two feet of dike are typically reserved for a freeboard zone, serving as a margin of safety to accommodate contingencies which may develop during use of a site. The next two feet are reserved for temporary storage of the water which is used to transport the dredged material to the disposal site. Water is ponded in the disposal area to allow time for the dredged material to settle out of the slurry which is pumped to the site. The storage volume below the ponded water zone is used to contain dredged material. Dikes are to be designed to allow retention of ponded water for extended periods of time. This allows water to be held to within two feet of the dike crest for the duration of a disposal operation plus additional time for draining. The large ponding volume and long retention time may be required to meet suspended solids and/or dissolved oxygen restrictions in the weir discharges. The dikes may also be required to hold ponded water for extended periods after disposal operations cease in a particular disposal area to meet wildlife-related mitigation commitments.

H.2.02 Approximately every 5 years, the disposal areas are mapped and the available capacity is computed from cross-sections generated from the contour maps. Savannah District's Operations Division provides the local sponsor with information concerning the quantity of material to be deposited in each disposal area in the near future. This data is used in a simple modeling technique which includes the swelling of the insitu material (sand and/or silt) and compensates for drying. The available capacity is simply accounted for by subtracting the volume consumed by each dredging event. Likewise, capacity is added when the dikes are raised. A sample of the computations is shown on the following page. When the ponded water zone is forecast to invade the freeboard zone, the need for raising the dikes is triggered. The design process can be lengthy, so the process is begun prior to the actual need of the dike raising.

H.2.03 The dikes forming the disposal areas are built over very soft soils. Early dike construction consisted more or less of a trial and error method. Soil was piled up with a dragline or hauled in to form a dike. The soft marsh soils were often used to form the initial embankment. If the dike failed or collapsed, more soil was piled up until the desired dike height was reached.

H.2.04 Incorporation of high strength geosynthetics, such as plastic fabrics and geogrids, into the embankment as reinforcement has allowed the design and construction of significantly higher dikes. These materials provide strength to the embankment similar to the way reinforcing steel increases the strength of concrete. They also increase the strength of the underlying soil so that they can then support the use of trucks to haul borrow material over soft soils.

H.2.05 When dikes are raised only two to four feet, as required for some dredging events, the design process does not include an in-depth geotechnical analysis and fabric is not used. However, when dikes are raised four to six feet, a geotechnical analysis is performed. If adequate soil boring records are not on file, new borings are taken. A topographical survey is made to identify the existing dike cross-sections around the perimeter of the area. This data is used to design the new dike cross-section and compute the volume of fill which will be required.

SAMPLE OF AREA CAPACITY COMPUTATIONS

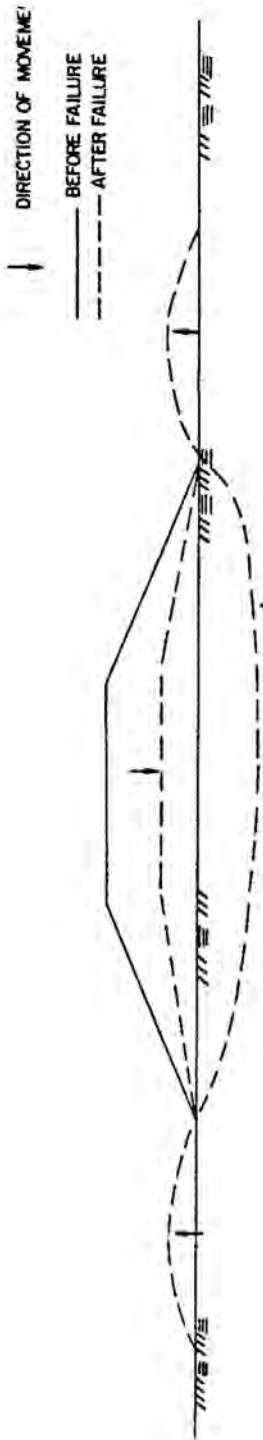
AREA 12A AREA = 95R ACRES PERIMETER = 28,420 FEET

NOTES:1) ALL VOLUMES IN CUBIC YARDS

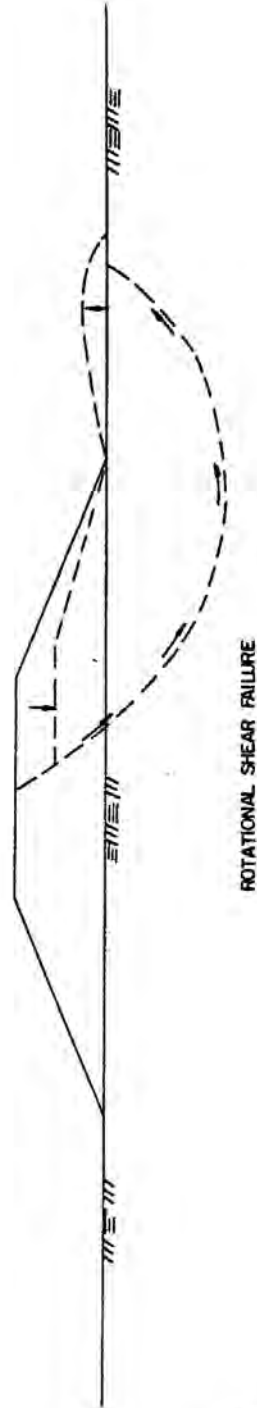
2)* VOLUMES IN THE AREA ARE IN ADDITION TO 2' FREEBOARD (3,091,147 CUBIC YARDS FOR AREA 12A)
 3)* CONSOLIDATION DUE TO UNDERDRAINS & DITCHING OFFSET THE SWELL FACTOR (COL4=COL1-COL2)
 4)* REQUIRED VOLUME IN AREA INCLUDES THE DREDGED MATERIAL WITH APPLIED SWELL FACTOR(S) AND PONDED WATER (2' MAXIMUM)
 COL3=(COL2 X (1-COL5))1.5 + [COL2 X COL5]1.2 + [COL2/0.1 (WHERE COL2/0.1=PONDED WATER WHICH IS 3,091,147 MAXIMUM)

DATE BEG	DATE END	DESCRIPTION OF OPERATION	STATION	PRE DREDGE AVAILABLE VOL IN AREA*	COL1 DREDGED	COL2 IN SITU VOL DREDGED	COL3 REQ. VOLUME IN AREA**	COL4 POST DREDGING AVAIL VOL. **	EST % SAND	CONTRACTOR	COST PER C.Y. ‡	COMMENTS
6/79		COUNTY PURCHASES 2 REAR PARCELS IN AREA 12 FROM HASKELL & TAYLOR WITH DOT FUNDS								5 MERRITT		
6/80		MAINT DREDGING	70+000			4,055,959				ANSLEY&SUT	\$87,598	
7/81		DOT PURCHASES 2 FRONT PARCELS IN AREA 12 FROM HASKELL & TAYLOR;COUNTY DERDS REAR PARCELS TO DOT								SOUTHERN		
4/82		DIKE CONSTRUCTION								SOUTHERN		
6/82	11/82	MAINT DREDGING SB	0+500			4,038,456				HIGG/BUCH	\$110,065	
10/83	10/84	MAINT DREDGING	70+000	112+500		4,598,594				HIGG/BUCH	\$708,627	
1/84		DIKE CONSTRUCTIONRAISE SCREVEN FERRY RD TO ELEV 32'MLW								PROSPERITY		
9/84		DIKE CONSTRUCTIONRAISE REAR DIKE TO ELEV 26'MLW								BEAN	\$3,425,000	
10/85	2/86	MAINT DREDGING SB	0+500	13+300		3,530,109				BEAN		
8/86		DIKE CONSTRUCTIONRAISE FRONT TO 36'MLW;LT 34'MLW;REAR 32'MLW;HYDRAULIC FILL FROM 2A								MC ANDERSON	\$23,803	
1/87	3/87	MAINT DREDGING SB	0+983	9+000		886,287				ATKINSON	\$57,275	
6/87		DIKE CONSTRUCTIONBUILD SUBCOMPARTMENT FOR WIDENER PROJECT				1,946,791				APFOLTER	\$183,360	
8/87	12/87	MAINT DREDGING SB	0+500	8+500						MC ANDERSON		
6/88		DIKE CONSTRUCTIONRAISE SCREVEN FERRY RD TO ELEV 36'MLW								ATKINSON		
10/88	12/88	VEGETATION								0		
12/88	3/89	MAINT DREDGING SB	0+500	13+300		10,246,250		7,988,533	6,981,326	0	0.91	
11/89	3/90	MAINT DREDGING	30+000	66+000		6,981,326	3,264,924	4,852,572	5,783,078	10	0.22	
1/90	3/90	MAINT DREDGING SB	0+500	13+300		6,783,078	865,155	4,373,880	4,787,923	0	0.22	
6/90	8/90	MAINT DREDGING SB	6+000	7+300		4,927,923	262,310	3,016,565	4,665,613	0	1.09	
11/90	12/90	MAINT DREDGING	55+000	79+000		4,665,613	494,025	3,817,364	4,171,588	10	0.66	
11/90	12/90	MAINT DRG FIGHTB	67+500	70+000		4,171,588	233,359	2,683,629	3,938,229	0	1.09	
2/91	2/91	MAINT DREDGING	58+150	60+000		3,938,229	20,063	230,123	3,918,166	10	2.08	
9/91	3/92	WIDENER PROJ	89+310	79+015		3,918,165	1,186,324			90 AMERICAN		IN SUBAREA

FIGURE 1



BEARING CAPACITY FAILURE



ROTATIONAL SHEAR FAILURE

CRITICAL FAILURE MODES FOR ANALYSIS OF EMBANKMENTS OVER SOFT SOILS

FIGURE 2

H.2.06 The design of embankments over soft soils is complex. Incorporation of the geosynthetics into an embankment requires evaluation of several failure modes of the embankment/geosynthetic/foundation soil system. The two failure modes which affect the design most are shown in the drawing on the following pages. These failure modes are summarized as follows:

- (1) Bearing Capacity - Prevention of the embankment from sinking into the soft soils.
- (2) Rotational Stability - Prevention of a rotational shear through the embankment and foundation soils.

H.2.07 Analysis of the failure modes determines the combination of side slopes, berms and reinforcements possible for a particular site. An economic analysis is then performed to determine the optimum combination of embankment configuration and reinforcement.

H.2.08 Dike Construction. Contract plans and specifications for dike improvements are advertised by Chatham County, who then usually awards the contract to the lowest responsive bidder. GA DOT assists Chatham County with materials testing, construction supervision, settling disputes, supplemental agreements and other actions which may be required to ensure completion of the specific construction project.

H.2.09 Dike construction usually incorporates the use of geosynthetic fabrics. Installation of the fabric involves the use of pickup trucks, semi-trucks which deliver the fabric, four-wheel all-terrain vehicles, generators, field sewing machines and several people. Each layer of fabric is covered with a foot of earth, which is delivered from a borrow site by truck or self-loading pans and then spread to a uniform thickness with a small bulldozer. The embankment is raised in one-foot increments until the final elevation is reached. There are no compaction requirements. Observations made during previous construction projects at the disposal areas indicate that continual movement of equipment compacts the material to a 95 percent level. The material is mostly sand, with the top 18 inches consisting of a mixture of 75 percent sand and 25 percent silt. A higher percentage of silt in the riding surface allows vehicles to move in both wet and dry conditions.

H.2.10 Borrow sites for dike construction work have, to date, been found within the diked disposal areas. Deposits of sand near the dredge discharge head locations are identified in the project plans as being available for use by the contractor. The recently completed Savannah Harbor Deepening Project provided

large quantities of sand suitable for dike construction. Dump trucks and self-loading pans have, historically, been used to transport the sand to the construction sites. However, the limited period during which that equipment can presently operate within a disposal site before its next scheduled use severely restricts the use of those sites. A lengthy drying period is typically required after a disposal operation is complete before the sediments deposited on the floor of the disposal area have the bearing capacity to support heavy earth-moving equipment. With no change in disposal practices or disposal area management strategies, offsite material will likely be required in the future to provide the fill material needed for these dike improvements. Rotational use of the confined disposal areas and installation of underdrains would significantly increase the availability of the onsite material.

H.2.11 A method of obtaining onsite borrow material, called the Crust Method, involves reclamation of silty material from within the disposal area. After a disposal area's top 8 to 12 inches has dried, a small bulldozer can push up windrows along which small self-loading pans can travel and pick up the dried material which is then transported to the site of the new dike construction. The drying of the area is critical and is accomplished through ditching and/or installation of underdrain pipes. The Crust Method has been successfully implemented in Areas 12B and 13A. Future use of this process would increase the beneficial uses of materials deposited in the disposal areas.

H.2.12 The disposal areas are located on the property of several different landowners. Some property owners have questioned whether material which has been deposited on their land can or should be removed to other properties. If one views the activities performed at a specific disposal site in a very narrow context, it is clear that material will be removed from specific tracts at some point in time. However, if one views those same actions over time and in the larger context of activities performed at the adjacent disposal areas as a group, one concludes that (1) the material which is removed from a tract is still used to support the purpose of the easement obtained on the property, i.e. dredged material disposal, and (2) material which is removed will be replaced during subsequent disposal operations. Material used to raise dikes may be obtained from three sources, (1) the disposal area which is actually being improved, (2) an adjacent disposal area, or (3) brought in from offsite if suitable borrow material is not readily available within the disposal areas at the time it is needed. When there is a need for construction material at one of the disposal areas, the preference is to use readily available material from one of the areas. To minimize transportation costs, obtaining material from the closest source is preferable. Over time, the effect of new dike improvements on the properties produces a net gain of dredged materials to the property owner.

H.3.00 MAINTENANCE.

H.3.01 Overview. The diked disposal areas are to be maintained in a manner so that they will be suitable for dredged material disposal operations. This includes having the weirs in working order, roadways around the dike passable and well maintained, and sufficient capacity within the site for efficient placement of dredged material and settlement of suspended solids, and maintenance of the stability of the dikes through erosion control measures. Prior to commencement of deposition of dredged material, the dredge contractor will inspect the site and agree to the suitability of the dikes for his use. After that certification, the responsibility for the condition of the dikes rests with the dredge contractor for the period of the disposal operation. Many tasks are performed in an effort to maintain the diked disposal areas in a safe and usable manner. The following paragraphs describe the purpose, frequency and type of equipment which is commonly used to perform each maintenance item.

H.3.02 Weir Replacements. Weirs are used during dredging events to remove the water which has transported the sediment through the pipeline to the disposal site. The water is discharged through the weirs after it has settled sufficiently to meet water quality guidelines. Between dredging events, the weirs are used to remove rain water and water drained from the area through ditches. Logically, weirs are placed at the lowest elevations of the floor of the disposal area. The settling patterns of the solids in the dredged slurry result in the formation of a sloped surface, with the highest point being at the location of the discharge head.

H.3.03 The weirs are generally 16 to 20 feet tall. The top of the weir is near the elevation of the top of the adjacent dike. The weir is accessed via a wooden catwalk elevated to the same height as the top of the weir and is connected to the dike directly behind the weir.

H.3.04 Weirs are replaced as needed, but the work is usually done at the same time as a dike raising contract. The weirs are installed with the inlet invert approximately four feet below the elevation of the adjacent floor of the disposal area. This allows most ditches to drain through the weirs. This criteria is not always possible, especially, when the floor of the disposal area is not more than four feet higher than the elevation of the natural ground at the outlet end of the discharge pipe behind the weir.

H.3.05 New weirs are bolted to concrete footings supported by four 12-inch diameter timber piles. The friction bearing that develops along the length of the pile is more effective than the end bearing in supporting the weir. This foundation aides in maintaining the weir in a plumb position. Previous use of swamp anchor screws proved to be inadequate.

H.3.06 Water flowing into the weir is transported through the dike in a pipe; typically a 48-inch diameter plastic pipe. The plastic pipe is thermally butt-fused at the joints along its length. Chatham County had previously used corrugated metal pipe joined by bands, but the bands had a repeated history of failure, resulting in cave-ins of the dike. The plastic pipe has experienced very few failures at the joints. The 48-inch diameter pipe is much larger than needed for hydraulic purposes to remove the discharged water. However, the additional size provides a margin of safety desirable for this type of drainage application. The outlet end of the discharge pipe terminates near the toe of the dike's outside slope. The invert elevation of the pipe outlet is either at the same elevation as the marsh or elevated on a support system, such as that shown in the drawing on the following page. A small amount of riprap is placed at the outlet end to dissipate the erosive energy of the discharged water.

H.3.07 In the past, the height of weirs was sometimes increased by simply bolting new sections on the existing weir, thereby allowing continued use of the existing structure and outfall pipe. Recent experience indicates that the wooden stop logs in the face of the weir can fail relatively quickly, resulting in the weir and pipe filling with dredged material. This event prevents removal of the weir. Weirs with inlet inverts more than 8 feet below the elevation of the disposal area floor of the area are nearly impossible to remove due to the excavation through the dredged material which is required to allow personnel to disconnect the weir from the outfall pipe. Outfall pipes at this depth are also difficult to remove due to the large volume of excavation required through the cross-section of the dike. Experience has led to a policy that weirs be replaced when 8 feet of sediment has accumulated at the weir, with the old discharge pipes being plugged and buried. The new replacement weirs and pipes are located in the vicinity of the old weir, usually within 50 feet. Some wetlands (less than 0.1 acres per weir) may be lost during installation of the new discharge pipe, but this loss is compensated for by the natural redevelopment of wetland vegetation at the location of the old discharge pipe.

H.3.08 Equipment used to remove old weirs, plug old pipes and install new weirs and pipes includes long reach excavators, bulldozers, small cranes, and support equipment. The piles are generally driven into the ground with a small pile driver.

WEIR DETAILS

OUTLET END

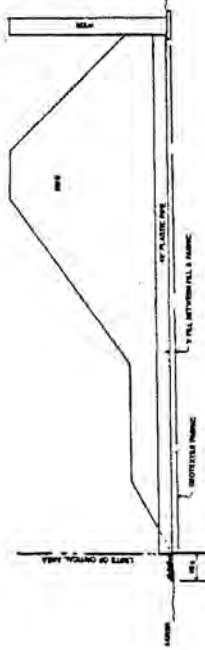
Sheet 11 of 12	GA
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TYPE 1

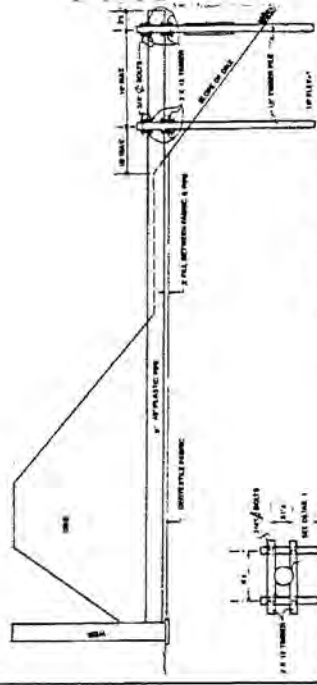
TYPE 2

GENERAL NOTES

1. ALL DIMENSIONS ARE IN FEET. DIMENSIONS SHALL BE IN ACCORDANCE WITH THE REQUIREMENTS OF SECTION 403 OF GA DOT STANDARD SPECIFICATIONS.
2. ALL DIMENSIONS SHALL BE IN ACCORDANCE WITH THE REQUIREMENTS OF THE STANDARD SPECIFICATIONS OF THE STATE OF GEORGIA.
3. ALL DIMENSIONS SHALL BE IN ACCORDANCE WITH THE REQUIREMENTS OF THE STANDARD SPECIFICATIONS OF THE STATE OF GEORGIA.



SEE DETAIL 1 FOR FILL BETWEEN WALL & WEIR



SEE DETAIL 1 FOR FILL BETWEEN WALL & WEIR



DETAIL 1

SEE DETAIL 1

SEE DETAIL 1 FOR FILL BETWEEN WALL & WEIR

SEE DETAIL 1 FOR FILL BETWEEN WALL & WEIR

FIGURE 3

H.3.09 Routine Maintenance. Routine maintenance of the disposal area dikes includes scraping the crest of the dike to improve the riding surface, filling washouts on the slopes of the dikes to maintain the integrity of the dike, excavating drainage ditches along the travelways to direct water away from the roadways, and other actions required to maintain a stable dike. This work is performed on an as needed basis, and is initiated primarily as the result of observations made during field inspections.

H.3.10 Equipment used for these operations include dump trucks, motor graders, bulldozers, excavators and support equipment.

H.3.11 Ditching. The dredge material enters the disposal area in a slurry consisting of 10 to 20 percent solids, with the remainder being water. If the material placed in the disposal areas were dry, maintenance of the areas would be extremely simple. Unfortunately, that is not the case and the water accompanying the solids must also be managed. At the completion of a dredging event, the dredged water is decanted through the weirs at a rate which ensures compliance with the water quality criteria. At that point in time, the floor of the disposal area would be super saturated with water. Removal of the water contained within the deposited sediment is desirable for two reasons: (1) it removes the breeding grounds for salt marsh mosquitoes and (2) it allows a more complete consolidation of the material.

H.3.12 The Chatham County Mosquito Control Commission (CCMCC) excavates shallow (2 feet deep) ditches within the disposal area to drain water near the surface of the area to control the mosquito population. Their work is not part of the local sponsor's responsibility. In the past, CCMCC has been reimbursed by the Corps for this work. However, recent Corps policy changes will result in no further Federal payments to CCMCC for mosquito control beginning in FY97 (October 1996). The local sponsor does benefit from the CCMCC ditching as the improved drainage assists in the material consolidation process.

H.3.13 Chatham County attempts to dry the interior of the disposal areas by ditching and/or installation of perforated underdrain pipes. These ditches are deeper than the one the CCMCC places. All ditches are sloped toward the weirs to allow water to flow to a discharge point. Sump holes are also excavated in the front of each weir following dredging events to initiate the flow of water toward the weir. Excavation of the sumps is usually the first step in the dewatering process.

H.3.14 In previous years, the County has hired a contractor to dig the deeper (6 to 7 feet deep) ditches. The County operates equipment owned by the State to maintain the ditches after those ditches are initially constructed. Prior to the next dredging event, the ditches are filled with dried crust material. This filling prevents deep zones of dredged material from concentrating in the full depth of the ditches.

H.3.15 Equipment used consists primarily of hydraulic rotary ditchers with amphibious undercarriages. Depending on the diameter of the rotary cutter installed on the ditcher, the equipment is able to excavate ditches to 40 inches deep. Deeper ditches are constructed by long reach excavators mounted on amphibious undercarriages or conventional excavators using wooden mats for support.

H.3.16 Underdrains. Chatham County and GA DOT believe that the best way to increase the usable life of the disposal areas is to remove all the water as soon as possible and keep the areas dry. Removal of water from a soil matrix aids in the consolidation process and allows the deposited material to be used as a source of borrow in the crust construction method. The ditching process is the primary tool used to dewater an area. The sponsor has successfully demonstrated that underdrain pipes function as deep ditches in the continual removal of water from the site. The advantage of underdrains is that there their placement results in only a one-time excavation and backfilling cost for a certain drainage capability. The one-time cost of installing the pipe is more economical than multiple (from 3 to 5) cycles of deep ditch excavation and backfilling. Observations conclude that the underdrains drain continuously, with the pipes appearing to run constantly from half to three-fourths full. Flows appear to increase following heavy rains and dredged material disposal operations. The lowest foot of ponded water at the rear of the areas has been observed to exit the area in as little as 2 weeks time. The following two factors lead one to quickly conclude that this drainage is the result of the underdrains since (1) the ponded water is not passing over the weir boards, since the boards are not removed to an elevation which would allow such drainage to occur, and (2) drainage ditches have not yet been constructed since the material is still too soft to support the equipment required for such excavation.

H.3.17 The underdrains accelerate the drying process, thereby enabling machinery to work sooner on the floor of the disposal area to reclaim the dredged material for dike construction. Removal of the deposited material extends the life of the areas by restoring some of the site's previously used storage capacity.

H.3.18 At Savannah, underdrains had been installed in Disposal Areas 12B and 13A. Problems subsequently experienced with the underdrain pipes were primarily associated with the quality of the water discharged into the environment. Records indicate that past discharges were sometimes below state water quality standards for dissolved oxygen at the end of the outfall pipes. State resource agencies have not allowed the use of mixing zones to this point in time. Further analysis of the underdrain water quality was a component of this LTMS. Those investigations are described in Appendix E. Due to concerns about the quality of the discharges, the underdrains in Disposal Areas 12B and 13A which discharge to small tidal creeks draining to Wright River were plugged by the end of 1994.

H.3.19 The local sponsor desires to continue the use of underdrain pipes. Their contribution is deemed essential for extending the useful life of the disposal areas. Currently, the realistic implementation of underdrains is limited to Disposal Areas 2A, 12A, 12B and 13A. Area 13B will be a candidate in the near future. The other areas do not contain enough material yet to place the pipes at elevations for the system to function properly.

H.3.20 The local sponsor has found the following design to be the most effective and intends to use this design in future application of these drainage devices. Pipes are placed at a depth so that there is a minimum of 4 feet of soil coverage at the pipe's highest point. The pipe is sloped at 1 foot of fall per 1000 lineal feet (0.1 percent slope). A main manifold is used consisting of 12-inch diameter pipes fed by a system of 8-inch diameter pipes spaced at 500-foot intervals. The pipes are perforated plastic enclosed inside a fabric sock. The outfalls of the underdrain pipes would be separate from the weirs used to drain the ponded water in the disposal areas. The underdrain pipe would extend through the dike and have a shutoff valve along the outside dike slope which would be easily accessible. This design would allow the flow to be regulated. Riprap would be placed at the invert of the discharge pipe to prevent erosion of the outside dike slope. The local sponsor prefers the outfalls be located along the same dike as the weir structures. This would allow the contractors to take advantage of the flow patterns created in the areas as a result of historical disposal events. A constant depth can be excavated below the grade of the sloping floor of the disposal area. It has been suggested that the underdrain outfalls be directed away from Wright River which is where the weirs currently outfall. It is possible to drain the underdrains in the opposite direction, but it will be more expensive. Disposal Area 12A currently drains toward Back River via a ditch paralleling the west dike which is the location of the weir structures. The proposal in the EIS consists of installing the underdrains so that they discharge to either the

Savannah or Back Rivers. The local sponsor will be responsible for abiding by the underdrain design features required in the South Carolina Water Quality Certification.

H.3.21 The useful life of the disposal areas should be maximized to avoid the need for additional sites to be used for dredged material disposal. Underdrains have proven they aid in the drying of the disposal areas and have been successfully implemented in other harbors. They are beneficial to the material consolidation process and to reclamation of dredged material. The local sponsor supports the use of underdrains in Savannah to assist in maximizing the use of the existing disposal areas.

H.3.22 Erosion Control. The local sponsor recognizes a need to prevent the erosion of the soil. If allowed to erode, the material could make its way to the navigation channel where it would be dredged and placed into the disposal areas, consuming valuable capacity. Eroded material can also make its way to the marsh causing undesirable environmental impacts. Erosion of the dikes affects the dike integrity and produces new work for the local sponsor. The local sponsor follows "Best Management Practices" in this work. These practices currently consist of silt fences and grassing. Erosion of the front dikes along the Savannah River is a higher magnitude. Various forms of bank protection will be installed by the local sponsor at the edge of the Savannah River along the eroded sides of the front dikes, including Jones/Oysterbed Island, with the goal being to establish the most efficient and cost effective system of bank protection.

H.3.23 Silt fence is installed during construction at the boundary of the marsh near new weir discharge pipe outfalls. It is effective in holding eroded soils until grass is established. It has been found that it is better to remove the silt fence in areas that will be mowed to minimize the down-time of mowing equipment.

H.3.24 Grassing the dikes is usually an integral part of the dike construction contracts. The current grass mixture used is 50 pounds of Pensacola Bahia grass, 4 pounds of hulled common Bermuda grass and 4 pounds of unhulled common Bermuda grass, all on a per acre basis. The ground is prepared, then fertilizer, lime and grass seeds are applied at specified rates. After the grass is at a proper height, nitrogen is added.

H.3.25 The erosion of the outside slope of the front dikes along the Savannah River is a significant problem. A dump truck has fallen into the river due to the eroded roadway sub-base. Fortunately, the tide was low and no one was seriously injured. The apparent major cause of the erosion is the wakes and propwash

produced by the large container ships. The Corps has produced an Environmental Assessment for the initial project by the local sponsor to determine which method of slope protection will be the most feasible for continued use along the dikes adjacent to the Savannah River. When the results of that project become available, the selected form/forms of bank protection will then be used along all dike faces where erosion is taking place. The local sponsor will also place bank protection along the Jones/Oysterbed Island portion of the river bank where the District has estimated that 2.6 acres of wetlands would be impacted.

H.3.26 Mowing. Vegetation on the dikes must be periodically cut to a height so inspection for washouts and possible dike failures can be observed. Uncontrolled vegetation can obscure the view of inspectors. Mowing the roadway located on top of the dikes ensures the safety of trips for inspection and disposal operation purposes.

H.3.27 Chatham County has used its own public works employees for mowing, but has recently determined it is better to contract the work to private business. Mowing contractors are required to mow the vegetation across the width of the dike and 6 feet down each shoulder. Areas along slopes between dikes are also mowed. The dikes are mowed usually twice each year, sometimes more pending available funds and rainfall. No mowing of the dike slopes or other non-traveled areas would be performed from March 1 to July 15 to protect nesting migratory birds. The traveling surface (roadway) on the dike crest would continue to be mowed when necessary to allow safe movement around the dikes. Mowing of dike side slopes would only be performed outside the March 1 to July 15 period.

H.3.28 Equipment used by mowing contractors include medium to large tractors equipped with bushhogs, side mowers, boom axe and bat wing mowers. Support equipment such as pickup trucks, fueling trucks, low boy (for delivery of equipment), etc. are also used.

H.3.29 Devegetation. The floor of the confined disposal facilities should be relatively clean of vegetation at the beginning of disposal operations since a reduction in dissolved oxygen concentrations occurs in the ponded water as a result of decaying vegetation. Minimizing the growth of vegetation within a disposal site also assists in drying the material deposited in the site. This allows the evaporative forces of the sun and wind to act on the floor of the disposal area. Clearing the area also allows the dredged slurry waters to uniformly distribute over a disposal site, rather than channeling through the vegetation. To date, the sponsor has used mechanical means to remove vegetation.

Plans are being made to coordinate a controlled onsite burn with the US Fish and Wildlife Service. The primary plant growth in the disposal areas is the salt cedar. Herbicides do not have a noticeable impact on this plant. It has been observed that use of underdrain pipes seem to deter salt cedar growth and encourage the establishment of volunteer grasses.

H.3.30 Two types of mechanical devegetation are used in the areas; (1) mowing and (2) clearing and grubbing. Both have been successful, but the longest lasting benefits are obtained using the clearing and grubbing method. Each area should be devegetated every three years.

H.3.31 Equipment typically used for devegetation includes large tractors pulling bushhogs or harrows and discs.

H.3.32 Pipe Ramps. Earthen pipe ramps are located outside the front dikes adjacent to the Savannah River. These structures allow the Corps' dredging contractors to lay the dredge pipe on a gradual slope up from the river over the crest of the disposal area dikes. Borrow material for this work is the dredged material located inside the disposal areas. The ramps are grassed in the same manner as the dikes. There are presently 36 pipe ramps existing along Savannah River (5 in GA and 33 in SC). Two ramps would be constructed to allow use of Disposal Area 14A. One other ramp is expected to be needed over the 20-year study period. Approximately 1.7 acres of wetlands would be lost in South Carolina as a result of these operations. Expansion of ramps would be necessary as the height of dikes is increased. This is expected to result in the loss of 0.67 acres of wetlands in South Carolina and 0.14 acres of wetlands in Georgia. No relocation of ramps is anticipated.

H.4.00 ENVIRONMENTAL CONSIDERATIONS.

H.4.01 Outer Toe Of Dikes. All dike improvements (raisings) are to be performed inside the existing alignment of the outer toe of the dikes. Improvements within the existing toe would result in those actions having no permanent adverse impacts to wetlands.

H.4.02 Number/Location Of Pipe Ramps. Two additional pipe ramps would be needed for use of Disposal Area 14A. One other pipe ramp is expected to be needed during the 20-year period of analysis. No enlargements of ramps are expected which would result in additional losses of wetlands. Each new ramp is expected to result in the loss of wetlands in an area approximately 100 feet by 150 feet. The combined permanent wetland losses from these 3 ramps would be 1.70 acres.

Mitigation for these impacts in South Carolina is included in the approved Mitigation Plan. Expansion of ramps is expected to result in the loss of 0.67 acres of wetlands in South Carolina and 0.14 acres of wetlands in Georgia. Mitigation for the South Carolina impacts is included in the approved Mitigation Plan. Mitigation for the impacts in Georgia would be at a 2:1 rate and would be through the mitigation plan which has yet to be developed. No relocation of ramps is anticipated.

H.4.03 Weir Installation. Installation of new weirs is required during the initial diking of Disposal Area 14A. Approximately 0.1 acres of wetlands are expected to be lost during this construction. Mitigation for these wetland losses in South Carolina are included in the approved Mitigation Plan.

H.4.04 Weir Replacement. Minor temporary losses of wetlands are expected on an infrequent basis when weirs are replaced and new discharge pipes are installed. Weirs are normally replaced when dikes are raised. Usually this occurs about every 5 years. When replacement occurs, a small area of wetlands (about 30 feet by 50 feet) could be lost at each new discharge pipe. However, ending the discharge and associated activities at the original discharge pipe would allow some wetlands to reestablish at that location. Loss of 0.43 acres of wetlands in South Carolina and 0.04 acres in Georgia are expected. Mitigation for the South Carolina impacts is included in the approved Mitigation Plan. Mitigation for the impacts in Georgia would be at a 2:1 rate and would be through the mitigation plan which has yet to be developed.

H.4.05 Timing Of Work. The disposal areas would continue to be managed around the potential for work stoppage during the migratory bird nesting season to ensure compliance with the laws which protect the nesting of those species. Activities which are commonly used to maintain the disposal areas could result in impacts to those nesting birds if the activities were performed while the birds were nesting. Due to the lead time resulting from required contracting procedures, precise timing of field work is generally not available. Therefore, some degree of uncertainty will exist when construction activities are scheduled for inside the disposal areas during the March through August nesting season. Any work proposed for the nesting season must be coordinated with Savannah District (PD-E) to ensure compliance with the Migratory Bird Treaty Act.

H.4.06 Dike Mowing. The mowing of dikes is a component of normal dike maintenance practices. Some species of migratory birds do nest on the Savannah Harbor disposal area dikes and could be impacted by dike maintenance activities, particularly mowing. To ensure that these birds receive the protection required while nesting, the dike side slopes and other non-traveled portions of the dikes would not be mowed from March 1 to July 15. The traveling surface (roadway) on the dike crest would continue to be mowed when necessary to allow safe movement around the dikes for inspection and disposal area use purposes. Mowing of dike side slopes would only be performed outside the March 1 to July 15 period.

H.4.07 Underdrain Installation. Wetlands are expected to be lost when underdrain discharge pipes are installed. The loss is not expected to occur simultaneously, as sufficient depths of material may not exist for 10 years at Disposal Areas 14A and 14B to warrant installation at those sites. For each pipe installed, an area about 30 feet by 50 feet could be temporarily impacted during construction and a permanent loss of an area about 20 feet by 20 feet due to riprap installed below the pipe to prevent bank erosion. Since wetlands do not exist along the entire north bank of the Savannah River, not every underdrain discharge pipe would result in a loss of wetlands. At this time, it is estimated that 70 percent of the discharge pipes would result in a wetland loss, for a total loss of about 0.21 acres based on a general design with underdrains discharge pipes located roughly every 2,000 feet along a dike. For that design, a total of 32 underdrain discharge pipes would be needed over time in the confined disposal facilities.

H.4.08 The proposed SC Water Quality Certification contains a condition that underdrains be constructed with flap gates to restrict discharge during low flow conditions. This feature would be included in the final design of these structures.

H.4.09 Construction of underdrains could potentially impact cultural resources located along the pipe alignment. Prior to excavation, archival information would be reviewed to determine if any proposed underdrain alignment had the potential for impacting any known cultural resource sites in the confined disposal areas. If there was a significant potential for adverse impact to a known site, a cultural resource survey would be performed of the underdrain alignments and approval of the study's findings from the SHPO would be obtained prior to excavation.

H.4.10 Savannah River Bank/Front Dikes Erosion Control. No overall wetland impacts or other environmental impacts are expected from construction of bank protection systems along eroding banks. As sediment from eroding banks enters the river, it can smother benthic organisms and cause other turbidity impacts. If bank protection is not constructed, ongoing erosion is expected to continue, destroying wetland vegetation adjacent to sites where the vegetation has already been lost. The proposed erosion controls should minimize such impacts. Installation of erosion control features on Jones/Oysterbed Island is expected to impact 2.6 acres of wetlands. Mitigation for these impacts are included in the approved wetland Mitigation Plan.

H.4.11 Testing Of Underdrain Effluent. Design calculations indicate that a maximum mixing zone of just under 30 feet would be required before the discharge from the new underdrains would meet acceptable water quality standards for all parameters. This mixing distance is judged to be acceptable, as it is much less than the mixing zones of hundreds of feet which are typical for permitted industrial point discharges along the Savannah River. A chemical evaluation would be performed of the underdrain discharges every three years to ensure that all state water quality standards are being met in the receiving water at the edge of a 100-foot mixing zone.

H.4.12 Mitigation For Loss Of Wetlands. The non-Federal sponsor is responsible for mitigating wetland losses stemming from actions associated with the provision of disposal areas. Such actions would include the diking of Disposal Area 14A, construction of the access road to Disposal Area 2A, and what are referred to in the EIS as miscellaneous disposal area operations. Implementation of the approved Mitigation Plan for wetland losses in South Carolina -- Appendix G -- is one such responsibility. The sponsor will also be responsible for implementation of the mitigation plan -- as yet undeveloped -- for wetland losses in Georgia resulting from miscellaneous disposal area operations in that state.

H.4.13 The Disposal Area 14A Mitigation Plan is described in detail in Appendix G. The Plan consists primarily of constructing additional wildlife habitat within existing diked disposal areas and operating those areas for increased use by wildlife. Water levels would be managed in Disposal Areas 12A, 12B, 13A, 13B, 14A, 14B and Jones/Oysterbed Island after

completion of a disposal event to maximize use by shorebirds and waterfowl. The sponsor is responsible for implementing and maintaining several construction-type features of the Plan. These include the following:

- (1) A 25-acre bare ground nesting area outside the dike at the Jones/Oysterbed Island Disposal Area.
- (2) Two 1-acre nesting islands within the seven CDFs involved in the rotation program.
- (3) An island in the nearshore area off Turtle Island. The island would have a 2.0-acre crown located at +14 feet MLW.
- (4) Restoration/creation/protection of 25 acres of tidal wetlands in South Carolina. SC DHEC-OCRM would select feasible sites and identify either (1) construction actions necessary to improve/create wetlands at the site, and/or (2) measures which would be necessary to adequately protect the site from future development. The SC DHEC-OCRM would administer a \$300,000 escrow account established by the local sponsor or its designee to accomplish the necessary actions.
- (5) A second water control structure at an existing 228-acre impoundment within the Savannah National Wildlife Refuge.
- (6) Purple martin nesting houses and bat houses at the CDFs in the rotation program.

H.4.14 Prior to implementing several of these construction items, additional environmental work is needed to ensure the final design would not unacceptably impact environmental resources. The following actions are needed before construction can proceed:

- (1) At the bare ground nesting area on Jones/Oysterbed Island: A Special Use Permit has been requested from the US FWS to conduct this work and vegetative clearing has begun.
- (2) For the bird nesting island offshore of Turtle Island:
 - a). Performance of a side scan sonar investigation and magnetometer survey to ensure no significant cultural resource would be impacted. The conclusions and the results of these investigations would be provided to the SHPO for approval.
 - b). Performance of a benthic survey to ensure critical benthic species would not be lost. The conclusions and results of this survey would be provided to the US FWS, NMFS and the SC DHEC-OCRM for approval.

c). Permission from the SC DHEC-OCRM for construction and maintenance of the island. (Through the EIS, the SC DHEC-OCRM has approved the concept of the island and awaits detailed design information prior to providing the necessary real estate easement.)

- (3) Detailed designs of riprap to be placed on the shoreline of Jones/Oysterbed Island to protect that eroding bank must be submitted for approval to the SC DHEC-OCRM. The SC DHEC-OCRM will make a field inspection to confirm that the design minimizes the loss of wetlands along that shoreline. Mitigation for the loss of 2.6 acres of wetlands resulting from this activity was included in the approved Mitigation Plan for the LTMS Project.

H.4.15 The mitigation plan for the losses of other wetlands in Georgia consists of the restoration of 6.4 acres of tidal marsh in the harbor area. The plan would replace 3.2 acres of wetlands which would be permanently lost at a 2:1 rate. The Plan will be coordinated with the GA DNR Coastal Resource Division and the US FWS for approval. In light of the relatively small number of acres involved, it is expected that a site can be identified in the general Savannah Harbor area where the sponsor or the GA DOT can restore previously impacted marsh as a component of another construction project. The acreage lost consists of that which would be impacted during construction of an access road to Disposal Area 2A, including approximately 2.9 acres of tidal marsh and other wetlands would be permanently impacted by construction, and another 1.0 acre which would be impacted only during the actual construction period and is expected to recover quickly once construction activities cease. An additional 0.14 acres would be lost during expansions of existing pipe ramps. Implementation of this wetland mitigation plan would occur before the access road is placed in service. Approximately 0.04 acres would be lost in Georgia as a result of the weir/discharge pipe replacements.

H.4.16 Mosquito Control. As stated in Section H.3.12, the Chatham County Mosquito Control Commission (CCMCC) performs actions to control the mosquito population at the confined disposal facilities. The CCMCC applies mosquito-control chemicals in CDFs, usually by aerial spraying, after disposal operations have ceased and the sites are drying. The chemical they typically use is effective for 3 to 5 days and is designed to specifically target mosquitos. The chemical is an insect growth regulator (juvenile hormone mimic) that disrupts mosquito pupation by preventing emergence of mosquito larvae to the adult stage. These chemicals have been shown to have no effect on other aquatic or shellfish populations.

H.4.17 Since the mosquito control chemicals are applied when the CDFs are dry or nearly dry, no effluent discharges are occurring on a regular basis. At those times, discharges would only occur in an uncontrolled manner as stormwater runoff after rainfall events. The CCMCC generally does not apply these chemicals immediately before rainfall events, as the rainfall would dilute the strength of the chemicals making them less effective. Since the travel time across a dry CDF is much larger than the half-life of the chemicals applied, the concentrations leaving a CDF would be too small to have a significant effect on the receiving waters. The combination of the application timing, travel time across a CDF, half-life of the applied chemicals, and relatively low toxicity of these chemicals on estuarine biota result in the runoff of mosquito control chemicals not being a significant environmental issue at the Savannah Harbor CDFs.

H.4.18 As stated in Section H.4.13, purple martin nesting houses and bat houses would be constructed and maintained at the CDFs in the rotation program. These items would provide a measure of biological control for additional mosquitos which may develop as a result of implementing the water control management program in the SC wetland Mitigation Plan.

H.4.19 Erosion Control And Sedimentation Plan. The District prepared an Erosion and Sediment Control Plan, which is contained in Appendix N. That plan described actions which would be taken to minimize adverse impacts resulting from non-point source pollution from construction projects at the dikes at the confined disposal facilities (dike raising projects). In that document, the District committed the sponsor to use "Best Management Practices", as defined in the Manual For Erosion And Sediment Control In Georgia or the South Carolina Stormwater Management And Sediment Control Handbook For Land Disturbance Activities, whichever is appropriate, during those construction events. The local sponsor will prepare and submit documents to the SC DHEC-OCRM to obtain a Stormwater Management Permit for initial construction of the Disposal Area 14A dikes. The documents will describe actions to be taken to minimize adverse impacts resulting from non-point source pollution during that construction project. Implementing the procedures described in the Erosion and Sediment Control Plan prepared by the District will provide environmental clearance for subsequent Project dike raising activities in South Carolina.

APPENDIX I

SITE MANAGEMENT PLAN

SAVANNAH HARBOR OCEAN DREDGED MATERIAL DISPOSAL SITE (ODMDS)

SITE MANAGEMENT PLAN

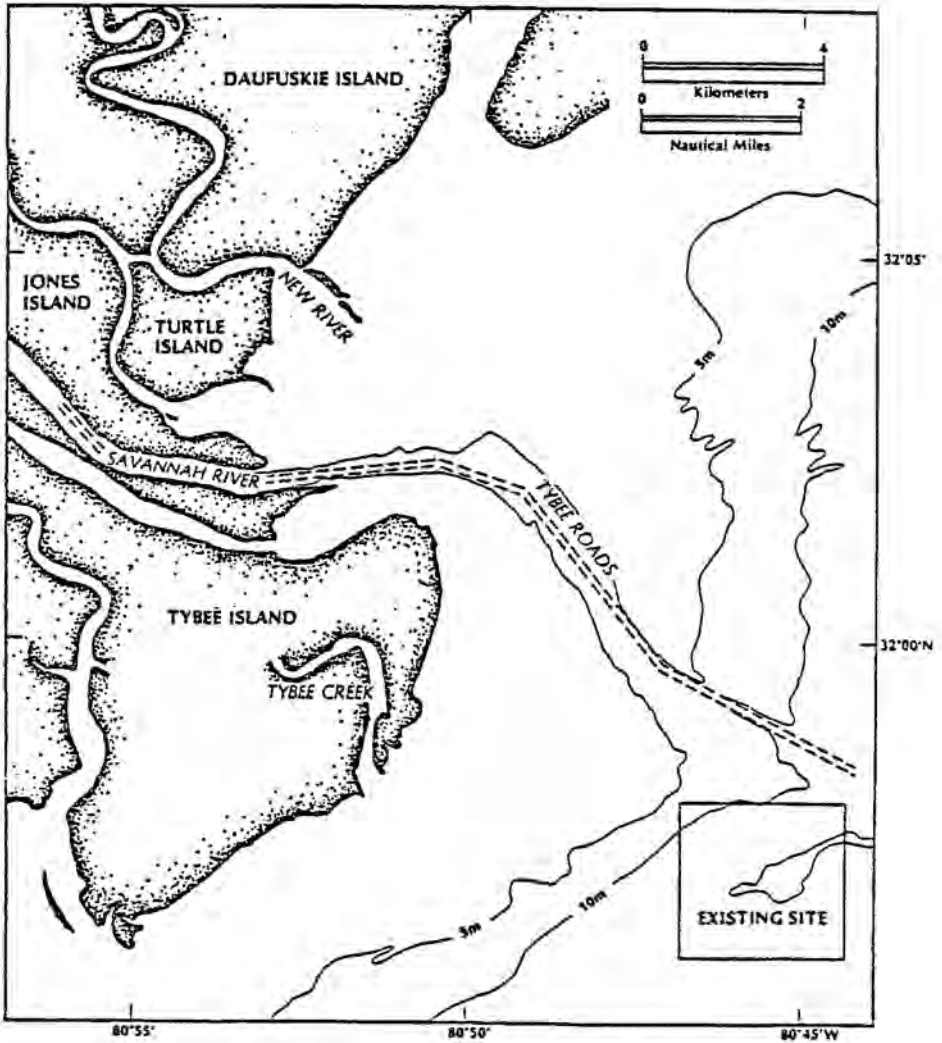
SAVANNAH HARBOR ODMDS

I.1.00 INTRODUCTION. The Environmental Protection Agency (EPA) formally designated the Savannah Harbor Ocean Dredged Material Disposal Site (ODMDS) in August 1987. The location of that site is shown in Figure 1. It is the responsibility of the EPA under the Marine Protection, Research, and Sanctuaries Act (MPRSA) of 1972 to manage and monitor ODMDSs designated by the EPA pursuant to Section 102 of MPRSA. As part of this responsibility, EPA/Region IV in conjunction with the Savannah District, U.S. Army Corps of Engineers (COE) developed a management and monitoring plan to specifically address deposition of dredged material into the Savannah Harbor ODMDS.

I.2.00 SITE MANAGEMENT AND MONITORING TEAM. An interagency Site Management and Monitoring Plan (SMMP) team, consisting of representatives of EPA, COE, Georgia Department of Natural Resources (GA DNR), and Chatham County has been established to review and comment on all Savannah Harbor ODMDS management and monitoring activities. Other agencies will be asked to participate when appropriate. This SMMP Team will coordinate annually to discuss upcoming disposal activities, suitable management practices, and monitoring efforts for the Savannah Harbor ODMDS.

I.3.00 SITE MANAGEMENT

I.3.01 Section 228.3 of the Ocean Dumping Regulations (40 CFR 220 to 229) states: "Management of a site consists of regulating times, rates, and methods of disposal and quantities and types of materials disposed of, developing and maintaining effective ambient monitoring programs for the site; conducting disposal site evaluation studies; and recommending modifications in site use and/or designation." The plan may be modified if it is determined that such changes are warranted as a result of information obtained during the monitoring process.



SAVANNAH OCEAN
DREDGED MATERIAL
DISPOSAL SITE

FIGURE 1

I.3.02 Management Objectives. There are three primary objectives in the management of an ODMDS. These are:

- * Protection of the marine environment;
- * Beneficial use of dredged material whenever practical; and
- * Documentation of disposal activities at the ODMDS.

The following sections provide the framework for meeting these objectives to the extent possible.

I.3.03 Material volumes. To this point in time, the Savannah ODMDS has only received materials excavated from the entrance channel of the Savannah Harbor Navigation Project. Those sediments average about 15 percent fines and are located in areas of high current and wave energy. The sediments are typically removed from that channel on an annual basis. COE records indicate that annual removal has averaged 934,000 cubic yards over the 16-year period from 1976 to 1992. EPA's Final EIS for designation of the ODMDS stated that approximately 1,000,000 cubic yards per year are excavated from the entrance channel and deposited at the site. Over 1993 and 1994, the entrance channel was deepened by the COE and annual deposition at the ODMDS averaged 3,000,000 cubic yards for those two years. Future deposition is expected to return to the long term average and approximate 1,000,000 cubic yards per year. That quantity may decrease if beneficial uses, such as beach placement or construction of nearshore berms or islands, are implemented for the entrance channel sediments.

I.3.04 The 1983 Final EIS for designation of the Savannah ODMDS placed no restrictions on disposal volumes. Disposal of unrestricted volumes is dependent upon results from future monitoring surveys.

I.3.05 Material suitability. There is no general restriction regarding the type of material that may be placed at the site at this time. However, the suitability of dredged material for ocean disposal must be verified by the COE and agreed to by EPA prior to disposal activities. Verification will be valid for three years from the date last verified. Verification will involve: (1) a case-specific evaluation against the exclusion criteria (40 CFR 227.13(b)), (2) a determination of the necessity for bioassay (toxicity and bioaccumulation) testing for non-excluded material based on the potential for contamination of the sediment since last tested, and (3) implementing testing and determining that the non-excluded, tested material is suitable for ocean disposal.

I.3.06 Documentation of verification will be completed prior to use of the site. Documentation for material suitability for dredging events proposed for ocean disposal more than 5 years since last verified will consist of a new Section 103 Evaluation and Public Notice. Documentation for material suitability for dredging events proposed for ocean disposal less than 5 years, but more than 3 years, since last verified will consist of a review through an exchange of letters between the COE and EPA.

I.3.07 Should EPA conclude that reasonable potential exists for contamination to have occurred, testing acceptable to EPA will be completed prior to use of the site. Testing procedures to be used will be those delineated in the EPA/Corps testing manual (Green Book) and the Regional Implementation Manual. Only material determined to be suitable through the verification process by the COE and EPA will be placed at the designated ocean disposal site.

I.3.08 Time of disposal. At present, no restrictions related to seasonal variations in ocean current or biotic activity have been determined to be necessary. As monitoring results are compiled, should any such restrictions appear necessary, disposal activities will be scheduled to avoid adverse impacts. Additionally, if new information indicates that an endangered or threatened species is being adversely impacted, restrictions for protection of that species may be instituted.

I.3.09 Disposal Technique. No specific disposal technique is required for this site. However, it is the intent of this plan to maximize any advantages of strategic placement of materials and minimize off-site migration of deposited materials.

I.3.10 Previous disposal has generally occurred in the northeast quadrant of the site. This has apparently resulted in the formation of a mound of deposited sediments (see Figure 2). Future deposition would be managed to limit excessive mounding and minimize impacts to nearby benthic communities. Materials should be placed in a manner such that the resulting top elevation does not interfere with navigation.

I.3.11 Use of any beach-compatible dredged material for beach nourishment or other beneficial use is encouraged by both the Corps and EPA where economically feasible and environmentally sound. Expected environmental benefits should be included in the evaluation of the the feasibility of placement alternatives. Disposal of coarser material should be planned to allow placement within or accessible to the littoral zone, to the maximum extent practical and following the provisions of the Clean Water Act.

I.3.12 Placement of Materials. Prior to any disposal of dredged materials other than normal Bar Channel maintenance sediments, an agreement between EPA and the COE will be reached concerning the exact placement of these materials. Permits/contracts will specify locations for the disposal of any material from the project. Until monitoring results necessitate the need for any alterations, materials will be placed within the ODMDS according to paragraphs I.3.8 through I.3.10. Predominantly coarse-grained material may be used for beach nourishment or another beneficial purpose (i.e. submerged berms, feeder berms or nearshore islands).

I.3.13 Disposal Monitoring. For all disposal activities, the dredging contractor will be required to prepare and operate under an approved electronic verification plan for all disposal operations. As part of this plan, the contractor will use an automated system that will continuously track the horizontal location and draft condition (vertical) of the disposal vessel from the point of dredging to the disposal area, and return to the point of dredging. Accuracy and precision of the locational system will be at least as good as provided by Loran C. Required digital data are as follows:.

- (a) Date;
- (b) Time;
- (c) Vessel Name;
- (d) Dump Number;
- (e) Map Number on which dump is plotted;
- (f) Beginning and ending coordinates of the dredging area for each load, and the beginning and ending coordinates for each dump and the compass heading at the beginning of each dump;
- (g) Channel stations from which dredged material came; and
- (h) Volume and brief description of material disposed.

I.3.14 Prior to commencement of disposal operations, a baseline bathymetric survey will be conducted of the disposal area and adjacent areas by the site user. The survey will be taken along lines spaced on 500-foot intervals and be of sufficient length to adequately cover the area. Accuracy will be +/- 1.0 feet. The survey will be referenced to MLW and corrected for tide conditions at the time of the survey. The Savannah District ARTIS tide gauge will be used for tidal corrections. As a follow-up to the baseline bathymetric survey, the site user will conduct a similar survey after disposal. The number of transects and accuracy required will be the same as in the baseline survey.

I.3.15 The user will be required to prepare and submit to the COE daily reports of operations and a monthly report of operations for each month or partial month's work. The information contained in items (a) through (h) above will be provided in IBM-compatible computer format.

I.3.16 When disposal operations are complete, the contractor will provide to the COE two scatter plots showing where each load was deposited (beginning and end of each dump). One plot would be on a scale of 1 inch equals 2,400 feet (fit an 8 1/2 by 11 inch paper), and the other plot would be a scale of 1 inch equals 500 feet (fit a full size blue line drawing). The plots would also show the boundaries of the ODMDS.

I.4.00 SITE MONITORING

I.4.01 Part 228 of the Ocean Dumping Regulations establishes the need for evaluating the impacts of disposal on the marine environment. Section 228.9 indicates that the primary purpose of this monitoring program is to evaluate the impact of disposal on the marine environment by referencing the monitoring results to a set of baseline conditions. Section 228.10(b) states that in addition to other necessary or appropriate considerations, the following types of effects will be considered in determining to what extent the marine environment has been impacted by materials disposed at an ocean site (excerpted):

1. Movement of materials into estuaries or marine sanctuaries, or onto oceanfront beaches, or shorelines;
2. Movement of materials toward productive fishery and shellfishery areas;
3. Absence from the disposal site of pollution-sensitive biota characteristic of the general area;
4. Progressive, non-seasonal, changes in water quality or sediment composition at the disposal site, when these changes are attributable to materials disposed of at the site;
5. Progressive, non-seasonal, changes in composition or numbers of pelagic, demersal, or benthic biota at or near the disposal site, when these changes can be attributed to the effects of materials disposed at the site; and
6. Accumulation of material constituents (including without limitation, human pathogens) in marine biota at or near the site.

I.4.02 Part 228.10(c) states: "The determination of the overall severity of disposal at the site on the marine environment, including without limitation, the disposal site and adjacent areas, will be based on the evaluation of the entire body of pertinent data using appropriate methods of data analysis for the quantity and type of data available.

I.4.03 Impacts will be classified according to the overall condition of the environment of the disposal site and adjacent areas based on the determination by the EPA management authority assessing the nature and extent of the effects identified in paragraph (b) of this section in addition to other necessary or appropriate considerations."

I.4.04 The Monitoring Plan for the Savannah Harbor ODMDS is described in Attachment A. The Monitoring Plan will be implemented subject to the availability of funding. Should shortfalls in funding occur, the SMMP team will recommend which aspects of the Monitoring Plan should receive priority. Results of monitoring will be reviewed by the SMMP team and recommendations made to the Corps and EPA on appropriateness and detail of future monitoring efforts.

I.5.00 MODIFICATION OF THE SITE MANAGEMENT PLAN.

I.5.01 Should the results of monitoring surveys indicate that continuing use of the Savannah ODMDS would lead to unacceptable impacts, then either the Savannah ODMDS Site Management Plan will be modified to alleviate the impacts, or the location of the ODMDS will be modified.

I.5.02 This Site Management Plan may be modified at any time by joint agreement of the signatory parties to the reflect the views of the SMMP team

ATTACHMENT A

SITE MONITORING PLAN

FOR THE

SAVANNAH HARBOR ODMS

ATTACHMENT A

SITE MONITORING PLAN
FOR THE
SAVANNAH HARBOR ODMDSA.1.00 INTRODUCTION

A.1.01 The Savannah Harbor Ocean Dredged Material Disposal Site (ODMDS) is an active, frequently used site in the South Atlantic Bight (part of EPA's Region IV area of responsibility). This is the first Site Management Plan which has been developed for the Savannah ODMDS.

A.1.02 The Savannah ODMDS encompasses an area of 4.26 nautical miles (NM) (approximately 2.1 by 2.0 NM) and is located about 3.7 NM east of the coastline and about 0.25 NM (1,500 feet) south of the Navigation Channel. The site's center is located at 31 56'54"N and 80 45'34"W. The site was formally designated by EPA as an ODMDS on August 2, 1987. To date, the site has only been used for placement of material obtained from the Savannah Harbor Navigation Project. The site has received both new work and maintenance dredged material from the harbor's Bar Channel (entrance channel), which is located oceanward of Station 0+000. No disposal activities are known to have occurred outside the boundaries of the site.

A.1.03 Monitoring activities were initially conducted by Savannah District in 1994 to assess the fate of dredged material placed within the ODMDS during the early 1994 disposal activities. At that time, both new work material from the Savannah Harbor Deepening Project and maintenance material were placed at the site. The primary objectives of these bathymetric surveys were to: (1) document the bathymetry of the site prior to the 1994 disposal activities, (2) document the location and configuration of mounds created at the site with dredged material during the 1994 disposal activities, (3) determine whether any material deposited is moving offsite, and (4) attempt to determine the rate and/or direction of material migration.

A.1.04 The Monitoring Plan is a component of the initial Site Management Plan for the Savannah Harbor ODMDS. The Monitoring Plan should be regarded as a flexible strategy with the various task and techniques applied as appropriate and as dictated by disposal activities and observed effects. The following sections describe the objectives and methods for the site monitoring.

A.2.00 OBJECTIVES

A.2.01 Major objectives of the Savannah ODMDS Monitoring Plan are to:

- (1) Determine the fate of dredged material placed at the site, and
- (2) Assess the impact of dredged material through the early detection of changes in sediment characteristics (physical and chemical), and biological communities which may be deemed as adverse and chronic.

A.2.02 Since several different ecological components are susceptible to perturbation by dredged material disposal, and an alteration to one component may have a resultant impact on another, a comprehensive monitoring approach is proposed with several specific objectives. These objectives are to:

- (1) Continue bathymetric mapping of the ODMDS and surrounding area, and relate findings to plotted coordinates of disposal events.
- (2) Using sediment mapping techniques, periodically review the direction and rate of migration of deposited dredged material.
- (3) Evaluate the effects of disposal and subsequent movement of dredged material on the physical and chemical characteristics of the sediments and benthic infaunal communities in and adjacent to the ODMDS.
- (4) If determined necessary, determine the areal distribution of turbidity plumes generated during a major disposal operation and compare the turbidity data with the ambient turbidity plume emanating from Savannah River.
- (5) Select and characterize a sediment testing "reference site" meeting Green Book criteria, for use by public and private dredging projects, in conducting sediment toxicity and bioaccumulation test for ocean dumping evaluation.

A.2.03 Responsible Party. The activities described above in Section A.2.02 will be implemented by various agencies and parties. The site user will implement activities to accomplish objectives 1 and 5. EPA will implement activities to accomplish objectives 2 and 3. Should implementation of objective 4 become necessary, the SMMP team will advise its members which agency should be responsible and could best perform the necessary work.

A.3.00 MONITORING APPROACH AND RATIONALE

A.3.01 Sediment Mapping and Site Bathymetry.

A.3.02 An essential initial requirement for effective implementation of site monitoring activities at the Savannah ODMDS is accurate placement, recording, and plotting of disposal events. The Savannah District, USACOE, will require such information from all dredging contractors and will compile and continuously update computer plots depicting placement of dredged material. Plotted coordinates will be in GPS-corrected latitude/longitude to enhance use by all associated monitoring agencies.

A.3.03 Using the above information as a basis, close grid bathymetry will be conducted at least annually. The sediment mapping effort should encompass the entire area of the ODMDS designated for maintenance disposal and a 0.25 NM buffer zone around that site (Figure 1). The spacing of the grid may be expanded on the southern half of the ODMDS if disposal activities occur only in the northern half of the site. While the scheduling of these surveys is complicated by the frequency and quantity of dredged material disposal at the site, it is expected that sediment mapping will occur at least twice annually; before and after annual winter disposal operations. Experience with these techniques at the Savannah ODMDS thus far indicates that this frequency is the minimum necessary to effectively detect gross changes in dredge material redistribution. Due to the apparent highly dynamic nature of sediment transport at the site, detection of more discrete migration patterns may require mapping at a greater frequency, possibly targeting a specific disposal mound. In addition to bathymetric sediment mapping, areal mapping of sediment chemistry may be employed to differentiate and track native sediments and dredged material migration. Baseline studies were conducted in August 1991 to develop a complete isotopic, elemental, and physical (particle size) history for this location. The 1991 study indicated higher concentrations of fine sediments in the western half of the ODMDS.

A.3.04 Two existing bathymetric surveys conducted at the Savannah ODMDS sites (late 1993 and 1994) clearly depict the location of mounds within the ODMDS. These surveys indicate that significant off-site migration of deposited material is occurring, as the post-construction survey revealed a smaller total volume than did the pre-construction survey, even with deposition of 2.3 million cubic yards of sediments at the site as part of the 1993/1994 Savannah Harbor Deepening Project.

A.3.05 Biological Impact Assessments.

A.3.06 The primary intent of these sampling efforts will be to assess whether ocean disposal of dredged material at the Savannah ODMDS results in unacceptable adverse impacts to the biological communities adjacent to the ODMDS.

A.3.07 Benthic organisms are the resident community at the disposal site and do not have an ability to avoid increased sedimentation resulting from sediment disposal and movement. They also serve as a primary food source for the fisheries associated with the nearshore zone off the Georgia coast. Their sessile life cycle subjects them to both the physical and chemical perturbations on the seafloor generated by disposal activities. Because of their importance in food web dynamics, assessment of the benthic community structure should be a primary focus for detection of biological impact.

A.3.08 A limited benthic assessment consisting of one station within and one station southeast of the ODMDS was conducted by EPA in March and December 1979 prior to its official designation of the site as an ODMDS. A more comprehensive benthic survey of the ODMDS was conducted in May 1992. Six benthic monitoring stations were located within the disposal area and six stations were located just outside this area. The latter survey indicated the presence of two main species assemblages, based on apparent habitat type; a gravelly sand assemblage, and a silty sand assemblage. The gravelly-sand stations occurred in the eastern portion of the study area, and the silty-sand stations in the western half of the disposal site. The 1992 study will be used to direct subsequent benthic monitoring efforts.

A.3.09 In order to expand the benthic database and allow evaluations to be made on the impacts which disposal operations at this site have on benthic communities, benthic surveys will be conducted both in the ODMDS and in the area immediately surrounding the site. The benthic data will allow determinations to be made concerning whether benthic resources outside the ODMDS are being affected by disposal of fine-grained materials, and determine whether these changes are detrimental. The primary focus of this monitoring effort will be to determine whether disposal operations cause a major change in the faunal composition of benthos (which could affect trophic functions) and/or whether there are significant alterations in species numbers or biomass. Changes in other biological metrics, similar to those currently being evaluated in EPA's EMAP program will also be considered based on their applicability to this survey area.

A.3.10 After the bathymetric surveys, sediment mapping, and current studies conclusively determine the direction(s) of sediment migration, benthic surveys would be conducted. The benthic monitoring would be concentrated in those areas where sediment transport was expected or documented to occur. The benthic surveys will involve collecting benthic samples in and around the ODMDS using an appropriate stratified sampling design based on available information, such as areal mapping of sediment chemistry. The general zones (strata) will include areas both within the ODMDS and adjacent to all boundaries of the ODMDS. The zones within the ODMDS would be used to document changes in the benthic communities following disposal operations for comparison with zones outside the ODMDS.

A.3.11 The number of samples obtained per zone will be sufficient to adequately represent the benthic community composition (based on species saturation curves) and detect moderate changes in faunal densities, biomass, and species numbers (based on power analyses). At least one sample will be taken within the area of steepest slope in the south-central portion of the ODMDS. Each benthic sample obtained for faunal assessment will be subsampled to determine sediment characteristics of the sample (eg, grain size, percent silt, clay, sand, CaCO_3 , etc.). The sediment samples will be used to (1) further characterize the composition of surficial sediments in and around the ODMDS, and (2) aid in interpreting changes in benthic infaunal composition.

A.3.12 Disposal Plume Dispersion.

A.3.13 At infrequently used disposal sites, the turbidity plume generated during ocean disposal of dredged material is generally viewed as an episodic event with impacts being limited and temporary. However, at frequently used ODMDS's, consideration of the potentially chronic effects of the turbidity plume should be considered. Sessile live bottom organisms such as octocorals and sponges may be particularly susceptible to suspended solids concentrations chronically above ambient. While no live bottom communities are known to be associated with the Savannah ODMDS, such communities, when present, are an important habitat for productivity and fish use. Should any significant benthic communities be identified in the area, an evaluation would be conducted to determine if they would be impacted by turbidity plumes. At that time, a typical turbidity plume generated by a major disposal event should be delineated and its areal distribution plotted. A ship-mounted transmissometer could be used to profile light attenuation at grid points encompassing the plume. The outer boundaries of the grid could be determined using an aircraft mounted GPS during an aerial reconnaissance of

the disposal operation prior to initiating the grid profiling. Information gleaned during this effort could be compared to plume turbidity/suspended solids concentrations for consideration of plume impact.

A.3.14 Sediment Turbidity Transport Studies.

A.3.15 An overall southerly movement of littoral material occurs in the general vicinity. That trend is interrupted, somewhat, by flows leaving the Savannah River. It is believed that the tidal inlet at Savannah tends to shift the overall southerly littoral drift pattern seaward to some degree. Shoaling patterns along the Bar Channel support the position that the littoral drift movement is from north to south.

A.3.16 There is no known existing data on ocean currents specifically at the Savannah ODMDS. However, predictions can be made based on the overall direction of waves which are recorded nearby. Review of the Hindcast Wave Information for the U.S. Atlantic Coast (WIS Report 30) prepared in March 1993 by the Corps of Engineers, Waterways Experiment Station (WES) reveal the predominant wave directions are from the E-SE. Those directions also produce both the largest and longest period waves. July and August are the months of lowest wind strength, while the period of November through March produce winds of the greatest strength (over 40 miles per hour).

A.3.17 Based upon these limited findings, present management strategies involve placement of dredged material and construction of submerged berms down the eastern side of the ODMDS. Actual current data over an annual cycle would (1) add confidence to this management strategy, and (2) help clarify sediment redistribution patterns revealed by bathymetric surveys.

A.3.18 The primary task required for current data collection would be the deployment and retrieval of continuously recording current meters. Ideally, a long-term continuous data base obtained over a two-year period should be obtained to evaluate both seasonal and yearly variability in current patterns. Deployment of a Acoustic Doppler Current Profiler (ADCP) placed within or adjacent to the ODMDS would provide the best data base for this effort. Quarterly or semiannual retrieval of the data record would provide timely information on prevailing current patterns. Collection of such data should be coincident with a major disposal project during which sediment mapping, plume dispersion, and sediment sampling occurs. This would allow integration of current data into these programs, thus enhancing interpretation of plume dispersion, sediment transport and sedimentation.

A.4.00 CONTAMINANT STUDIES

A.4.01 Sediment Contaminant Monitoring.

A.4.02 Previous sampling of sediments in and around the ODMDS conducted by EPA prior to their official designation of the site as an ODMDS did not detect significant elevations of sediment contamination. A critical component of the proposed monitoring plan will be to periodically sample sediments in and adjacent to the ODMDS to monitor for changes in sediment contaminant levels. This sampling would be conducted using a tiered approach, where sites outside the ODMDS are not monitored until elevated levels are detected inside the ODMDS. A Tier I evaluation of the need for sediment chemical testing would be conducted every 3 years to coincide with a similar evaluation of sediments in the Bar Channel. More frequent sampling of the sediments may be warranted if elevated levels of certain contaminants are found, but the analysis could be restricted to only those constituents which are above acceptable levels.

A.4.03 Reference Site Assessment.

A.4.04 Testing of sediments for ocean disposal in conformance with the "Green Book" requires comparison of the project sediments with that from sediments outside the influence of the project. Questionable results can arise if low survival is experienced in the reference sediment. Concern for the acceptability of the reference sediment is also generated when the survival in both the reference and test sediments is low and there are similar percentages for survival or mortality. As defined in the testing guidance, a reference sediment should (1) be substantially free of contaminants, (2) be as similar to the grain size of the dredged material and sediment at the disposal site as practical, and (3) reflect conditions that would exist in the vicinity of the disposal site had no dredged material disposal ever occurred, but had all other influences on sediment conditions taken place. These are the optimum conditions for evaluation of toxicity and bioaccumulation and, quite often, are not attainable. If it is not possible to fully meet these conditions, test organisms should be selected that are not sensitive to grain size differences among the reference, control, and test sediments.

A.4.05 Satisfaction of the above requirements is often complicated because the disposal activity often does not involve the disposal of "like" material. The grain-size of sediments removed from the Bar Channel may be different than that found several miles offshore where the ODMDS is located. Sediments in the Bar Channel would be expected to be somewhat finer since that channel carries ebbing tidal water which have just flooded extensive salt marshes known for their detrital export functions.

A.4.06 Finding a reference sediment which is uncontaminated and similar to the grain size of the Bar Channel sediments, and yet represents conditions which would exist at the disposal site, which is primarily sand, is difficult. However, to aid in the long-term analysis of disposal at the Savannah Harbor ODMDS, selection of a single location for a suitable reference sediment which can be used for repeated sediment analyses would (1) ease the process of developing a sampling plan, and (2) allow comparison of the dredged material with similar material outside the influence of the project in accordance with the "Green Book".

A.4.07 Test Organism Assessment.

A.4.08 Selection of test organisms appropriate for the Savannah area, yet consistent with recommended national and regional "Green Book" species should be a part of this assessment. Information developed from this effort could then be used by the Corps both in-house and as instruction to any other organization which may be considering use of the Savannah Harbor ODMDS.

The following Site Management Plan for the Savannah Harbor Ocean Dredged Material Disposal Site (ODMDS) has been developed and agreed to pursuant to the Marine Protection, Research, and Sanctuaries Act of 1972, as amended, for the management and monitoring of ocean disposal activities, as resources allow, by the U.S. Environmental Protection Agency (EPA) and the U.S. Army Corps of Engineers (Corps).

Grant W. Smith
Colonel, U.S. Army
District Engineer
Savannah District
U.S. Army Corps
of Engineers
Savannah, Georgia

Date

Robert F. McGhee Date
Acting Director
Water Management Division
U.S. EPA, Region IV
Atlanta, Georgia

This plan is effective from the date of the last signature and shall be reviewed and revised as necessary.

APPENDIX J

CULTURAL RESOURCES MANAGEMENT PLAN

SAVANNAH HARBOR NAVIGATION PROJECT
SAVANNAH RIVER
CHATHAM COUNTY, GEORGIA, AND JASPER COUNTY, SOUTH CAROLINA
HISTORIC PROPERTIES MANAGEMENT PLAN

Prepared by

The Environmental Resources Branch
Planning Division
Savannah District
U.S. Army Corps of Engineers

FY 1995

HISTORIC PROPERTIES MANAGEMENT PLAN
FOR THE
SAVANNAH HARBOR NAVIGATION PROJECT

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J.1.00 EXECUTIVE SUMMARY

J.1.01 This document details the Historic Preservation Management Plan (HPMP) for the Savannah Harbor Navigation Project. Corps of Engineers regulation ER 1130-2-438, Project Construction and Operation, Historic Preservation Program, governed its preparation.

J.1.02 Historic resource surveys completed during and after construction of the Savannah Harbor Navigation Project identified historic properties on fee-owned Government land and adjoining project lands. A number of these sites are either listed on the National Register of Historic Places, possess sufficient integrity to be eligible for listing on the National Register, or are potentially eligible for the National Register. The impact of the Navigation Project on each of these resources or potential resources is addressed, needed investigations are described, and recommendations for avoidance/protection activities are provided. The staff liaison for historic resources within or near the Savannah Harbor Navigation Project is Ms. Judy Wood, PD-EI.

J.2.00 AUTHORITY

J.2.01 The Corps of Engineers is responsible for all aspects of protection of historic properties located on fee-owned lands. This includes protection from project efforts, permitted and licensed efforts by others, easements, vandalism, and natural deterioration. For sites located on tracts with less than fee simple ownership, the Corps is responsible only for project induced effects.

J.2.02 Savannah Harbor has had a very dynamic history, undergoing some type of Savannah District affiliated modification/ improvement in every decade since the 1850's. These improvements have included construction of wing dams, closing dams, training walls, disposal area dikes, a Sediment Basin and Tidegate, turning basins, deeper wider and longer channels, and a LASH facility. It is reasonable to assume that such changes will continue to occur.

J.2.03 The Savannah Harbor Navigation Project is part of the Port of Savannah. Public entities (e.g. the City of Savannah, the Georgia Ports Authority, a United States Navy Reserve Unit, and the United States Coast Guard) and private corporations construct and maintain facilities that make use of the Federal navigation channel and turning basins. These facilities are located on the banks of Savannah River within 200 feet of the Federal navigation channel. Construction, maintenance, and modification of these facilities often requires Section 10 and/or

404 Regulatory permits and a review of the effect of the project upon navigation servitude. Between 1972 and September 1994, 188 regulatory permits were issued within and in the immediate vicinity of Savannah Harbor.

J.2.04 Studies conducted as part of the 1989/1990/1991 Savannah Harbor Widening Project, 1992 New Cut Closure Project, 1993/1994 Savannah Harbor Deepening Project, and the 1993-1995 Savannah Harbor Long Term Management Strategy (LTMS) Study have revealed a number of significant and potentially significant cultural resources that abut the Savannah Harbor Navigation Project. Because of their proximity to the navigation channel, it is likely that one or more of these sites could be impacted by changes in operating procedures or harbor improvement projects, issuance of Section 10 and/or 404 permits, or navigation servitude clearances.

J.2.05 Under the authority and requirements of the following laws, regulations, and guidelines, the Savannah District, U.S. Army Corps of Engineers has the responsibility to inventory, manage, and take into account the effects of its actions on historic properties meeting criteria of eligibility for inclusion in the National Register of Historic Places within and in the vicinity of the Savannah Harbor Navigation Project.

- * The Antiquities Act of 1906, PL 59-209 (16 U.S.C. 431, 432, 433)
- * The Historic Sites Act of 1935, PL 74-292 (16 U.S.C. 461 et seq.)
- * The Reservoir Salvage Act of 1960, PL 86-523 as amended by the Archeological and Historical Preservation Act of 1974
- * The National Historic Preservation Act of 1966, PL 89-655 as amended including the National Historic Preservation Act Amendments of 1980 and 1992 (16 U.S.C. 470 et seq.)
- * National Environmental Policy Act of 1969, PL 91-190 (42 U.S.C. 4371 et seq.)
- * The Archaeological and Historic Preservation Act of 1974, PL 93-291 (16 U.S.C. 469-469c)
- * The Archaeological Resources Protection Act of 1979, PL 96-95 (16 U.S.C. 470aa-470mm)
- * American Indian Religious Freedom Act, PL 95-341 (42 U.S.C. 1986)
- * Abandoned Shipwreck Act of 1987, PL 100-298 (43 U.S.C. 2101 et seq.)
- * Native American Graves Protection and Repatriation Act, PL 101-601 (25 U.S.C. 3001-3013)
- * River and Harbor Act of 1899
- * Clean Water Act of 1974
- * Executive Order 11593

- * Abandoned Shipwreck Act; Final Guidelines, Department of the Interior. Federal Register, Tuesday, December 4, 1990, Pages 50116-50145
- * Dredging Guidance Letter No. 909-01, Policy and Procedures for the Conduct of Underwater Historic Resource Surveys for Maintenance Dredging and Disposal Activities. March 13, 1989
- * 32 CFR 229, Archaeological Resources Protection Act of 1979; Final Uniform Regulations
- * 33 CFR 325, Processing of Department of the Army Permits: Appendix C., Procedures for the Protection of Historic Properties, dated November 13, 1987.
- * 36 CFR 327, Shoreline Management at Civil Works Projects, dated May 1986
- * EC 405-1-71, Implementation of Archaeological Resources Protection Act Uniform Regulations
- * ER 200-2-2, Policy and Procedures for Implementing NEPA
- * ER 1130-2-433, Project Operations, Collections Management and Curation of Archeological and Historical Data
- * ER 1130-2-438, Project Construction and Operation, Historic Preservation Procedures

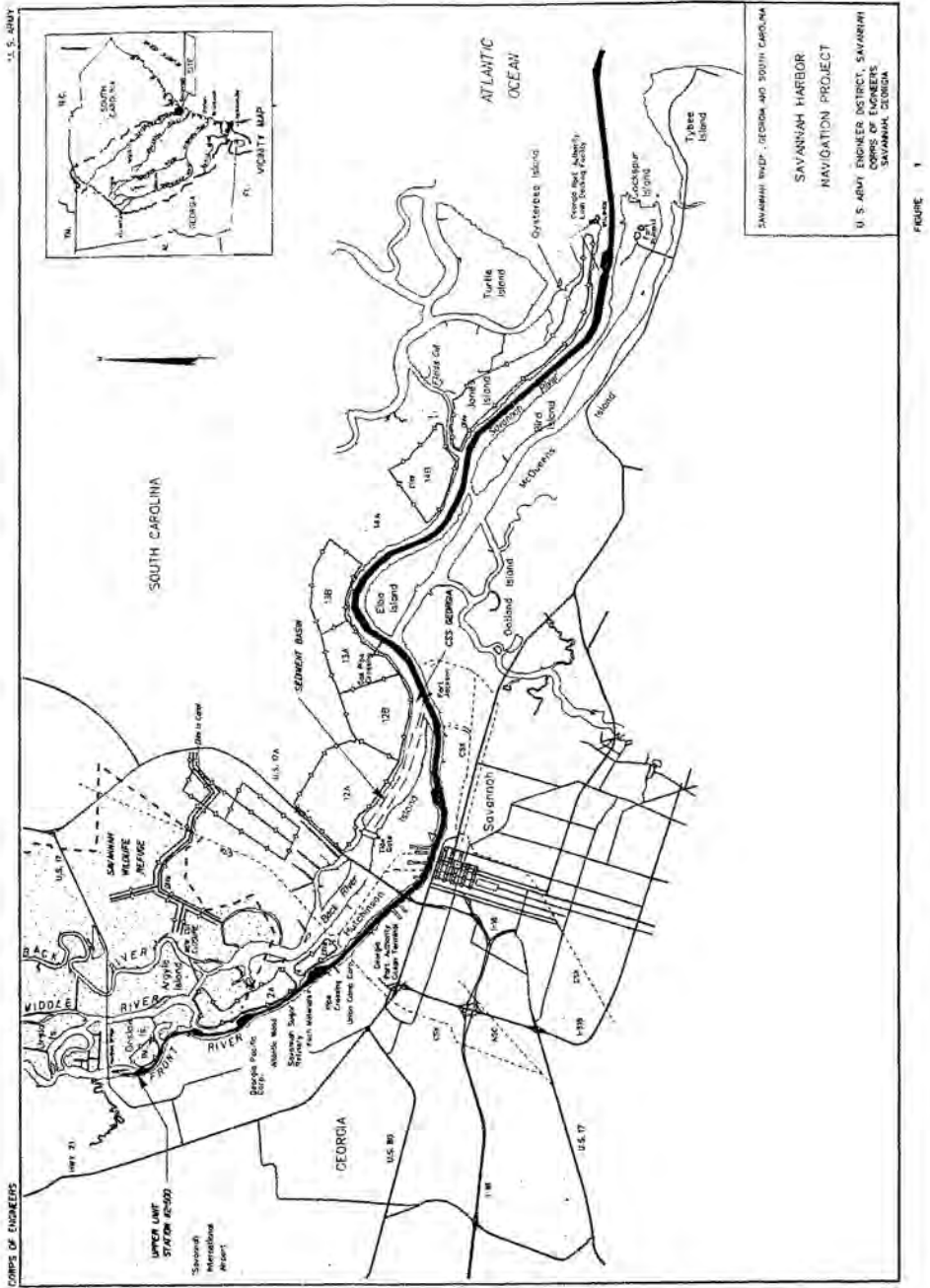
J.3.00 PROJECT DESCRIPTION

J.3.01 The Savannah Harbor Navigation Project consists of a dredged navigation channel, turning basins, disposal areas, berthing areas, an Engineer Depot, a Sediment Basin, a Tidegate, and a Tidegate access area (Figure 1).

J.3.02 Navigation Channel.

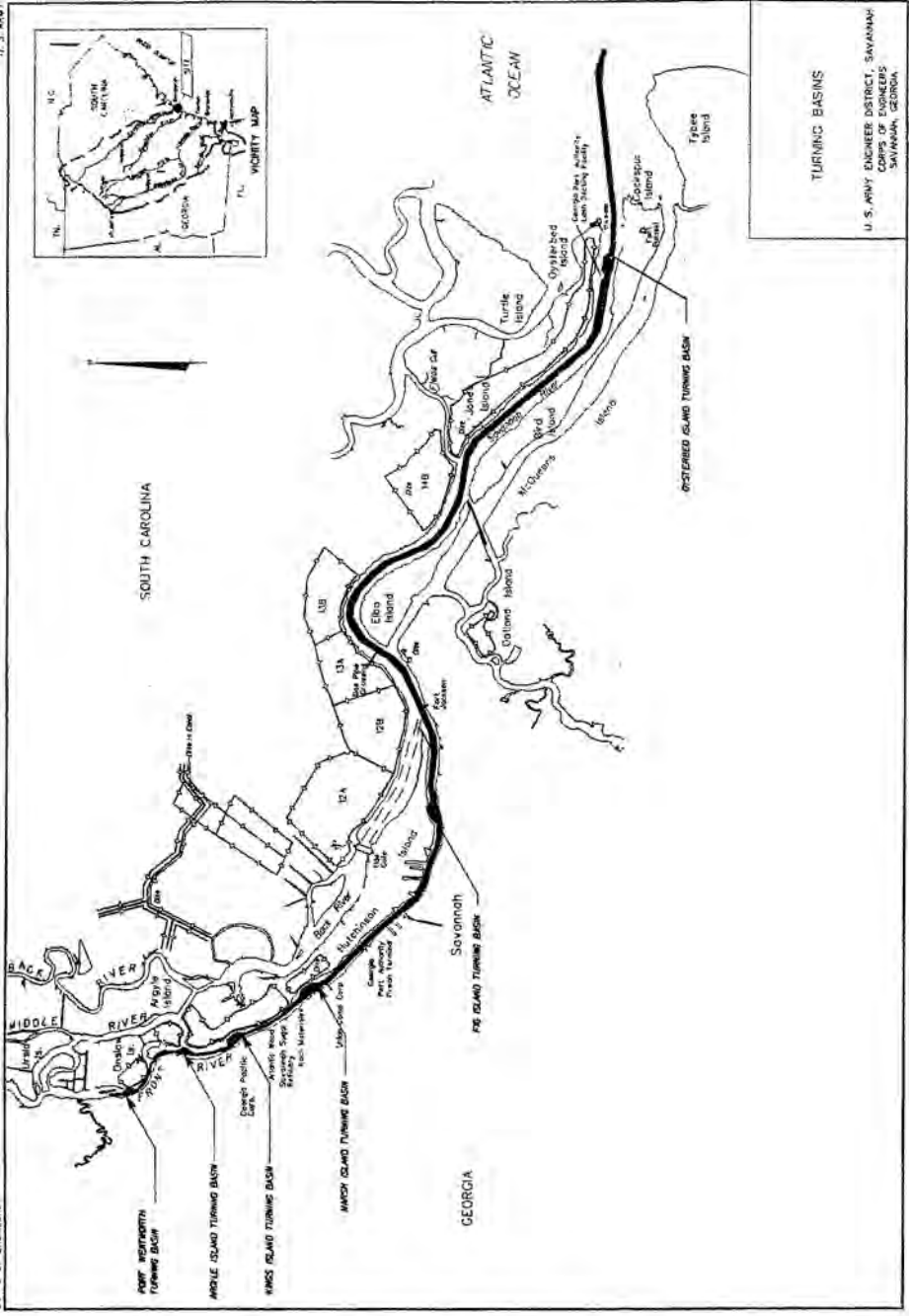
J.3.03 The navigation channel is 44-feet deep and 600 to 800-feet wide from ocean station -60+000 to station -14+000 between the jetties. It is 42-feet deep and 500-feet wide from station 14+000 to the upstream end of the Kings Island Turning Basin at station 101+500. The channel is 36-feet deep and 400-feet wide from station 101+500 to the upstream end of the Argyle Island Turning Basin at station 104+250. From station 104+250 to the harbor's upstream limit at station 112+500, the channel is maintained to a depth of 30 feet and is 200-feet wide.

J.3.04 In order to maintain harbor depths more efficiently, Savannah District has been authorized to conduct advance maintenance dredging in certain channel segments. Two feet of advance maintenance dredging has been approved for ranges 0+000 to 24+000, 70+000 to 79+000, and 100+000 to 112+000. Four feet of advance maintenance dredging has been approved for the channel between stations 24+000 to 70+000.



11.5. 2004

CORPS OF ENGINEERS



TURNING BASINS

U.S. ARMY ENGINEER DISTRICT SAVANNAH
CORPS OF ENGINEERS
SAVANNAH, GEORGIA

J.3.05 Turning Basins.

J.3.06 Savannah District maintains six turning basins in the harbor. Oysterbed Island Turning Basin is located on the north and south side of the channel between stations 2+250 and 4+250. It is maintained to a depth of 38 feet. The portion on the north side of the channel is 450 feet wide. The south side portion is 100 feet wide. Fig Island Turning Basin is located on the north side of the channel between stations 67+500 and 69+750. It is maintained at a depth of 38 feet and has a width of 400 feet. Marsh Island Turning Basin is located on the northeast side of the channel between stations 89+350 and 91+750. It is maintained to a depth of 38 feet with a width of 400 feet. Kings Island Turning Basin is located on the northeast side of the channel between stations 92+750 and 102+000. It is maintained at a depth of 42 feet and averages about 1230 feet wide. Argyle Island Turning Basin is located on the east side of the channel between stations 102+000 and 104+250. It varies from 100 to 200 feet in width and is maintained at a depth of 30 feet. Port Wentworth Turning Basin is located between stations 109+150 and 112+250 on the east side of the channel. It has a maximum width of 500 feet and is maintained at a depth of 30 feet.

J.3.07 Sediment Control Works.

J.3.08 Authorized sediment control works in Savannah Harbor include a Tidegate structure across Back River and a sediment basin immediately downstream of the tidegate. The Sediment Basin is dredged to a 40-foot depth and 600-foot width, and is approximately 2 miles long. Its 38-foot-deep and 300-foot-wide entrance channel joins the navigation channel at station 59+000. Savannah District holds fee title to lands located on either end of the tidegate. The Hutchinson Island tract contains approximately 11.91 acres of land owned in fee simple and 4.52 acres under easement (access road). This area was filled and the shoreline riprapped as part of Tidegate construction. The area is used for accessing the Tidegate and as an equipment staging and parking area. Floating docks for some Savannah District vessels are located along the shoreline. The South Carolina tract contains 14.72 acres owned in fee title; some of which was removed during tide gate construction and 6.47 acres under easement (access road). This area is used for access to that end of the Tide gate. The area has been filled and the shoreline has been riprapped.

J.3.09 U.S. Army Corps of Engineers Depot.

J.3.10 The U.S. Army Corps of Engineers Depot consists of a 7.75-acre parcel of land located on the south shore of what is now known as Hutchinson Island at Savannah Harbor Station 72+250. The facility includes offices, storage space, equipment and vehicular parking areas for various Savannah District offices (LM, IM, EN-GG, EN-S), boat and automobile fueling stations, a wharf, floating docks, and a boat ramp. The area is also used by the U.S. Coast Guard's Captain of the Port (office, maintenance area, and wharf space) and a U.S. Navy Reserve Unit (office and boat storage).

J.3.11 Disposal Areas.

J.3.12 Disposal areas for Savannah Harbor dredged material are provided by local sponsors. There are nine diked disposal areas and one off-shore disposal area for the Savannah Harbor Navigation Project. The off-shore area covers an area of 4.26 nautical square miles and is located 3.7 nautical miles from shore, south of the Savannah Harbor navigation channel.

J.3.13 Six of the diked disposal areas are located in South Carolina and three are located in Georgia. The areas are owned by the Georgia Ports Authority, Georgia Department of Transportation, Chatham County, the U.S. Fish and Wildlife Service, and private individuals.

J.3.14 Private, State, and Federally Owned Wharf Facilities. Numerous private, state, and Federally owned wharves line the navigation channel. These facilities were constructed and are maintained in accordance with permits issued by Savannah District under the authority of Section 10 of the River and Harbor Act of 1899 and Section 404 of the Clean Water Act of 1974.

J.4.00 PREVIOUS CULTURAL RESOURCES INVESTIGATIONS

J.4.01 Numerous cultural resources investigations have been conducted within and in the vicinity of the Savannah Harbor Navigation Project. Only the more important surveys are described here.

J.4.02 In 1973, the University of Georgia conducted a survey of portions of the areas to be affected by the construction of the sediment control works. This survey area was to include the tide gate construction area and proposed new disposal areas. At the time of the survey, construction of the tide gate had already

been initiated and only the disposal areas could be surveyed. Two prehistoric archaeological sites were located in judged potentially eligible for inclusion in the National Register of Historic Places.

J.4.03 In 1984, Southeastern Archeological Services, Inc., conducted a survey of the southern shoreline of Hutchinson Island preparatory to construction of the Savannah Harbor Navigation Project. The survey identified two sites that were believed eligible for inclusion in the National Register of Historic Places, Willink's Marine Railway and the Fig Island Channel Site. Willink's Marine Railway was later determined eligible for inclusion in the National Register and documented as part of a Section 10 and 404 permit for P.D. Oil and Gas Company wharf and slip construction. The work was carried out by Armstrong State College. Two vessels contained within the Fig Island Channel Site were recorded as part of the harbor widening project. The work was carried out by Tidewater Atlantic Research and S.S.I.

J.4.04 In 1987, a derelict vessel was noted eroded from the south shore of Hutchinson Island near station 76+000. The vessel was subsequently determined eligible for the National Register and was the subject of a data recovery effort by O.S.M. Archaeological Consultants in 1988.

J.4.05 In 1992, Tidewater Atlantic Research, Inc. (TAR), conducted a survey of the areas to be affected by the proposed Savannah Harbor Deepening Project. The survey included archival research, remote sensing, and shoreline inspection. The archival research concentrated on the existing disposal areas, the harbor navigation channel from stations -60+000 to +103+000, and the harbor in general. Remote sensing investigations included proton magnetometer, sidescan sonar, and sub-bottom profiler studies of the toes, sideslopes, and top of sideslopes of the navigation channel and the King's Island Turning Basin.

J.4.06 All but one of the anomalies identified by TAR were investigated by Savannah District and contract archaeological divers. None were found to represent significant cultural resources. The remaining anomaly was determined to be just outside the area of effect for the deepening project. In consultation with the Georgia State Historic Preservation Officer, it was agreed that before and after deepening hydrographic surveys would be conducted in the anomaly vicinity to determine if there was some effect. The surveys were accomplished and no change in bottom profile was noted.

J.4.07 Only one shoreline site, the Fig Island Channel Site, was recommended for data recovery as part of the deepening project. From September 1993 to January 1994, nine data recovery contracts were carried out. Over 20 historic vessels and vessel remnants and a marine railway were excavated and documented by TAR, Mid-Atlantic Technology, and Panamerican Consultants.

J.4.08 In 1992, TAR conducted a survey of the areas to be affected by the Section 1135 project to remove the Tide Gate from operation and close New Cut. The survey included archival research, remote sensing, and shoreline inspection of Back River from its mouth at the eastern end of Hutchinson Island to New Cut. The remote sensing survey included proton magnetometer, sidescan sonar, and sub-bottom profiler investigations of all submerged areas above the Tide Gate and the toe, sideslope, and area between the top of sideslope and the high water mark below the tide gate. Seven magnetic and sonar targets and seven shoreline sites were identified and recommended for further evaluation. The area above the Tide Gate is no longer part of the Savannah Harbor Navigation Project and has been addressed as part of the Section 1135 Project.

J.4.09 In 1993, Savannah District inspected the shoreline below the tide gate and found that the sites were unaffected by the New Cut Closure Project. The District also inspected each of the anomalies using sidescan sonar and found no evidence for erosion and no effect from the New Cut Closure Project.

J.4.10 Also in 1993, Mid-Atlantic Technology, Inc. (MAT) conducted a survey of the remaining portions of the Savannah Harbor Navigation Project that had not been investigated as part of the New Cut Closure Project and Savannah Harbor Deepening Project. The survey area included the toes, sideslopes, and tops of slopes for all remaining turning basins (e.g. all but King's Island) and the navigation channel from stations 103+000 to 112+500.

J.5.00 IDENTIFIED HISTORIC PROPERTIES

J.5.01 Federal Lands Owned or Administered by Savannah District.

J.5.02 U.S. Army Corps of Engineers Depot.

J.5.03 The Depot is located on a portion of the Fig Island Channel Site. The site consists of the former mouth of Fig Island Channel, a channel that once separated Fig Island from Hutchinson Island. Beginning as early as 1804, local interests attempted to close this channel by placing derelict shipwrecks in its mouth. This practice continued until the first quarter of the 20th century. Savannah District constructed a pile dam

across the mouth in 1854, wing dams in the 1870's and 1880's, and a training wall in the 1890's. The area behind the training wall was backfilled with dredged material, completely blocking the old channel and creating high ground suitable for development. The archaeological site stretches for about 1,750 along the south shore of what is now known as Hutchinson Island. The extent of the site inland has not been determined. The Engineer Depot occupies the eastern 750 feet of the site. The shoreline portion of the site within the Depot area is protected by a bulkhead.

J.5.04 The Fig Island Channel Site was determined eligible for inclusion in the National Register of Historic Places. The site is significant at the local level under National Register criterium d. for its ability to provide information important in history. The channel contains the stripped and derelict remains of a large number of watercraft that once navigated Savannah Harbor. Studies of these poorly documented craft can provide new information on vessel types used historically in the harbor, vessel repair techniques, and on vessel abandonment. Questions about how long various vessels were in use, the uses to which various vessel designs were put, reuse of vessels over time, and reasons and procedures for abandonment can be addressed. Additional research questions concerning the methods that were used to prepare vessels for use as obstructions can also be addressed.

J.5.05 Excavations were carried out in 1991 and 1994 on non-Depot portions of this site as part of the mitigation of impacts associated with the Savannah Harbor Widening Project and Savannah Harbor Deepening Projects. In the Engineer Depot portion of the site, with the exception of the boat ramp area, archaeological deposits are buried from 10 to 20 feet beneath dredge material. Present operation and maintenance practices at the Depot have no effect upon the site. However, any proposal to modify the bulkhead wall or boat ramp, or to construct facilities requiring ground disturbance to a depth of more than 10 feet will need to be evaluated for their effect upon this site.

J.5.06 Tidegate and Access Areas.

J.5.07 Since the Tide Gate was already under construction at the time of the 1973 University of Georgia survey, this area was not surveyed prior to construction disturbance and backfilling to create a higher land surface. Archival research has revealed that the Hutchinson Island Tide Gate access area was the site of Spaulding Plantation. An 1812 map indicates that main plantation village was located in the access area. It is not known if the archaeological remains of this occupation were destroyed during Tide Gate construction. This area has been covered with fill material and the shoreline is ripped. Present uses of the access area are surficial in nature and do not affect any remaining buried archaeological deposits. If any new

construction or use of the area is proposed involving excavations below +9 feet MLW, deep archaeological testing would need to be conducted to determine the existence and significance of remaining archaeological deposits.

J.5.08 Disposal Areas.

J.5.09 Only one Disposal Area, 12A, was surveyed prior to use. Two resources, site 38 JA 23 and 38 JA 24 were identified as a result of this survey. Site 38 JA 23 was described as a shell midden approximately 5 feet high and 80 feet wide and 180 feet long. Observed ceramics indicated an occupation spanning 800 B.C. and A.D. 1100. This site was located along the proposed north dike alignment. Impact was avoided during construction by realigning the dike away from the site. In 1981 information was received that unauthorized individuals were using the dike road to enter the area and loot the site. Inspection revealed that, while the dike missed the site, mosquito control ditches now ringed and bisected it. The mosquito control activity was stopped and the gate providing access to the area was locked.

J.5.10 A second, higher dike has been built inside the disposal area adjacent and parallel to the old dike. It is this dike that is now maintained and is used as an access road. A 1994 inspection revealed that the site is not being impacted by dike modifications and maintenance.

J.5.11 This site is potentially eligible for inclusion in the National Register of Historic Places. It is not being impacted by Savannah Harbor Navigation Project activities. The gate providing access to the area is kept locked. Savannah District and Georgia Department of Transportation personnel monitor the area for trespassing and looting.

J.5.12 Site 38 JA 24 was identified as a sand mound 2 feet high, 200 feet long, and 60 feet wide. The site was believed to be a small burial mound dating sometime between A.D. 0 and the historic period. The site was subsequently buried by disposal activities.

J.5.13 Archival research was conducted by TAR on the existing land disposal areas as part of the Savannah Harbor Deepening Project. The research concentrated on old maps and documents that might indicate occupation and use of the areas. The draft report of this research has not been submitted.

J.5.14 The Ferry Wharf was located on the South Carolina bank of Back River near what is now the Tidegate. The Union/Screven Ferry Road ran north from the wharf site to uplands in South Carolina. This wharf was a center of activity from the 1770's until the early 20th century. There, individuals caught the

ferry to Georgia to visit and conduct business in the city. The remains of small craft could be located in the river bottom in this area. Upland portions of the wharf were destroyed during construction of the Tidegate and disposal area dikes. The Union/Screven Ferry Road was incorporated into the dike system for the disposal areas, effectively burying the roadbed under many feet of fill. This location is not currently being affected by the Savannah Harbor Navigation Project. However, any future enlargements of the Sediment Basin could adversely affect any vessel remains lying near the wharf site.

J.5.15 All of the prehistoric and most of the historic resources that were located within the disposal area tracts will exist as archaeological deposits below elevation +10 feet MLW. The known exceptions are the Oysterbed Light Structure in the Jones/Oysterbed Disposal Area and the Civil War earthwork once located on Barnwell Island in Disposal Area 12B. When the draft TAR report is submitted, Savannah District will work with the Georgia and South Carolina State Historic Preservation Officers to determine avoidance depths for each potential resource area to insure that they are not borrowed for dike raising and other purposes.

J.5.16 Sites Adjoining the Federal Navigation Channel.

J.5.17 National Monuments.

J.5.18 Fort Pulaski National Monument is located on the south shore of the navigation channel between Savannah Harbor Stations -2+000 and +8+000. The site is significant at the national level for its architecture, association with events and people, and for archaeological potential. The site is administered by the National Park Service. It contains a lighthouse, the fort, and archaeological deposits associated with the fort and a quarantine station constructed in 1893. The Savannah Harbor Pilots Association and United States Coast Guard maintain structures and wharf facilities at Savannah Harbor station +5+000. The site is not being affected by the Savannah Harbor Navigation Project. Any modifications to the Coast Guard and Pilot Association wharves would require a Section 10 or 404 permit from Savannah District and trigger Section 106 of the National Historic Preservation Act. Close coordination with the Superintendent of Fort Pulaski will be maintained regarding any Savannah District actions in the fort vicinity. The superintendent can be contacted at (912) 786-5787.

J.5.19 National Historic Landmarks.

J.5.20 The Savannah, Georgia, National Historic Landmark District abuts the navigation channel between stations +72+000 and +77+000 (between Randolph Street and Martin Luther King Boulevard). The District is significant at the national level for its architecture, landscape architecture, and archaeology. New wharves and bulkheads were constructed for the district's entire length along the navigation project as part of a 1970's redevelopment project. It is not known if any remaining historic wharves were completely destroyed at that time, were cut down, or were built over. The district is not being affected by the Savannah Harbor Navigation Project. Ms. Elizabeth Reiter, Historic Preservation Officer with the Savannah/Chatham County Metropolitan Planning Commission, is the initial contact person for the administration of the district (912) 236-9523.

J.5.21 National Register Listed Sites.

J.5.22 Old Fort Jackson Historic Site is owned by the State of Georgia and administered by the Coastal Heritage Society. The site consists of a brick fort, moat, and surrounding, buried archaeological deposits. It is significant for its architecture and archaeology. It is located about 3 miles east of the city of Savannah at station 58+500. The site is being impacted by bank erosion and is in danger of falling into the navigation channel. Savannah District is preparing a Memorandum of Agreement with the State of Georgia to identify procedures for determining the causes of the erosion problem, any possible Federal involvement with the problem, potential solutions, and funding sources. A copy of the preliminary draft of the agreement is Attachment 1.

J.5.23 The C.S.S. GEORGIA is the wreck of a Confederate ironclad constructed in Savannah in 1862 and scuttled to prevent capture in December 1864. The wreck site is significant at the national level for its architecture, associations with events and people, and for its archaeology. The site was first located in 1968 when it was impacted by a harbor widening project. The site has been the subject of a number of Savannah District sponsored investigations to determine its geographic limits and condition. Savannah District is preparing a Memorandum of Agreement with the states of Georgia and South Carolina to identify impacts to the site, the Federal interest in mitigating these impacts, mitigation alternatives, and funding sources.

J.5.24 National Register Eligible Sites.

J.5.25 The Venus Point Light Structure was located in South Carolina near Savannah Harbor station 15+000. It was located on the river shore in front of the south dike for the Jones/Oysterbed Island Disposal Area. It had been undermined and was in danger of collapse as a result of harbor deepening activities and operation and maintenance dredging. The site was determined eligible for inclusion in the National Register of Historic Places in 1994. It was significant at the local level for its architecture and history. It was to be documented to Historic American Engineering Standards. The site collapsed into the river shortly before the contractor arrived on site. The contractor is gathering historical documentation, photographs, and drawings, and is using measurements taken in 1993 by Savannah District archaeologists to document the site. No further cultural studies are proposed for this site.

J.5.26 The Fig Island Channel Site is located on privately owned and Savannah District lands. The site consists of the former mouth of Fig Island Channel, a channel that once separated Fig Island from Hutchinson Island. Beginning as early as 1804, local interests attempted to close this channel by placing derelict shipwrecks in its mouth. This practice continued until the first quarter of the 20th century. Savannah District constructed a pile dam across the mouth in 1854, wing dams in the 1870's and 1880's, and a training wall in the 1890's. The area behind the training wall was backfilled with dredged material, completely blocking the old channel and creating high ground suitable for development. The archaeological site stretches for about 1,750 along the south shore of what is now known as Hutchinson Island. The extent of the site inland has not been determined. The portion of the site located beneath the Engineer Depot has been discussed previously.

J.5.27 The Fig Island Channel Site was determined eligible for inclusion in the National Register of Historic Places. The site is significant at the local level under National Register criterion d. for its ability to provide information important in history. The channel contains the stripped and derelict remains of a large number of watercraft that once navigated Savannah Harbor. Studies of these poorly documented craft can provide new information on vessel types used historically in the harbor, vessel repair techniques, and on vessel abandonment. Questions about how long various vessels were in use, the uses to which various vessel designs were put, reuse of vessels over time, and reasons and procedures for abandonment can be addressed. Additional research questions concerning the methods that were used to prepare vessels for use as obstructions can also be addressed.

J.5.28 Excavations were carried out in 1991 and 1994 on portions of this site as part of the mitigation of impacts associated with the Savannah Harbor Widening Project and Savannah Harbor Deepening Projects. The data recovery efforts were sufficient to document all wrecks and other features that would be impacted by slope destabilization resulting from the harbor deepening project. The private and state owned portions of the site have not been bulkheaded. The present navigation channel spans the entire river channel between the Savannah National Historic Landmark District. Any change in harbor maintenance procedures or any channel modification will impact this site.

J.5.29 Potentially Significant Sites.

J.5.30 The Irene Mound Site, a Mississippian Period ceremonial center, was once located at the juncture of Pipe Maker's Canal and the Savannah River. The site area was severely impacted by 1960's period non-Federal port development activities. It is not known if any intact portions remain beneath existing structures. This site is not being impacted by Savannah District activities. This site will need to be taken into account if there is any change in Savannah District activities that might impact the area or if a change in land use is proposed that triggers a Section 10 or 404 permit.

J.5.31 Battery Lee is a Confederate earthwork located on the edge of the Savannah Harbor navigation channel. It is being impacted by dredging associated with a privately owned wharf. A determination of National Register eligibility and a determination of effect need to be made when the agitation Sections 10 and 404 regulatory permits are proposed for renewal.

J.5.32 Turnbull's Tavern Site is the archaeological remains of a late 18th/early 19th century tavern and wharf located on the river shore. Any modifications to the navigation channel may undermine this site.

J.5.33 Southeastern Shipyard is a World War II period shipyard that produced commercial ocean-going vessels. The buildings have all been removed or razed. The launching rails are still visible at low water. The site is not being impacted by the present navigation project.

J.5.34 Miller's Iron Foundry Site is the archaeological remains of an antebellum and bellum iron foundry. The foundry was a major supplier of local steam plants prior to the war. During the war, it also produced ordnance. It was burned in December 1864 to keep it out of Union hands. For a brief period after the war it was used by Union troops. The site is not being affected by the navigation project.

J.5.35 Willink's antebellum and bellum shipyard was the largest shipbuilding facility in Georgia from 1840 to 1865. It produced intracoastal and river steamers, sailing pilot boats, and other craft. During the war it completed one ironclad and nearly completed two others. It was burned in December 1864 to keep it out of Union hands. The site is not being affected by the navigation project.

J.5.36 Eleven potentially significant stripped and derelict vessels are eroding from the harbor shoreline. They appear to be the remains of a late 18th/early 19th century sloop or schooner, a late 18th/early 19th century pole boat, an intracoastal steamer, a late 19th/early 20th century steel lifeboat(?), a mid to late 19th century steam powered, propeller driven vessel, two 19th century sailing vessels, and four late 19th/early 20th century wooden barges. While none are being affected by the Savannah Harbor Navigation Project, streambank erosion is slowly destroying all of them.

J.5.37 Terry Shipyard is a World War I period shipyard that was apparently built tugboats for the war effort. No buildings have been preserved, however, the remains of at least three slipways and access wharves are present. The site is not being affected by the navigation project, however, streambank erosion is impacting the shoreline portions of the site.

J.5.38 The Krenson and Hawkes Shipyard was active from about 1840 to 1875. It constructed intracoastal steamers and tugboats during the antebellum period. During the war it constructed one Maury Gunboat for the Confederate Navy and had an ironclad on the stocks when it was burned to prevent its capture in 1864. The yard was at least partially rebuilt after the war. At least one sailing pilot boat was constructed during this period. In the latter part of the 19th century, this was the site of a large steamship wharf. It is not known if any archaeological deposits are preserved beneath the present wharf facility.

J.5.39 The Ferry Wharf was located on the shore of Savannah Harbor at the foot of East Broad Street. This was a center of activity from the 1770's until the early 20th century. There, individuals caught the ferry to South Carolina and more their sailing and rowing small craft when visiting the city. The remains of numerous small craft may be clustered in the river bottom in this area. This location is not being affected by the Savannah Harbor Navigation Project, however, any future channel widening or deepening, dredging for mooring vessels, or bulkheading could adversely affect this potential resource.

J.5.40 Federal Batteries were once located along the south shore of South Channel from the northeast tip of Tybee Island to Lazaretto Creek. The archaeological remains of these batteries may be preserved. Live ordnance may also be located in the river channel. If the remains of these batteries exist, they are of National Landmark significance due to their association with Fort Pulaski National Monument. Since these resources are located along South Channel, they are not being affected by the Savannah Harbor Navigation Project. Any development in this area should consider the area's archaeological potential and aesthetic effects upon the National Monument.

J.5.41 The archaeological remains of the 18th century Savannah quarantine station may still be at least partially extant. Portions of the associated cemetery exist. This site is not being affected by the Savannah Harbor Navigation Project.

J.5.42 Two possible 19th century crib wharves are located along the harbor shoreline. The wharves are not being affected by the Savannah Harbor Navigation Project but are being impacted by streambank erosion.

J.5.43 Submerged Anomalies. Sixteen uninvestigated submerged magnetic and/or sonar targets have been identified in the vicinity of the navigation channel or sediment basin. Only are potentially being affected by the Savannah Harbor Navigation Project or other harbor related activities. These five anomalies are located in the upper harbor on or near the channel side slope. Diver investigations are planned to determine their identity and potential significance.

J.6.00 SUMMARY OF IMPACTS

J.6.01 Federally Owned or Managed Properties.

J.6.02 The National Register eligible Fig Island Channel Site and the potential site of the Spaulding Plantation complex are located on fee owned lands. Both sites are deeply buried and the shorelines have been riprapped or bulkheaded. Neither site is being affected by present land uses.

J.6.03 Navigation Channel and Turning Basins.

J.6.04 Two significant resources may be undergoing impacts from channel maintenance dredging, Old Fort Jackson and the C.S.S. GEORGIA. Savannah District is preparing a Memorandum of Agreement (MOA) for each site. Under the terms of the MOAs, the District will identify impacts to the sites, any Federal involvement in the impacts, alternatives for mitigation, and

funding methods. Signatory parties for the MOA for Old Fort Jackson will include Savannah District, the Georgia State Historic Preservation Officer, the Coastal Heritage Society, and the Advisory Council for Historic Preservation. Signatory parties on the MOA for the C.S.S. GEORGIA will include Savannah District, the Georgia and South Carolina State Historic Preservation Officers, and the Advisory Council for Historic Preservation.

J.6.05 Five magnetic and/or sonar anomalies have been identified in the upper harbor that may be located within the area of effect for operation and maintenance dredging. Future investigations as to the source of these anomalies is planned.

J.6.06 Disposal Areas.

J.6.07 Under the terms of a Savannah District contract, Tidewater Atlantic Research is conducting archival research to determine the locations of historic period resources that may be buried beneath the disposal areas. Their report will be coordinated with the Georgia and South Carolina State Historic Preservation Officers and preservation and/or avoidance procedures will be determined. Site 38 JA 23 is located immediately adjacent to Disposal Area 12A. The access gate to this area will be kept locked and District and GADOT personnel area will monitor the area for trespass and vandalism.

J.6.08 Other Shoreline and Submerged Resources.

J.6.09 Many areas of Savannah Harbor are lined with historic properties. While these resources are not being affected by the Savannah Harbor Navigation Project, they need to be taken into account when processing Section 10 and 404 regulatory permits.

J.7.00 VIEWS OF THE STATE HISTORIC PRESERVATION OFFICERS

J.7.01 This plan was reviewed by the Georgia and South Carolina State Historic Preservation Officers. Comments of the GA SHPO have been incorporated/addressed in the final document. The SC SHPO furnished no comments.

J.8.00 STATEWIDE COMPREHENSIVE HISTORIC PRESERVATION PLANS

J.8.01 The States of Georgia and South Carolina's plans call for the preservation of sites within all cultural and time periods, and develops historic contexts for each. Historic preservation activities at the project within Georgia will be conducted in coordination with the Georgia State Historic Preservation Officer.

J.9.00 MASTER AND OPERATIONAL MANAGEMENT PLANS

J.9.01 There are no Master or Operational Management Plans for Savannah Harbor Navigation Project. Information from the this Historic Preservation Plan will be incorporated into the Savannah Harbor Navigation Project's Long Term Management Strategy (LTMS) Study. Exact locations and dispositions of historic properties on project fee and easement lands and privately and publicly owned lands adjoining the project will not be identified in the LTMS study.

J.10.00 CONSULTATION WITH AFFECTED INDIAN TRIBES

J.10.01 Federally Owned or Managed Lands.

J.10.02 All future studies of historic properties on fee owned or easement lands on Savannah District projects will include appropriate provisions to insure full compliance with the Native American Graves and Repatriation Act of 1990 (NAGPRA).

J.10.03 NAGPRA addresses the recovery, treatment, and repatriation of Native American and Native Hawaiian cultural items by Federal agencies on Federally owned or controlled lands and Indian Reservations. It also applies to museums receiving Federal funding or containing Federally owned collections. Cultural items include human skeletal remains, associated funerary objects, unassociated funerary objects, sacred objects, and objects of cultural patrimony.

J.10.04 There are many data gathering, reporting, consulting, and permitting provisions in the law that will have some degree of impact on the historic resources program for the Savannah District. The Department of the Interior is developing Federal regulations that will aid in carrying out NAGPRA. Meanwhile, the Savannah District has begun implementation of NAGPRA.

J.10.05 There are no known Native American sites located on Savannah District's fee owned or easement lands. The Engineer Depot is located entirely upon a river channel that was filled in the late 19th and early 20th centuries. The Tide Gate access

tracts were formerly marsh areas that were covered by several feet of modern fill in 1968. The shorelines are riprapped or bulkheaded. If any Native American archaeological sites are present, they are deeply buried and are not being affected by present and proposed future District activities.

J.10.06 Native American Resources on Non-Federal Lands.

J.10.07 NAGPRA does not apply directly to Native American cultural objects located on non-Federal or Indian Reservation lands. However, it does apply to the collections if they are curated at a Federally funded museum or other facility.

J.10.08 Native American graves and associated materials on non-Federal lands located in Georgia are covered under various State laws. The following information is taken directly from a brochure distributed by the Council on American Indian Concerns.

- * Indian burials and burial grounds are protected by law in the same manner as any grave without an appropriate permit. It is also illegal to know about, and fail to report, the disturbance of a grave. Important points of the law are:

- * It is illegal to disturb Indian burials (unless part of an authorized excavation by an archeologist).

- * If human remains or burial goods are accidentally exposed, it should be immediately reported to the local law enforcement agency (usually the sheriff).

- * Any activity likely to further disturb the burial must cease until local or state authorities permit activity to continue.

- * The local law enforcement agency must work with the local coroner or medical examiner to determine if accidentally discovered human remains are a crime event or archeological site.

J.10.09 Georgia Code Section 12-3-621 makes it illegal to dig, disturb, or harm an archaeological, aboriginal, prehistoric or historic site without first receiving written permission from the landowner. Anyone wishing to excavate a site must notify the Georgia Department of Natural resources, in writing, five business days before the excavations are scheduled to begin.

J.10.10 Georgia Code Section 12-3-622 makes it illegal to knowingly buy, sell, trade, import, or export for profit American Indian burial objects or sacred objects. Georgia Code Section 31-21-45 makes it illegal to display the bodily remains of Native Americans.

J.10.11 Only one Native American site has been identified in the immediate vicinity of the navigation channel in Georgia. The Irene Mound Site, a Mississippian Period ceremonial center, was once located at the juncture of Pipe Maker's Canal and the Savannah River. The site appears to have been abandoned by A.D. 1450. Archaeological investigations revealed that the site contained human remains and ceremonial objects. The National Park Service is complying with NAGPRA for these remains and objects.

J.10.12 The Irene Mound Site area was severely impacted by 1960's period non-Federal port development activities. It is not known if any intact portions of the site remain beneath existing structures. This site is not being impacted by Savannah District activities. This site will need to be taken into account if there is any change in Savannah District activities that might impact the area or if a change in land use is proposed that triggers a Section 10 or 404 permit.

J.10.13 Two Native American sites are known to be associated with disposal areas. Site 38 JA 23 is located outside Disposal Area 12A. It may contain human remains and grave goods. No NAGPRA artifacts have been recovered by Savannah District. It is not being affected by dike construction and maintenance. The access gate to the dike road is kept locked and the area is monitored by Savannah District and Georgia Department of Transportation (GADOT) personnel to preclude vandalism. Any future impacts to this site associated with dike maintenance, disposal area enlargement, or other activities would be the responsibility of GADOT personnel in coordination with the South Carolina State Historic Preservation Officer, Savannah District, Native American representatives, and the Advisory Council on Historic Preservation.

J.10.14 Site 38 JA 24 is buried beneath Disposal Area 12A. It is a small sand mound that may contain human remains. No archaeological materials of any kind have been recovered from it. This mound was only 2 feet high and is now covered by 10 or more feet of dredged disposal material. Both the mound and the disposal material are composed of sand. It is not known if this mound survived various dike raisings and repairs that have occurred since 1973. No sand borrowing for dike construction or other activities will be allowed in the vicinity of this mound location. Any future impacts to this site associated with dike maintenance, disposal area enlargement, or other activities would

be the responsibility of GADOT personnel in coordination with the South Carolina State Historic Preservation Officer, Savannah District, Native American representatives, and the Advisory Council on Historic Preservation.

J.11.00 PUBLIC INTERPRETATION

J.11.01 Several times each year, Savannah District archaeologists present slide shows to civic groups, schools, and clubs. Over the last few years, these groups have included the May Howard Elementary School 5th Grade Search Class (a yearly event), other school groups, Rotary Clubs, Optimist Clubs, the Coastal Georgia Archaeological Society, the Society for Georgia Archaeology, the Conference on Historical and Underwater Archaeology, the Savannah Maritime Festival, etc.

J.12.00 REQUIRED ACTIONS

J.12.01 Federally Owned or Administered Lands.

J.12.02 Present management practices and uses at the Engineer Depot are not affecting the deeply buried cultural resources located on these tracts. Any modification of these areas or changes in land use that involves subsurfaces impacts to an elevation at or below +10 feet above mean low water should be reviewed for potential impacts to these resources.

J.12.03 Since the proposed installation of underdrains at the confined disposal areas would require excavation below a +13 MLW elevation (less than 6 feet above MHW), there is a potential for adverse impacts to cultural resources located on those sites. A review will be performed of historic maps and archival records of sites known to be located on the disposal areas. If proposed underdrain alignments conflict with known or suspected cultural resource sites, a cultural resources survey would be conducted along the proposed underdrain alignments. If a cultural resource is found, either the underdrain alignment would be shifted to avoid the site or a mitigation plan would be prepared to determine the appropriate action. This procedure would be performed to ensure no significant cultural resources would be impacted. Approval from the SC SHPO of the survey's findings and proposed actions would be obtained prior to construction (underdrain installation) being initiated at the site.

J.12.04 Navigation Channel and Turning Basins.

J.12.05 Two resources may be undergoing impacts from harbor maintenance dredging, the C.S.S. GEORGIA and Old Fort Jackson. The Memorandums of Agreement need to be completed and signed by the consulting parties, and their terms implemented.

J.12.06 Other Shoreline and Submerged Resources.

J.12.07 Significant and potentially significant cultural resources line portions of the navigation channel and sediment basin. These resources need to be considered if any changes are made in harbor maintenance, channel modifications are proposed, or activities subject to Section 10 or 404 regulatory permits are proposed. Open communication needs to be maintained with the superintendent of Fort Pulaski National Monument, the Savannah/Chatham County Historic Preservation Officer, the Coastal Heritage Society, and other preservation organizations.

J.12.08 ARPA Permits.

J.12.09 Anyone conducting archaeological investigations on Savannah District owned portions of the project requires an ARPA permit. A contract for cultural resource work awarded by Savannah District constitutes a permit. All others must apply to Savannah District for the permit. This includes archaeological work generated by another task, such as pipeline and electrical easements, construction easements, etc. and independent archaeological research. The Savannah District contact for technical archaeological information on such permits is the Environmental Resources Branch of Planning Division. For further information, call (912) 652-5325 or FAX at (912) 652-5787. The permits are administered and issued through the Real Estate Division (CESAS-RE-MC). Information can be obtained at 912-652-5013.

J.12.10 Curation.

J.12.11 ER 1130-2433, Project Operations, Storage and Curation of Archaeological and Historic Data, dated 30 April 1991, describes curation needs and procedures. Planning Division (PD-E) is developing an overall district curation program for archaeological and historical collections from operational and planning projects. Collections from previous investigations associated with the construction and operation of Savannah Harbor Navigation Project are stored at Savannah District, Savannah

History Museum, Armstrong State College, and various contractor offices. As contracts are closed out, collections held by contractors are being returned to Savannah District for interim storage until a curation program has been put in place.

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APPENDIX K

MEMORANDUM OF AGREEMENT
CONCERNING
OLD FORT JACKSON

MEMORANDUM OF AGREEMENT
BETWEEN
THE U.S. ARMY ENGINEER DISTRICT, SAVANNAH,
THE COASTAL HERITAGE SOCIETY,
THE GEORGIA STATE HISTORIC PRESERVATION OFFICER, AND
THE ADVISORY COUNCIL ON HISTORIC PRESERVATION
CONCERNING
OLD FORT JACKSON, SAVANNAH, GEORGIA

WHEREAS, the U.S. Army Engineer District, Savannah (Savannah District) operates and maintains the Savannah Harbor Navigation Project, as authorized by various public laws, and

WHEREAS, Savannah District recognizes that the existing Savannah Harbor Navigation Project may have an effect upon Old Fort Jackson, a property owned by the State of Georgia and included on the National Register of Historic Places, and has consulted with the Advisory Council on Historic Preservation (Council) and the Georgia State Historic Preservation Officer (GASHPO) pursuant to Section 800.13 of the regulation (36 CFR Part 800) implementing Section 106 of the National Historic Preservation Act (16 U.S.C. 470h-2(f)), and

WHEREAS, the definitions given in Appendix A are applicable throughout this Memorandum of Agreement (Agreement);

NOW THEREFORE, Savannah District, the Council, and the GASHPO agree that the following stipulations will satisfy Savannah District's Section 106 responsibilities for identifying, evaluating, and mitigating any effects of the Savannah Harbor Navigation Project upon Old Fort Jackson.

STIPULATIONS

The Savannah District, U.S. Army Corps of Engineers shall ensure that the following measures are carried out:

1. Savannah District shall conduct such studies as are necessary to determine the nature, extent, and cause(s) of the streambank erosion problem at Old Fort Jackson.
2. Savannah District shall determine the contributing effect of the construction and/or maintenance of the Savannah Harbor Navigation Project on bank erosion at the Old Fort Jackson Historic site, in accordance with 36 CFR Parts 800.5 and 800.9.

3. If the conclusion from studies conducted under Stipulations #1 and #2 is that construction and/or maintenance of the Savannah Harbor Navigation Project contributes to the bank erosion problem at the Old Fort Jackson Historic Site, then Savannah District will implement Stipulations #4 through #12.

4. Savannah District shall identify and evaluate alternatives to eliminate, minimize, and retard the contribution to bank erosion problem at the Old Fort Jackson Historic site, caused by the construction and/or maintenance of the Savannah Harbor Navigation Project.

5. Savannah District shall develop a mitigation plan to minimize the adverse effects of streambank erosion on Old Fort Jackson, resulting from the construction and/or maintenance of the Savannah Harbor Navigation Project, in accordance with 36 CFR Part 800.5.

6. The District's studies, study results, evaluations and determinations shall be documented in a report. The report will include a discussion of various erosion control alternatives, the merits, efficacy, and projected costs of each alternative, and make recommendations as to the optimal erosion control alternative(s). The optimal erosion control plan shall be incorporated into a draft mitigation plan for mitigating the adverse effects to the Old Fort Jackson Historic site resulting from the Savannah Harbor Navigation Project.

7. The draft mitigation plan shall be provided to the GASHPO, the Council, the Coastal Heritage Society, and interested local historical groups for comment. A review by managers of historic sites which have experienced similar problems will also be pursued. A final mitigation plan, including mitigation recommendations and projected costs of implementation, shall be developed following receipt and consideration of all comments.

8. Savannah District shall, in consultation with the property owner, the State of Georgia, and the property lessee and operator, the Coastal Heritage Society, develop a cost-sharing program by which the mitigation measures recommended as the optimal solution to the bank erosion problem at the Old Fort Jackson Historic Site may be implemented.

9. Savannah District, in conjunction with the GASHPO and the Coastal Heritage Society, shall implement the recommended plan subject to the availability of funds. Savannah District shall function as the lead party in coordinating and implementing the work necessary to implement the mitigation plan.

10. Should the mitigation plan entail the alteration or destruction of any features associated with the Old Fort Jackson Historic Site, such that data recovery of buried archeological deposits/artifacts might be recovered, a research design for the

necessary data recovery shall be developed by the Savannah District and coordinated with the GASHPO and the Coastal Heritage Society, who shall have the opportunity to review and comment on the proposed data recovery plan.

11. The final mitigation plan shall be submitted by Savannah District to the GASHPO and the Council for a 45-day review period. Unless the GASHPO or the Council objects during the review period, the mitigation plan shall be considered approved.

12. Savannah District shall ensure that any archeological data recovery carried out pursuant to this Agreement is carried out by, or under, the direct supervision of an individual meeting, at a minimum, the standards for an archeologist as set forth in the Department of the Interior's Archeological and Historic Preservation: Secretary of the Interior's Standards and Guidelines (48 FR 44716-42) for a historic archeologist.

13. Savannah District shall ensure that any and all materials and records resulting from any investigations (data recovery) conducted as part of Stipulation #12 are curated in accordance with 36 CFR Part 79. Curation facilities at the following locations will be considered for these materials and records: (1) University of Georgia, (2) South Carolina Institute of Archaeology and Anthropology, and (3) University of Alabama. Other facilities may be considered, but the facility selected for use must be able to fulfill the Federal curation requirements. Short or long term loans of "exhibit quality" artifacts will be considered to reputable museums or historic sites which can address these special needs.

14. Savannah District shall ensure that all final reports resulting from actions pursuant to this Agreement will be provided to the GASHPO and the Council, and to the National Park Service, Southeast Regional Office for possible peer review and submission to the National Technical Information Service (NTIS). Savannah District shall ensure that all such reports are responsive to the contemporary professional standards, and to the Department of Interior's "Format Standards for Final Reports of Data Recovery Programs" (42 FR 5377-5379).

15. Any party to this Agreement may request that it be amended, whereupon the parties will consult in accordance with 36 CFR 800.5(e)(5) to consider such amendment.

16. Should the GASHPO or the Council object within 45 days to any actions proposed pursuant to the Agreement, Savannah District shall consult with the objecting party to resolve the objection. If Savannah District determines that the objection cannot be resolved, Savannah District shall request the further comments of

the Council pursuant to 36 CFR Part 800.4 to 800.6. Any Council comment provided in response to such a request will be taken into account by Savannah District in accordance with 36 CFR Part 800.6(c)(2) with reference only to the subject of the dispute; Savannah District's responsibility to carry out all actions under this Agreement that are not the subjects of the dispute will remain unchanged.

17. At any time during implementation of the measures stipulated in this Agreement, should an objection to any such measure be raised by a member of the public, Savannah District shall take the objection into account and consult, as needed, with the objecting party, the GASHPO or the Council to resolve the objection.

Execution of this Memorandum of Agreement and implementation of its terms evidences that the Savannah District, U.S. Army Corps of Engineers has afforded the Council an opportunity to comment on the Savannah Harbor Navigation Project and its effects on the Old Fort Jackson Historic Site and that the Savannah District has taken into account the effects of the undertaking on that historic property.

U.S. ARMY ENGINEER DISTRICT, SAVANNAH

BY: _____ DATE: _____
 GRANT M. SMITH
 COLONEL, U.S. ARMY
 DISTRICT ENGINEER

COASTAL HERITAGE SOCIETY, INC.

BY: _____ DATE: _____
 SCOTT SMITH
 DIRECTOR

GEORGIA DEPARTMENT OF NATURAL RESOURCES
 GEORGIA STATE HISTORIC PRESERVATION OFFICER

BY: _____ DATE: _____
 MARC R. EDWARDS
 DIRECTOR, HISTORIC SITES DIVISION AND GASHPO

ADVISORY COUNCIL ON HISTORIC PRESERVATION

BY: _____ DATE: _____
 ROBERT D. BUSH
 EXECUTIVE DIRECTOR

MEMORANDUM OF AGREEMENT
BETWEEN
THE U.S ARMY ENGINEER DISTRICT, SAVANNAH,
THE COASTAL HERITAGE SOCIETY,
THE GEORGIA STATE HISTORIC PRESERVATION OFFICER, AND
THE ADVISORY COUNCIL ON HISTORIC PRESERVATION
CONCERNING
OLD FORT JACKSON, SAVANNAH, GEORGIA

APPENDIX A

DEFINITIONS:

Savannah Harbor Navigation Project:

The Federal Navigation Project (Project) consists of those features authorized by the U.S. Congress, or authorized under authorities delegated by the U.S. Congress, to provide safe and efficient navigation through Savannah Harbor or to reduce adverse impacts of those features. The Project includes both the physical features constructed in conformance with prior authorizations, and subsequent maintenance activities associated with continued operation of those features. The physical features include the navigation channel, advance maintenance sections, bend wideners, turning basins, berthing areas, sediment control works, freshwater control works, and dredged material disposal areas.

Old Fort Jackson:

Old Fort Jackson consists of a brick fortification, moat, and surrounding, buried archaeological deposits. It is significant for its architecture and archaeology.

The property is owned by the state of Georgia and is included on the National Register of Historic Places. The site is administered by the Coastal Heritage Society.

The site is located at approximately Station 58+400 (River Mile 11.1) on the south bank of the Savannah River across from the mouth of Back River. The Fort is situated on a 7.8-acre tract bounded by the Savannah River on the northwest, with adjacent lands on the east, south, and southwest consisting of undeveloped lowlands owned by the American Cyanamid Corporation.

APPENDIX L

MEMORANDUM OF AGREEMENT
CONCERNING *
THE C.S.S. GEORGIA

MEMORANDUM OF AGREEMENT
BETWEEN
THE U.S. ARMY ENGINEER DISTRICT, SAVANNAH,
THE GEORGIA STATE HISTORIC PRESERVATION OFFICER, AND
THE SOUTH CAROLINA STATE HISTORIC PRESERVATION OFFICER, AND
THE ADVISORY COUNCIL ON HISTORIC PRESERVATION
CONCERNING
THE CONFEDERATE IRONCLAD, CSS GEORGIA

WHEREAS, the U.S. Army Engineer District, Savannah (Savannah District) operates and maintains the Savannah Harbor Navigation Project, as authorized by various public laws, and

WHEREAS, Savannah District recognizes that the Savannah Harbor Navigation Project may contribute to the effect upon the CSS Georgia, a Confederate ironclad which is listed on the National Register of Historic Places, and has consulted with the Advisory Council on Historic Preservation (Council), the Georgia State Historic Preservation Officer (GASHPO), and the South Carolina State Historic Preservation Officer (SCSHPO) pursuant to Section 800.13 of the regulation (36 CFR Part 800) implementing Section 106 of the National Historic Preservation Act (16 U.S.C. 470h-2(f)), and

WHEREAS, the definitions given in Appendix A are applicable throughout this Memorandum of Agreement (Agreement);

NOW THEREFORE, Savannah District, the Council, the GASHPO, and the SCSHPO agree that the following stipulations will satisfy Savannah District's Section 106 responsibilities for identifying, evaluating, and mitigating effects of the Savannah Harbor Navigation Project upon the CSS Georgia.

STIPULATIONS

The Savannah District, U.S. Army Corps of Engineers shall ensure that the following measures are carried out:

1. Savannah District shall conduct such studies as are necessary to determine the present condition of the vessel, its stability as a historic site/object, any factors which may threaten its present condition or stability, and restrictions which the vessel places on present harbor operations.

2. Savannah District shall determine the contributing effect of the construction and/or maintenance of the Savannah Harbor Navigation Project on the CSS Georgia, in accordance with 36 CFR Parts 800.5 through 800.9.

3. A draft report documenting the studies conducted under Stipulations #1 and #2, as well as the resulting findings and determinations shall be complete within three years of the signature of the last party to this agreement. If the conclusion from the studies is that construction and/or maintenance of the Savannah Harbor Navigation Project contributes to the degradation or reduced stability of the CSS Georgia, then the Savannah District will implement Stipulations #4 through #12.

4. The Savannah District shall identify and evaluate alternatives to eliminate, minimize, and retard the Savannah Harbor Navigation Project contribution to factors which may threaten the vessel's present condition or stability. If the vessel is restricting present harbor operations, alternatives shall be evaluated which would allow those restrictions to be eliminated or minimized.

5. Savannah District shall develop a mitigation plan to minimize the adverse effects on the CSS Georgia resulting from the construction or maintenance of the Savannah Harbor Navigation Project, in accordance with 36 CFR Part 800.5. The mitigation plan will document alternatives which were evaluated to eliminate or minimize restrictions which the CSS Georgia causes on the Savannah Harbor Navigation Project.

6. The District's studies, study results, evaluations and determinations shall be documented in a report. The report will include a discussion of the present condition of the vessel, factors which may threaten the vessel's present condition, adverse effects which construction and/or maintenance of the Project has had on the vessel, and restrictions which the vessel has on present harbor operations, the merits, efficacy, and projected costs of each alternative, and make recommendations as to the optimal alternative(s). The plan shall be incorporated into a draft mitigation plan for mitigating the adverse effects to the CSS Georgia resulting from the Savannah Harbor Navigation Project.

7. The draft mitigation plan shall be provided to the GASHPO, the SCSHPO, the Council, and interested local historical groups for comment. A peer review will also be pursued. A final mitigation plan, including mitigation recommendations and projected costs of its implementation shall be developed following receipt and consideration of all comments.

8. Savannah District shall implement the recommended plan, subject to the availability of funds. If funds do not appear to be available to implement all components of the recommended plan specified for a given year, the District will consult the parties to this agreement within 30 days of such a finding to determine what actions the District will need to perform to remain in compliance with Section 106 of the National Historic Preservation Act.

9. Should the mitigation plan entail the alteration or destruction of any features associated with the CSS Georgia, such that data recovery of buried archeological deposits/artifacts might be recovered, a research design for the necessary data recovery shall be developed by the Savannah District and coordinated with the GASHPO and the SCSHPO, who shall have the opportunity to review and comment on the proposed data recovery plan.

10. The final mitigation plan shall be submitted by Savannah District to the GASHPO, the SCSHPO, and the Council for a 45-day review period. Unless the GASHPO, the SCSHPO, or the Council objects during the review period, the mitigation plan shall be considered approved.

11. Savannah District shall ensure that any archeological data recovery carried out pursuant to this Agreement is carried out by, or under the direct supervision of, an individual meeting, at a minimum, the standards for an archeologist as set forth in the Department of the Interior's Archeological and Historic Preservation: Secretary of the Interior's Standards and Guidelines (48 FR 44716-42) for a historic archeologist.

12. Savannah District shall ensure that any and all materials and records resulting from any investigations (data recovery) conducted as part of Stipulation #11 are curated in accordance with 36 CFR Part 79. Curation facilities at the following locations will be considered for these materials and records: (1) University of Georgia, (2) South Carolina Institute of Archaeology and Anthropology, and (3) University of Alabama. Other facilities may be considered, but the facility selected for use must be able to fulfill the Federal curation requirements. Short or long term loans of "exhibit quality" artifacts will be considered to reputable museums or historic sites which can address these special needs.

13. Savannah District shall ensure that all final reports resulting from actions pursuant to this Agreement will be provided to the GASHPO, the SCSHPO, and Council, and to the National Park Service for possible peer review and submission to the National Technical Information Service (NTIS). Savannah District shall ensure that all such reports are responsive to the contemporary professional standards, and to the Department of Interior's "Format Standards for Final Reports of Data Recovery Programs" (42 FR 5377-5379).

14. Any party to this Agreement may request that it be amended, whereupon the parties will consult in accordance with 36 CFR 800.5(e)(5) to consider such amendment.

15. Should the GASHPO, the SCSHPO, or Council object within 45 days to any actions proposed pursuant to the Agreement, Savannah District shall consult with the objecting party to resolve the objection. If Savannah District determines that the objection cannot be resolved, Savannah District shall request the further comments of the Council pursuant to 36 CFR Part 800.4 to 800.6. Any Council comment provided in response to such a request will be taken into account by Savannah District in accordance with 36 CFR Part 800.6(c)(2) with reference only to the subject of the dispute; Savannah District's responsibility to carry out all actions under this Agreement that are not the subjects of the dispute will remain unchanged.

16. At any time during implementation of the measures stipulated in this Agreement, should an objection to any such measure be raised by a member of the public, Savannah District shall take the objection into account and consult, as needed, with the objecting party, the GASHPO, the SCSHPO, or the Council to resolve the objection.

Execution of this Memorandum of Agreement and implementation of its terms evidences that the Savannah District, U.S. Army Corps of Engineers has afforded the Council an opportunity to comment on the Savannah Harbor Navigation Project and its effects on the Confederate ironclad, CSS Georgia and that the Savannah District has taken into account the effects of the undertaking on that historic property.

U.S. ARMY ENGINEER DISTRICT, SAVANNAH

BY: _____ DATE: _____
 GRANT M. SMITH
 COLONEL, U.S. ARMY
 DISTRICT ENGINEER

GEORGIA DEPARTMENT OF NATURAL RESOURCES
 GEORGIA STATE HISTORIC PRESERVATION OFFICER

BY: _____ DATE: _____
 MARC R. EDWARDS
 DIRECTOR, HISTORIC SITES DIVISION AND GASHPO

SOUTH CAROLINA STATE HISTORIC PRESERVATION OFFICER

BY: _____ DATE: _____
 GEORGE L. VOGT, PhD.
 DIRECTOR, DEPARTMENT OF ARCHIVES AND HISTORY AND SCSHPO

ADVISORY COUNCIL ON HISTORIC PRESERVATION

BY: _____ DATE: _____
 ROBERT D. BUSH
 EXECUTIVE DIRECTOR

MEMORANDUM OF AGREEMENT
BETWEEN
THE U.S ARMY ENGINEER DISTRICT, SAVANNAH,
THE GEORGIA STATE HISTORIC PRESERVATION OFFICER, AND
THE SOUTH CAROLINA STATE HISTORIC PRESERVATION OFFICER, AND
THE ADVISORY COUNCIL ON HISTORIC PRESERVATION
CONCERNING
THE CONFEDERATE IRONCLAD, CSS GEORGIA

APPENDIX A

DEFINITIONS:

Savannah Harbor Navigation Project:

The Federal Navigation Project (Project) consists of those features authorized by the U.S. Congress, or authorized under authorities delegated by the U.S. Congress, to provide safe and efficient navigation through Savannah Harbor or to reduce adverse impacts of those features. The Project includes both the physical features constructed in conformance with prior authorizations, and subsequent maintenance activities associated with continued operation of those features. The physical features include the navigation channel, advance maintenance sections, bend wideners, turning basins, berthing areas, sediment control works, freshwater control works, and dredged material disposal areas.

CSS Georgia:

The CSS Georgia is a Confederate ironclad vessel which is located in Savannah Harbor at approximately Station 58+500 (River Mile 11.1). The vessel was constructed in Savannah in 1862 and was scuttled by Confederate forces in December 1864 to prevent her capture. The CSS Georgia is the only ironclad known to have been built in Savannah.

The property is owned by the state of Georgia and was included on the National Register of Historic Places in February 1987. The site is significant at the national level for its architecture, associations with events and people, and for its archaeology.

APPENDIX M

FEDERAL CONSISTENCY DETERMINATION

Federal Consistency Determination
for
Operation and Maintenance
of the
Savannah Harbor Navigation Project

M.1.00 PROPOSED ACTIVITY. To operate and maintain the authorized Savannah Harbor Navigation Project. The Project is located along the South Carolina/Georgia border near Savannah, Georgia. The Project includes a navigation channel beginning in the ocean and extending shoreward about 11 miles to the Savannah River entrance (Station 0+000), then 21.3 River Miles (R.M.) to just below the U.S. Highway 17 bridge (Station 112+500). Other components of the Project include turning basins, berthing areas, confined disposal facilities (CDFs), unconfined disposal areas, advance maintenance sections, sediment control works, and freshwater control works. The Project includes the dredging and disposal of sediments, and management of disposal areas for those sediments.

M.1.01 Operation and maintenance of the Savannah Harbor Navigation Project is a Federal activity which would be performed in the coastal zone. As such, Savannah District, as the Federal agency responsible for the activity, must determine the extent to which the proposed activity is consistent with the Coastal Management Programs of the affected states.

M.2.00 CONSISTENCY DETERMINATION STATEMENT. This activity is consistent to the maximum extent practicable with the South Carolina and Georgia Coastal Management Programs. Section M.3. describes the proposed project, while Section M.4. describes the evaluation factors which were considered prior to reaching this determination.

M.3.00 DETAILED DESCRIPTION OF THE ACTIVITY. The selected plan, Alternative 8, involves the continued maintenance of the Savannah Harbor Navigation Project from R.M. 21.3 to deep water in the ocean. The authorized Project depth is -44 feet Mean Low Water (MLW) from the ocean to Station -14B+000. The depth is then -42 feet MLW to Station 103+000 (R.M. 19.5), where it changes to -36 feet MLW until reaching Station 105.5 (R.M. 20.0). A -30 feet MLW depth is then maintained from that point to Station 112+500 (R.M. 21.3), the upstream end of the Project. Five turning basins are included to allow the safe turning of vessels in the harbor. Berthing areas for the loading/unloading of vessels are also included. Other components include sediment control works

(Tidegate and Sediment Basin) and freshwater control works near the Savannah Wildlife Refuge. CDFs consist of Areas 1N, 2A, 12A, 12B, 13A, 13B, 14B, and the Jones/Oysterbed Island. Areas presently undiked include New Cut, 1S, 14A and the EPA-approved Savannah Harbor Ocean Dredged Material Disposal Site (ODMDS).

M.3.01 Proposed changes to the authorized project consist of the following:

A) Diking of Disposal Area 14A to allow rotational use of the middle and lower harbor confined disposal areas, thereby extending their useful life;

B) A Mitigation Plan to compensate for the wetland losses resulting from the diking of Disposal Area 14A and miscellaneous disposal area operations in South Carolina, with the following features:

- 1) Operation of disposal areas during their use phase for the benefit of migratory birds;
- 2) Construction of nesting islands within each disposal area;
- 3) Maintenance of a bird nesting area on US FWS property at the east end of Jones island through clearing and unconfined disposal of sandy sediments;
- 4) Construction and maintenance of a bird nesting island north of the Savannah Harbor north jetty;
- 5) Establishment of a escrow account with the SC DHEC-OCRM to restore or otherwise benefit wetlands as in-kind mitigation for project wetland losses;
- 6) Construction of a water control structure on a 228-acre impoundment at the Savannah National Wildlife Refuge to establish fisheries function/value to the impoundment.

C) Construction and use of an access road to Disposal Area 2A to allow deposited sediments to be removed, thereby extending the useful life of that site;

D) A commitment to mitigate for the wetland losses in Georgia resulting from the construction of the access road to Disposal Area 2A and other minor wetland impacts from maintenance activities (replacement of weirs and construction/enlargement of pipe ramps);

E) Installation of underdrains which would drain to either the Savannah or Back Rivers to allow faster drying of deposited sediments; thereby enhancing the removal of those sediments and extending the useful life of the confined disposal areas;

F) Beneficial uses of nearshore sediments, consisting of construction and maintenance of submerged berms south of the Bar Channel, construction and maintenance of a feeder berm off Tybee Island, and placement directly on the Tybee and/or Daufuskie Island beaches. The nearshore/offshore disposal location to be used for a specific dredging contract would be decided during project design and award based on identification of the least cost, environmentally-acceptable disposal option. If disposal at a different location is found to be more desirable for environmental or other reasons but would be more costly than the one designated as the least cost, environmentally-acceptable, it could be pursued using appropriate cost sharing authorities;

G) Maintenance of berths by dock owners with a hydraulic dredge with placement of the excavated material directly in CDFs; and

H) Improvements in the sediment control features, consisting of advance maintenance deepening of the Sediment Basin and turning basins, and deepening the advance maintenance area at the Kings Island Turning Basin with the intent of creating additional off-channel storage for deposition of sediments prior to the periodic Federal maintenance dredging.

M.3.02 The diking of Disposal Area 14A would follow the dike alignment approved by the South Carolina Coastal Council in July 1984.

M.3.03 Rotational use of the middle and lower harbor CDFs would allow reuse of deposited sediments to the maximum extent practicable by enabling the deposited material to be removed and reused as construction fill for future dike raising projects.

M.3.04 CDFs would be used for sediments excavated from the inner harbor, except for completion of the previously authorized filling of New Cut. No disposal is proposed on Disposal Area 1S. Unconfined disposal would be used for sediments dredged from the Bar (Entrance) Channel and primarily sand material removed from the Project near the Jones/Oysterbed Island Disposal Area. This unconfined disposal would occur either at the EPA-approved ODMDS centered at 31° 56' 54" N and 80° 45' 34" W, at nearshore areas where the material could be more beneficially used, or in fulfillment of the Mitigation Plan for Disposal Area 14A. Such locations would consist of an area south of the Bar Channel where submerged berms and/or a feeder berm would be constructed, and the shorelines of Tybee and/or Daufuskie Island where deposition would occur for erosion control. Mitigation features comprised of unconfined disposal are construction and maintenance of the bird island north of the Savannah Harbor jetties and maintenance of a bird nesting area at the east tip of Jones/Oysterbed Island.

M.3.05 Maintenance of the Project would require excavation of about 7.2 million cubic yards of sediments per year. Excavation of the Bar Channel would be performed primarily by hopper dredges, although hydraulic dredges may be used where special placement needs occur, such as the beneficial use options. Excavation in the inner harbor would primarily be performed by hydraulic dredges. Clamshell dredges may be used for removal of debris or for maintenance of berthing areas. Agitation dredging of berths by private interests would continue to be allowed under separate environmental approvals.

M.3.06 The plan retains the present authorized depths for the navigation channel depths and overdepth criteria. Advance maintenance sections remain the same for most of the navigation channel. The area at the Kings Island Turning Basin is the only channel reach where the advance maintenance section would be deepened. Establishment of an advance maintenance section at the Sediment Basin is proposed. The other changes in the harbor's sediment control features are a form of lateral advance maintenance, where areas along the side of the navigation channel would be deepened to provide off-channel storage for deposition of sediments. This is expected to reduce the frequency of dredging events. Berths to be maintained by hydraulic dredging with placement of the excavated material directly in CDFs could be deepened to a depth of 6 feet below the authorized channel depth to increase the efficiency of hydraulic dredging and minimize the number of annual dredging events required to maintain adequate depths.

M.4.00 CONSISTENCY EVALUATION. Savannah District performed an evaluation of the proposal's consistency with the Coastal Management Programs of both Georgia and South Carolina. This document addresses each of the major policy issue outlined in the manual titled, South Carolina Coastal Council Guidelines and Policies of the South Carolina Management Program which applies to this project. Similar policies exist in the Georgia Coastal Management Program. In the following paragraphs, the section from the South Carolina manual is indicated in italics and quotes, followed by the District's response.

M.4.01 "GENERAL GUIDELINES FOR EVALUATION OF ALL PROJECTS
(Permitting and Certification of Other Permits) (Chapter III.D.3.
pg.III-14)

I. In review and certification of permit applications in the coastal zone, the Coastal Council will be guided by the following general considerations (apply to erosion control and energy facility projects, as well as activities covered under Activities Subject to Management):

(1) The extent to which the project will further the policies of the South Carolina General Assembly which are mandated for the Coastal Council in implementation of its management program, these being:

(a) To promote the economic and social improvement of the citizens of this State and to encourage development of coastal resources in order to achieve such improvement with due consideration for the environment and within the framework of a coastal planning program that is designed to protect the sensitive and fragile areas from inappropriate development and provide adequate environmental safeguards with respect to the construction of facilities in the critical areas of the coastal zone."

M.4.02 This project will allow the continued maintenance of the Savannah Harbor Navigation Project, with its beneficial effects on commercial deep-draft navigation and the national economy. Industries located in the region and workers residing in the immediate area would have the most direct economic benefit. Since the project is located on the State boundary, industries and/or persons located close to the port, but residing in either state can equally benefit from the harbor, even though most of the shipping currently crosses docks located in Georgia. Therefore, the port does provide economic opportunities for residents of the State of South Carolina.

M.4.03 Environmental safeguards are incorporated into all phases of harbor operations. Use of the CDFs includes provisions to ensure that applicable state water quality standards are met by discharges from those facilities. Dike raising actions would be performed using Best Management Practices to maximize erosion control during the construction process. An Erosion and Sedimentation Control Plan for the dike raising activities has been prepared and is included in Appendix N of the EIS.

M.4.04 "(b) To protect and, where possible, to restore or enhance the resources of the State's coastal zone for this and succeeding generations."

M.4.05 As expressed in the previous section, many environmental safeguards are incorporated into harbor maintenance activities to protect the coastal resources. These provisions deal with water quality, endangered species, and fisheries, among others.

M.4.06 One component of the proposed project would directly restore coastal resources. That is the beneficial use of nearshore sediments through the direct placement of dredged material on the beaches of Daufuskie and Tybee Islands to restore eroded shorelines.

M.4.07 Another component of the proposed project would directly enhance coastal resources. The Mitigation Plan developed for use of Disposal Area 14A includes components which would create rare isolated nesting habitat for shorebirds and colonial nesting birds. Nesting islands would be created inside some CDFs, a bird nesting area re-established at the east end of Jones/Oysterbed Island, and a new shorebird nesting area island established by construction of an island immediately offshore of Turtle Island. Nesting habitat for those bird species has diminished over time as the coastline has become more developed. The isolated nesting habitat which would be created is becoming increasingly rare in this region. The proposed nesting areas counter a long-term trend of habitat loss and are expected to enhance shorebird nesting in South Carolina through the addition of additional critical nesting habitat. The existence of such habitat could be critical to the survival of such species as the least tern, which now nest mainly on rooftops, the design of which may in the future not be conducive to successful nesting.

M.4.08 "(2) The extent to which the project will have adverse impacts on the "critical areas" (beaches, primary ocean-front sand dunes, coastal waters, tidelands)."

M.4.09 Continued operation and maintenance of the Savannah Harbor Navigation Project is not expected to have significant adverse impacts on these factors. Adverse impacts stemming from the project would consist of temporary increases in turbidity in the nearshore area and at the ODMDS resulting from open water disposal operations.

M.4.10 Beneficial impacts produced by the project include (1) the protection which beach placement of sediments on Daufuskie and Tybee Islands would provide to those eroding barrier island shorelines, (2) the protection from the erosive nature of wind-generated waves which the proposed bird island would provide to

the ocean shore of the adjacent Turtle Island Wildlife Management Area, (3) the protection which the submerged berms would provide to Tybee Island from northeasterly waves, especially ones of high amplitude, and (4) the protection which the feeder berm would provide to the Tybee Island beach from northeasterly waves.

M.4.11 *"(3) The extent to which the project will protect, maintain, or improve water quality, particularly in coastal aquatic areas of special resource value, for example, spawning areas or productive oyster beds."*

M.4.12 Implementation of the weir effluent monitoring described in the main EIS would adequately protect the water quality of the receiving body. Effluent from underdrains which drain to the Savannah or Back Rivers would meet water quality standards with only small mixing zones. No impacts are anticipated to striped bass spawning areas in Back River. Implementation of the proposed hydraulic dredging of berths with direct deposition of excavated sediments into CDFs would reduce the need for ongoing agitation dredging operations and its multiple handling of berth sediments. Temporary increases in turbidity in nearshore areas would occur as a result of the beneficial uses of nearshore sediments but are not expected to have long-term environmental impacts. Moreover, no hard bottom communities or submerged vegetation beds are known to exist in the project impact area. Side scan sonar and benthic surveys would be conducted prior to initial placement at the proposed nearshore sites to ensure significant benthic communities would not be adversely affected.

M.4.13 *"(4) The extent to which the project will meet existing State and Federal requirements for waste discharges, specifically point sources of air and water discharge, and for protection of inland wetlands."*

M.4.14 Past studies of weir releases at Savannah (Palermo, 1988) indicate that the CDFs are very effective in removing suspended solids, metals, and other nutrients prior to effluent releases. Effluent from the CDFs is expected to meet state water quality standards. To ensure that unacceptable water quality impacts do not occur from the weir releases, a water quality monitoring plan will be implemented. The Project will abide by the conditions of its State Water Quality Certification.

M.4.15 Wetlands would be protected to the extent practicable. Improvements to existing dikes would be made inside the disposal areas so that no additional wetlands would be impacted. The diking of Disposal Area 14A is proposed as a means of employing a

rotational use of all middle and lower harbor CDFs. Rotational use of the sites is necessary to maximize the useful life of those sites. By extending the life of existing sites, impacts to other wetlands would be postponed.

M.4.16 *"(5) The extent to which the project includes consideration for the maintenance or improvement of the economic stability of coastal communities."*

M.4.17 Continued operation and maintenance of the Savannah Harbor Navigation Project would have no negative impacts on the coastal economy. In fact, increasing the efficiency of harbor operations would make the port more competitive, possibly encouraging further use of the port facilities, thereby creating more jobs in the region.

M.4.18 *"(6) The extent to which the project is in compliance with local zoning and/or comprehensive plans."*

M.4.19 The feature of the proposed Project possibly subject to a question concerning local zoning would be the diking of Disposal Area 14A. However, since that site has been used in the past for disposal of dredged material, no change in land use would occur with the proposed diking and subsequent use as a CDF. The Special Area Management Plan (SAMP) prepared by the SCCC in October 1987 investigated environmental, regulatory and management options which might affect the development of the Lower Savannah River. That area was defined as being bounded on the west by the Savannah National Wildlife Refuge, on the north by Wright River, on the east by the Atlantic Ocean, and on the south by the City of Savannah. In speaking of Disposal Area 14A, the SAMP stated that "These dikes are expected to be constructed in later years as the areas presently under use are filled to capacity." In July 1984, the SCCC did approve an alignment so that Area 14A could be diked. The currently proposed diking follows that previously approved alignment.

M.4.20 *"(7) The possible long-range, cumulative effects of the project, when reviewed in the context of other possible development and general character of the area."*

M.4.21 Development and operation of the harbor has resulted in adverse impacts to the environment. After implementation of environmental laws in the 1970's, those impacts have predominantly been compensated for through some form of mitigation. The region has a long history tied to shipping as the original settlement of Savannah was as a seaport. Much of the original economy was dependent upon the export of locally produced goods through the harbor. Continued growth of the region's economy is expected to

increase the need for movement of goods in an economical manner. As the price of that movement increases or decreases, an inverse effect is felt on the competitiveness of industries in the area. Continued operation of the harbor may lead to further development along the harbor as industries seek to minimize transportation costs and their access to the export market. However, the environmental impacts of developing sites are dependent on the manner of that development and the specific site in question. Therefore, no precise determinations can directly be made on future cumulative impacts of harbor operation. Plans which organizations may have for future expansion of the harbor are not defined sufficiently at this time to allow their serious consideration in this document.

M.4.22 Rotational use of the middle and lower harbor CDFs will maximize the useful life of those existing facilities. This will delay the need for adverse impacts resulting from the need for new dredged material disposal areas. Under current operational procedures, a CDF in the middle harbor is expect to reach its useful life in year 6 of the project. After that time, the site (Disposal Area 2A) would only be available on a reduced basis, with the remaining sediments being shifted to the complex of Disposal Areas 12A/12B/13A. With the proposed project, the CDF system would be adequate for the entire 20-year period of evaluation.

M.4.23 *"(8) The extent and significance of negative impacts on Geographic Areas of Particular Concern (GAPCs). The determination of negative impacts will be made by the Coastal Council in each case with reference to the priorities of use for the particular GAPC. Applications which would significantly impact a GAPC will not be approved or certified unless there are no feasible alternatives or an overriding public interest can be demonstrated, and any substantial environmental impact is minimized."*

M.4.24 The proposed project would not significantly impact any Geographic Area of Particular Concern.

M.4.25 " (9) The extent and significance of impact on the following aspects of quality or quantity of these valuable coastal resources:

i. unique natural areas - destruction of endangered wildlife or vegetation or of significant marine species, degradation of existing water quality standards;"

M.4.26 Both of these issues are addressed in detail in the main EIS. Conditions have been placed on harbor maintenance activities to protect threatened or endangered species in the project area. A water quality monitoring plan will be implemented to ensure water quality standards are maintained.

M.4.27 "ii. public recreational lands - conversion of these lands to other uses without adequate replacement or compensation, interruption of existing public access, or degradation of environmental quality in these areas;"

M.4.28 Diking of Disposal Area 14A to allow continued use of the site would result in the loss of wetlands and their conversion to high ground. A Mitigation Plan is included in the project to compensate for those losses.

M.4.29 Other potential impacts of the project which could possibly affect public recreation lands would stem from any degradation of water quality associated with the project. Adverse impacts to water quality from the proposed project would be minimal.

M.4.30 "iii. Historic or archeological resources - irretrievable loss of sites identified as significant by the S.C. Institute of Archeology and Anthropology or the S.C. Department of Archives and History without reasonable opportunity for professional examination and/or excavation, or preservation."

M.4.31 The project's impacts on cultural resources are addressed in the main EIS. Extensive cultural resources investigations were conducted as part of the LTMS Study. These included archival research, land and water surveys. The findings of the investigations are summarized in the EIS. Where appropriate, data recovery efforts were conducted at specific sites after consultation with the State Historic Preservation Officer (SHPO). At nearshore sites which have not been investigated, cultural resource surveys would be conducted prior to construction to ensure no significant resource is located in the impact area. The results of all surveys would be coordinated with the appropriate SHPO before the site is impacted. A Cultural Resource Management Plan has been prepared to describe the procedures which would be

followed to protect known cultural resources within the management authority of the Corps. That Plan is contained in Appendix J to this EIS. A copy of the draft EIS was provided to both the South Carolina and Georgia SHPO for review and comment. Comments provided by the GA SHPO were incorporated in the Final EIS. No written comments were received from the SC SHPO, although conversations with the SC SHPO centered on the same topics discussed by the GA SHPO.

M.4.32 "(10) The extent to which the project is in the national interest."

M.4.33 Savannah Harbor is important to the national economy and to our nation's defense. Continued maintenance of the harbor will support both of these nationally important factors. The economic benefits have been weighted against the predicted adverse environmental impacts of the project and Savannah District has determined that the Savannah Harbor Navigation Project is in the public interest.

M.4.34 "Specific South Carolina Management Program Policy Applicable to the review of these documents.

M.4.35 VII. WILDLIFE AND FISHERIES MANAGEMENT (Chapter III, Policy Section III, p. III-51)

A. Wildlife and Fisheries Management Policies:

The following policies were developed by the South Carolina Coastal Council in conjunction with the South Carolina Wildlife and Marine Resources Department for inclusion in the S.C. Coastal Program.

(1) In the coastal zone, Council issuance or review and certification of permit applications which would impact wildlife and fisheries resources will be based on the following policies:

(a) Activities deemed, by the South Carolina Coastal Council in consultation with the South Carolina Wildlife and Marine Resources Department, to have a significant negative impact on wildlife and fisheries resources, whether it be on the stocks themselves or their habitat, will not be approved unless overriding socio-economic considerations are involved. In reviewing permit applications relative to wildlife and fisheries resources, social and economic impacts as well as biological impacts will be considered.

(b) Wildlife and fisheries stocks and populations should be maintained in a healthy and viable condition and these resources should be enhanced to the maximum extent possible.

(c) Critical wildlife and fisheries habitat should be protected and enhanced to the extent possible."

M.4.36 Impacts to fish and wildlife resources are addressed in the main EIS. No significant adverse impacts are anticipated.

M.4.37 "VIII. DREDGING (Chapter III, Policy Section VIII, pg. III-55)

A. Dredging Policies:

(1) In the coastal zone, Council review and certification of permit applications for dredging projects will be based on the following policies:

(b) Suspended sediments must be kept to a minimum. The use of structures such as weirs and silt curtains to minimize water quality degradation is encouraged. Where highly toxic sediments are encountered, dredging will be prohibited unless the activity is consistent with other dredging policies, as well as those for manufacturing or other industrial activities."

M.4.38 Previous studies (Palermo 1988) have shown the Savannah Harbor CDFs be very effective traps of suspended sediments, removing over 99 per cent of the solids. The CDFs do have weirs to allow regulation of the effluent. A water quality monitoring program is included to ensure the areas are functioning properly and performing in accordance with all applicable water quality standards. That plan is described in detail in Section 7 of the main EIS. A review of all existing sediment testing data indicates that harbor sediments contain no toxic substances at hazardous levels. A silt curtain would be used when the previously approved open water disposal occurs at the western side of New Cut. Other unconfined disposal operations would employ sediments with a high sand content. This is expected to minimize turbidity and suspended sediment effects.

M.4.39 "(c) Dredging should not reduce water circulation, water currents, mixing, flushing or salinity in the immediate area."

M.4.40 Normal maintenance of the navigation channel is not expected to impact these factors appreciably, although current velocities would theoretically decrease after a dredging event due to the increase in cross-sectional area of the channel. Proposed sediment control features and deepening at berths would decrease current velocities at those immediate sites, but are not expected to adversely impact mixing or flushing. No proposed dredging is expected to increase salinity intrusion in the harbor. The bird island proposed for the nearshore area off Turtle Island could cause local changes in these factors. However, the site selected

for this structure is a shallow water area with deeper channels to either side. No major currents are expected to exist within the footprint of the proposed island. The bird island would be expected to protect inland areas (Turtle Island Wildlife Management Area) from the erosion action of wind-generated waves. The proposed offshore berms are expected to attenuate high amplitude northeasterly wind-generated waves. These berms would be oriented to minimize their impact on both ebb and flood tidal currents. The proposed feeder berm is expected to attenuate high amplitude northeasterly wind-generated waves and protect the adjacent barrier island shoreline of Tybee Island. This berm is not expected to result in significant effects on current patterns or water circulation. Placement of channel sediments on Tybee and/or Daufuskie Islands is not expected to result in significant effects on current patterns or water circulation. Such placement is expected to lessen wave impacts to those beaches.

M.4.41 *"(2) In critical areas of the coastal zone, it is Council policy that:*

(c) To the maximum extent feasible, dredging and filling activities should be restricted in nursery areas and shellfish grounds and during periods of migration, spawning and early development of important sport and commercial species;"

M.4.42 In order to comply with existing state water quality certifications which contained stipulations to avoid potential impacts to the striped bass during their spawning run in the Savannah River, no dredging will be conducted from March 16 to May 31 of each year in the upper harbor (above River Mile 5.0). This policy could be curtailed when no longer required by state water quality certifications. In addition, the deposition of sediments in the nearshore area during the spring would be avoided to the extent practicable to minimize impacts to larval and young finfish and shellfish residing in those shallow areas.

M.4.43 *"(d) Dredging and excavation shall not create stagnant water conditions, lethal fish entrapments, or deposit sumps or otherwise contribute to water quality degradation;"*

M.4.44 The proposed project will not create such problems. Proposed changes in the Project's sediment control features and deepening of berths would produce larger areas for temporary storage of sediments. Since the oxygen demand of the sediment material is not dependent on the location of the material, the total oxygen demand which harbor sediments place upon the river would not be affected. In areas where sediment accumulates rapidly, that sediment which becomes buried and turns anoxic is outside of the influence of oxygen dissolved in the water and no longer places a demand on that critical water quality component.

Thus, the placement of a volume of sediment in a deep storage area removes that volume from the area of ready exchange with the water column, thereby reducing the oxygen demand of the total sediment volume.

M.4.45 "(e) Designs for dredging and excavation projects shall, where feasible, include protective measures such as silt curtains, diapers and weirs to protect water quality in adjacent areas during construction by preventing the dispersal of silt materials;

(f) Dredged materials shall be deposited and contained in such a manner so as to prevent dispersal into adjacent wetland areas."

M.4.46 All material excavated from the upper inner harbor would be placed in diked high ground disposal areas, except for completion of the previously authorized filling of New Cut. The proposed hydraulic dredging of berth sediments with direct deposition of the excavated sediments in CDFs would reduce the adverse impacts resulting from the present double handling of those sediments when they are initially removed from berths through agitation dredging. Sandy sediments from the outer portions of the inner harbor may be employed in maintenance of the upland Jones/Oysterbed Island nesting area or the nearshore bird island as part of the Mitigation Plan. The weir releases from the CDFs will be managed to minimize the potential for impact to water quality. A water quality monitoring plan will be implemented to observe the effectiveness of the disposal area operations. That plan is described in detail in Section 7 of the main EIS.

M.4.47 Materials excavated from the Bar Channel and possibly along the Jones/Oysterbed Island Disposal Area would be deposited in open water disposal areas or used in maintaining commitments under the Mitigation Plan. Commitments in the Mitigation Plan include construction and maintenance of the bird island off Turtle Island and maintenance of the unconfined upland Jones/Oysterbed Island nesting area. The majority of disposal actions are expected to be to the EPA-approved ODMDS. Beneficial uses of those sediments would involve their placement on the beaches of Daufuskie and/or Tybee Island, as well as the construction and maintenance of submerged berms and a feeder berm in the nearshore area. No open water placement would result in permanent adverse impacts to vegetated wetlands.

M.4.48 "(i) Wetlands shall not be utilized as depositories for waste materials except as discussed in R.30-12(I)."

M.4.49 Materials dredged from the inner harbor would be placed in high ground confined disposal areas, except for completion of the previously approved filling of New Cut and possible placement on the Jones/Oysterbed island nesting area. To maximize the useful life of the CDFs, a rotational program would be implemented. The effects of the rotational program are described in detail in the main EIS. The diking and use of Disposal Area 14A are required for effective use of that rotational program.

M.4.50 "(j) In all cases, dredging activities shall not be approved until satisfactory disposal sites have been acquired. (R. 30-12(G))."

M.4.51 No acquisition of new disposal sites is required for this proposed project. Disposal Area 14A has been used previously for placement of dredged material. The site was purchased in the 1980's by the Georgia Department of Transportation for use as a disposal site for the Savannah Harbor Navigation Project. With implementation of the proposed project, existing disposal sites would have sufficient capacity for the entire 20-year period of analysis.

M.4.52 "B. Dredged Material Disposal Policies:

(2) In critical areas of the coastal zone, it is Council policy that:

(a) Upland disposal of dredged material shall always be sought in preference to disposal in wetlands. Vegetated wetlands and mudflats shall not be utilized for disposal of dredged materials unless there are no feasible alternatives. Any other wetlands should not be utilized for disposal of dredged materials when other alternatives exist."

M.4.53 Upland disposal of dredged material is used as much as practicable. The diking and use of Disposal Area 14A will result in the loss of wetlands, but has already been found to be consistent with South Carolina Coastal Management Programs. A Mitigation Plan would be implemented to compensate for the loss of wetlands from the diking of Disposal Area 14A. In addition, the use of that area would allow a rotational program to be instituted in the middle and lower harbor CDFs so that their useful life could be maximized. Beneficial use and planned use of dredged materials under the Mitigation Plan would involve deposition on beaches and in subtidal nearshore areas. The adverse impacts

which such placement would produce are judged to be outweighed by the beneficial impacts which such placement would produce, including protection of eroding barrier island beaches, creation of rare isolated nesting sites for colonial nesting birds, and placement of dredged sediments in the immediate nearshore sand sharing system.

M.4.54 "(b) Open water and deep water disposal should be considered as an alternative if highland alternatives are not feasible. However, open and deep water disposal sites should be seriously considered only after careful consultation with the Council and other relevant State and Federal agencies."

M.4.55 Only sediments removed from the Bar Channel and possibly the channel near the Jones/Oysterbed Island Disposal Area are considered for placement in open water. The normal site for placement of sediments removed from the channel near the Jones/Oysterbed Island Disposal Area is the Jones/Oysterbed Island Disposal Area. Those sediments would not be placed in the CDF only if the beneficial use of those sediments in the nearshore area is pursued. The normal site for placement of Bar Channel materials would be at the EPA-approved ODMDS. Ocean disposal recently received approval from EPA through their concurrence of the Section 103 Evaluation in 1993. This EIS contains an update of that analysis for EPA's approval. Open water disposal would occur to complete the previously authorized filling of New Cut.

M.4.56 "(c) Dredged materials containing hazardous levels of toxic material must be disposed of with extraordinary caution. These materials shall never be disposed of in wetland areas and only in highland areas which are lined and diked with impervious materials. These materials will only be disposed in open water ocean dumping sites when maximum safety has been demonstrated after thorough review by the Coastal Council and other appropriate state and Federal agencies."

M.4.57 The District has reviewed all sediment testing data which is available to assess the quality of the sediments which settle in the harbor. The findings of that evaluation are contained in Appendix E in the EIS. In summary, the dredged materials do not contain hazardous levels of any toxic material. Specific chemicals have been identified in particular samples at levels which have produced adverse impacts to some aquatic species under certain conditions. No chemicals were found at levels which would produce adverse impacts to humans. The acceptability of ocean disposal of Bar Channel sediments has been reviewed and approved by EPA in 1993. Appendix D of the EIS contains an update of that evaluation. That Section 103 Evaluation was approved by EPA in a letter dated March 23, 1995.

M.4.58 "(e) Future disposal sites shall be reviewed on a case-by-case basis."

M.4.59 With implementation of the proposed project, no additional disposal sites would be needed for the 20-year period of analysis.

M.4.60 "(f) Wherever feasible, existing disposal areas shall be utilized to the fullest extent possible; this would include raising the height of embankments to increase the holding capacity of the disposal area."

M.4.61 The proposed project includes the use of existing CDFs and the raising of their dikes to increase their holding capacity. Implementation of the proposed project includes the use of a rotation program which would allow material from inside the CDFs to be used to raise the dikes. Thus, capacity of the sites would be increased in two ways; (1) removal of sediments previously deposited within an area, and (2) raising of the dikes to allow sediments to be deposited higher at that site.

M.4.62 "(9) Consideration must be given to the temporal aspects of spoil deposition, for example, impacts on spawning, fish migrations, shellfish harvesting, waterfowl nesting and wintering areas, and mosquito control. Attention must be given to possible adverse impacts of various alternative sites on the public health and welfare as well as on critical fish and wildlife areas."

M.4.63 Deposition of dredged material would have little impact on fish spawning and migration, shellfish harvesting, and waterfowl nesting. The Mitigation Plan developed for Disposal Area 14A would have beneficial effects on waterfowl wintering areas through the beneficial management of water levels within the CDFs. One of the management goals of that program is to provide flooded areas for migrating waterfowl to use for resting. Another component of that Mitigation Plan is the installation of purple martin houses and bat houses for biological control of any additional mosquitos which may result from the holding of ponded water at the CDFs for longer periods. Chatham County would continue to perform extensive work at the disposal areas to control mosquito populations. Construction and operation of an additional water control structure in an existing impoundment within the Savannah NWR, as part of the Mitigation Plan, would increase the fishery value of that impoundment by increasing the site's tidal exchange.

M.4.64 " (h) In all cases, dredging activities shall not be approved until satisfactory disposal sites have been acquired."

M.4.65 As stated previously, no acquisition of new disposal sites is required for this proposed project. Disposal Area 14A has been used previously for placement of dredged material. The site was purchased in the 1980's by the Georgia Department of Transportation for use as a disposal site for the Savannah Harbor Navigation Project. With implementation of the proposed project, existing disposal sites would have sufficient capacity for the entire 20-year period of analysis.

M.4.66 "D. Public Open Space Policies:

The Coastal Council will apply the following policies in review and certification of permit applications located in or which would directly affect public open space areas:

(1) Project proposals which would restrict or limit the continued use of a recreational open area or disrupt the character of such a natural area (aesthetically or environmentally) will not be certified where other alternatives exist."

M.4.67 The proposed project would have no adverse impacts on the Savannah National Wildlife Refuge. Implementation of the Disposal Area 14A Mitigation Plan would result in beneficial impacts to the Tybee National Wildlife Refuge through the periodic clearing of high areas within that Refuge. The cleared areas would be available for use by colonial nesting birds which greatly prefer cleared sandy areas for nesting. The areas would be maintained through subsequent clearing and possibly unconfined placement of dredged materials. The construction and maintenance of the bird island offshore of the South Carolina Turtle Island Wildlife Management Area would shield the shoreline of that barrier island from erosive storm waves, thereby increasing the stability of that shoreline. Construction and operation of the additional water control structure in an existing impoundment within the Savannah National Wildlife Refuge would increase the fishery value of that impoundment by increasing the site's tidal exchange. The construction and maintenance of the submerged berms and feeder berm off Tybee beach would shield the shoreline of that barrier island from erosive storm waves, thereby increasing the stability of that shoreline.

M.4.68 Placement of dredged material on the beaches of Daufuskie and/or Tybee Islands would generally be expected to increase the ease of walking on those beaches and their aesthetic appeal. The creation and maintenance of the submerged berms and feeder berm are not expected to significantly impact recreational use of the

area as the height of the berm would be restricted to -5 feet Mean Low Water, a depth which would not impact recreational boats. The berms are expected to have an overall beneficial impact on the nearshore environment.

M.5.00 DATE OF AGENCY'S FINAL DECISION. The Corps' South Atlantic Division is scheduled to make its final decisions by October 30, 1996 concerning completion of the Environmental Impact Statement for the Savannah Harbor Long Term Management Strategy Study (harbor operation and maintenance).

APPENDIX N

SAVANNAH HARBOR

CONFINED DISPOSAL FACILITIES

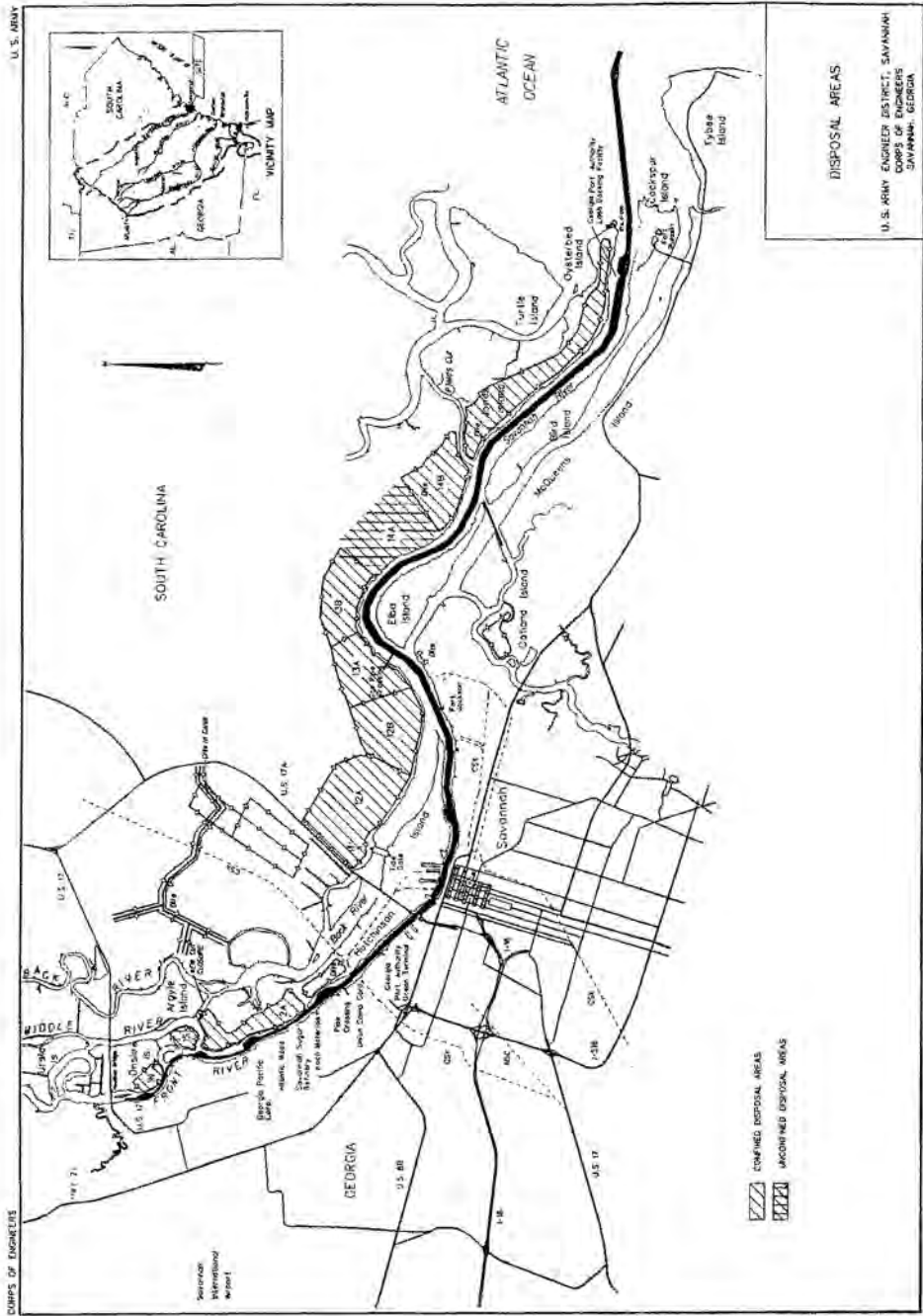
EROSION AND SEDIMENTATION CONTROL PLAN

SAVANNAH HARBOR
CONFINED DISPOSAL FACILITIES
EROSION AND SEDIMENTATION CONTROL PLAN

N.1.00 BACKGROUND. Section 319 of the Clean Water Act (P.L. 92-500) requires states to develop programs to control pollution from non-point sources to navigable waters within the state and improving the quality of such waters. Both Georgia and South Carolina have established such programs. The continued maintenance and periodic improvements to the dikes at the Savannah Harbor Navigation Project's confined disposal facilities (CDFs) must comply with those programs. To ensure such compliance, an Erosion And Sedimentation Control Plan has been developed. Dredging and disposal activities do not fall within the authorities of Section 319. Stormwater runoff is normally regulated under Section 402 of P.L. 92-500. However, an NPDES permit is not required for stormwater runoff from the confined disposal facilities since the effects and control of such runoff are included in the Section 404(b)(1) Evaluation for the Project, which is contained in Appendix C of the Environmental Impact Statement.

N.2.00 EROSION AND SEDIMENTATION CONTROL PLAN.

N.2.01 Location Information. The upland confined disposal facilities (CDFs) for the Project are located in Chatham County, Georgia and Jasper County, South Carolina. The sites are shown in Figure 1.



N.2.02 General Site Features. The non-Federal sponsor has provided nine CDFs for use for the Savannah Harbor Project. Those areas are as follows:

AREA NUMBER	AREA NAME	LOCATION (CHANNEL STATIONS)	SIZE (ACRES)
	Jones/Oysterbed	0+000 - 27+000	754
14B	-----	28+000 - 37+000	765
14A	-----	37+000 - 43+000	815
13B	-----	43+000 - 47+800	628
13A	-----	47+800 - 57+000	690
		(-2+000BR)	
12B	-----	57+000 - 6+600BR	710
		(-2+000BR)	
12A	-----	6+500BR- 10+100BR	1123
2A	Argyle-Hutchinson	93+000 - 103+000	185
1N	Onslow - North	107+500 - 112+600	130

NOTE: "BR" indicates the stationing up Back River as shown on the Savannah Harbor, Georgia, Annual Survey.

N.2.03 Disposal Area 14B receives dredged material from both the Savannah Harbor Navigation Project and the Atlantic Intracoastal Waterway (AIWW), another waterway managed by the Corps of Engineers. The non-Federal sponsor for the AIWW project in Georgia is the Georgia Department of Transportation, and in South Carolina it is the South Carolina Department of Health and Environmental Control, Office of Ocean and Coastal Resource Management. The other confined disposal areas only receive material from the Savannah Harbor Navigation Project, including the navigation channel, turning basins, Sediment Basin, and berthing areas.

N.2.04 A proposal to dike and use Disposal Area 14A is included in the proposed project. The other sites listed are already used on a regular basis for deposition of harbor sediments.

N.2.05 The dikes which confine the disposal areas are of various heights, depending primarily on the age of the particular site and the amount of deposition which has occurred at the site. The dikes are generally constructed on a 3 horizontal to 1 vertical side slope, with a 24-foot wide crest. The dikes are maintained in a grassed state to minimize erosion. Mowing is performed on an as-needed basis. Typically, stormwater collection ditches are not found at the outer toe of the dikes. On the Wright River side of Disposal Areas 12A, 12B, 13A and 13B the toe of the fill joins an unpaved 1-lane roadway which adjoins the diked area. Wetlands typically lie outside the roadway.

N.2.06 No enclosed buildings are located within the CDFs, nor are any planned. Surrounding properties are generally undeveloped and consist of open water areas and marshes. Therefore, wetlands surround the CDFs. Adjacent or nearby open water areas include the Savannah River, Middle River, Back River, Wright River, Atlantic Intracoastal Waterway, and the Atlantic Ocean. An aeration lagoon which is operated by the Union Camp Corporation is located on Hutchinson Island adjacent to Disposal Area 2A.

N.2.07 The CDFs are typically provided by Chatham County for use by the Federal Navigation Project. This use is generally provided through a disposal easement to the site, or portion of the site.

N.2.08 Borrow And Waste Areas. Dike improvement (raising) projects are performed periodically to increase the capacity of the CDFs. Fill material for those construction projects is typically obtained from sediments deposited within the disposal area which is being improved or another of the Project's CDFs. Therefore, no borrow sites are used, other than the CDFs themselves.

N.2.09 Site Drainage Features. The drainage features of the CDFs are fairly simple and uniform. Drainage from the exterior of the dikes typically flows down the slope, across an unpaved access road which borders many of the sites, to the adjacent wetlands. No collection devices exist or are proposed at the outer toe of the dikes. Drainage from the interior of the dikes typically flows down the side slope, across the floor of the CDF to weirs, where the drainage is discharged to the adjacent river or tidal creek. Drainage ditches are used inside the diked area to speed drying of the deposited sediments. Those ditches flow to the weir outlets. There are multiple overflow weirs at each CDF which typically drain to a tidal creek. Underdrains are also proposed for installation and use in most CDFs to speed drying of the deposited sediments. The underdrains would flow to either the Savannah or Back Rivers. The discharge from the underdrains would be separate from the weirs. There are no off-site areas which drain through the CDFs.

N.2.10 Erosion Control Measures. The need to prevent the erosion of soil is well established. Erosion of the dikes affects the dike integrity and produces additional work for the local sponsor. If allowed to erode, the dike fill material could make its way to the marsh, causing undesirable environmental impacts, or to the navigation channel where it would restrict navigation and require excavation and placement into the disposal areas, consuming valuable capacity. The local sponsor is

responsible for managing the CDFs and implementing appropriate erosion control measures. Those measures typically consist of the "Best Management Practices", as defined in either the Manual For Erosion And Sediment Control In Georgia, the South Carolina Stormwater Management And Sediment Control Handbook For Land Disturbance Activities, or A Guide To Site Development And Best Management Practices For Stormwater Management And Sediment Control, whichever is applicable for the location of the construction.

N.2.11 Silt fence is installed during construction at the boundary of the marsh near new weir discharge pipe outfalls. It is effective in holding eroded soils until grass is established. Experience at the CDFs indicate that it is better to remove the silt fences in areas that will be mowed to minimize down time of mowing equipment.

N.2.12 Since the CDFs are a component of the Savannah Harbor Federal Navigation Project and the District is responsible for ensuring use of environmentally acceptable methods to maintain that project in conformance with its environmental clearances, the Savannah District Engineer is ultimately responsible for maintenance activities at the CDFs. Correspondence dealing with the environmental clearances and permits for activities conducted at the CDFs should be addressed to that office. Day-to-day operations of the CDFs are managed by Chatham County's Engineering Department. That Department manages the CDFs and administers dike improvement contracts and dike maintenance work.

N.2.13 Vegetative Stabilization. Grassing the dikes is an integral component of the dike construction contracts. The current grass mixture used is 50 pounds of Pensacola Bahia grass, 4 pounds of hulled common Bermuda grass and 4 pounds of unhulled common Bermuda grass, all on a per acre basis. The ground is prepared, then fertilizer, lime and grass seeds are applied at specified rates. After the grass is at a proper height, nitrogen is added.

N.2.14 Vegetation on the dikes must be periodically mowed to a height so inspection for washouts, which would be the precursors to possible dike failures, can be observed. Uncontrolled vegetation can obscure the view of inspectors. Mowing the roadway located on top of the dikes ensures the safety of trips for inspection and disposal operation purposes. The dikes are typically mowed twice each year, sometimes more, pending available funds and rainfall. No mowing would be performed on the dike side slopes during the period from March 1 to July 15 to ensure nesting migratory birds which may nest on the side slopes are protected.

N.2.15 Other Requirements. The local sponsor will prepare and submit documents to the SC DHEC-OCRM for the purpose of obtaining a Stormwater Permit for initial construction of the Disposal Area 14A dikes. Implementing the procedures described in the Erosion and Sediment Control Plan prepared by the District will provide environmental clearance for subsequent Project dike raising activities in South Carolina. Application for a separate Stormwater Permit from the SC DHEC-OCRM will only be required with the construction of new dikes, not for the periodic raising of existing dikes.

N.2.16 Near the end of the design process for a periodic dike improvement (raising) contract, detailed design drawings which show the intended stormwater management and sediment control features will be provided to either the SC DHEC-OCRM or the GA DNR-EPD. Any design changes required by that agency to remain in compliance with their current regulations will be implemented.

N.2.17 The following paragraphs describe the typical construction process which occurs periodically at the CDFs. Dike improvements (raisings) are performed to increase the storage capacity of the confined CDFs. This is accomplished by raising the height of the dike which surrounds the disposal area. A widening of the dike's base is usually also included to maintain the same side slopes on the earth structure.

N.2.18 When a dike improvement contract is initiated, silt fences are installed along the exterior of the construction area to retain any soil material which erodes off the exposed face of the dike. The fences are placed at the edge of the construction area and wetlands. Existing vegetation on the dike is cleared to allow proper compaction of soil material which will be placed on the structure. If necessary for stability, geotextile fabric is then installed on the exposed soil substrate. The fabric strengthens the earth structure by distributing the load of the earth fill across a wider surface. The fabric is then quickly covered by about a foot of soil to avoid adverse effects of exposure to the sun. Soil is placed to increase the height of the dike in approximately 1-foot layers. Subsequent movement of construction equipment across the dike surface serves to compact previously deposited soil material. After the desired profile is produced, the exposed dike surface is treated with a grass seed/fertilizer/straw mixture. Silt fences are maintained throughout the construction period to ensure they continue to function as intended. Soil material removed from the fences are deposited on the inner side of the dikes or at the top of the dike slope to minimize its escape to the wetlands surrounding the CDFs. After vegetation is well established on the side slopes, the silt fences are removed to allow mowing operations to be conducted efficiently.

APPENDIX O

ENVIRONMENTAL CLEARANCES

FOR THE

SAVANNAH HARBOR NAVIGATION PROJECT

ENVIRONMENTAL CLEARANCES
FOR THE
SAVANNAH HARBOR NAVIGATION PROJECT

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ENVIRONMENTAL CLEARANCES
FOR THE
SAVANNAH HARBOR NAVIGATION PROJECT

0.1.00 PURPOSE. The appendix is intended to be a single source for review of the environmental commitments made by Savannah District and the clearances obtained from regulatory agencies for operation and maintenance of the Savannah Harbor Navigation Project.

0.2.00 ENVIRONMENTAL REVIEWS AND APPROVALS NEEDED. The following list summarizes the environmental reviews and approvals which are required for operation and maintenance of this project:

1. Threatened And Endangered Species
 - Approval from US FWS through Section 7 consultation
 - Approval from US NMFS through Section 7 consultation
2. Migratory Birds
 - Evaluation performed by Savannah District
 - Approval from US FWS for specific actions
3. Coastal Barrier Resources Act
 - Certification by the US FWS
4. Consistency With State Coastal Zone Management Program
 - Evaluation performed by Savannah District
 - Certification from the SC DHEC-OCRM
5. Ocean Disposal
 - Evaluation performed by Savannah District
 - Approval by the US EPA
6. Management of the Savannah ODMDS
 - Agreement with the US EPA
7. Section 404 Evaluation For Dredge And Fill Actions (CWA)
 - Evaluation performed by Savannah District
8. Water Quality Certification (Section 401 of CWA)
 - Certification from the SC DHEC
 - Certification from the GA DNR-EPD
9. Stormwater Runoff (Section 402 of CWA)
 - Evaluation performed by Savannah District
10. Erosion Control And Sedimentation Plan (Section 319 of CWA)
 - Approval from South Carolina DHEC/OCRM
 - Approval from Georgia DNR/EPD

11. Section 106 Compliance (Cultural Resources)
 - Approval from the SC SHPO
 - Approval from the GA SHPO
 - Approval from the Advisory Council on Historic Preservation
12. Wetland Mitigation Plan
 - Approval from US EPA
 - Approval from US FWS (FWS Coordination Act)
 - Approval from GA DNR or SC DNR
13. Environmental Review/Consideration (NEPA)
 - Evaluation/consideration performed by Savannah District
 - Public review of document

0.2.01 Actions which are taken outside the Base Plan (Federal Standard) described at the end of Section 5 of the main EIS would have to receive separate environmental approvals, very similar to those shown above. The organization proposing such actions would be responsible for obtaining the required permits and approvals.

0.3.00 SAVANNAH DISTRICT'S COMMITMENTS.

0.3.01 Threatened And Endangered Species. Savannah District prepared a Biological Assessment of Threatened and Endangered Species (BATES) to determine both (1) the impacts which the Project was likely to have on threatened and endangered species, and (2) what measures were appropriate to minimize the risk of impact to those species. That evaluation is contained in Appendix B. The US FWS provided Section 7 clearance in a letter dated November 29, 1995 and the NMFS provided Section 7 clearance in a letter August 23, 1995. On August 25, 1995, the NMFS issued a Regional Biological Opinion on hopper dredging of channels and beach nourishment activities in the Southeastern United States from North Carolina through Florida East Coast. That document also covered clamshell and pipeline dredging. The District will comply with the conditions in that document. The District will require each dredging contractor implement an Endangered Species Watch Plan to ensure the dredging contractor is aware of endangered species which he could encounter and precautions which would be taken to protect those species.

O.3.02 Sea Turtles. The District committed to the following measures to protect sea turtles:

- a. Hopper Dredges. All hopper dredging will be generally be scheduled for November through May, and the following conditions will apply*:
 1. One hundred percent inflow screening is required, and 100 percent overflow screening is recommended when sea turtle observers are required on hopper dredges in areas and seasons in which sea turtles may be present. If conditions disallow 100 percent inflow screening, inflow screening can be reduced but 100 percent overflow screening is required, and an explanation must be included in the preliminary dredging report.
 2. The sea turtle deflecting draghead is required for all hopper dredging during the months that turtles may be present, unless waiver is granted by the COE SAD in consultation with NMFS.
 3. To prevent impingement of sea turtles within the water column, every effort should be made to keep the dredge pumps disengaged when the dragheads are not firmly on the bottom.
 4. Reporting: A preliminary report summarizing the results of the dredging and the sea turtle take must be submitted to the COE and NMFS within 30 working days of completion of any given dredging project. An annual report (Based on either calendar or fiscal year) must be submitted to NMFS summarizing hopper dredging projects, documented sea turtle and sturgeon incidental takes, and whale sightings.
 5. Dredging may be conducted between 1 Nov and 31 May. One hundred percent observer monitoring is required from 1 Nov- 30 Nov and 1 Apr - 31 May.

6. Dredging must be suspended if more than one turtle is taken in any day, or once five or more turtles are taken. Dredging must also be suspended upon the taking of 1 hawksbill turtle. Dredging will not recommence until coordination with SAD and the NMFS is completed to determine the need for developing further mitigation measures or to terminate the remaining dredging activity.

NOTE: * These are the conditions in the NMFS 1995 Biological Opinion for Navigation Channels in the Southeast, and additional guidance provided by South Atlantic Division. Should a new Biological Opinion be issued, the District would consider the conditions listed here void, and would instead abide by the conditions as stated in that Opinion and any further guidance provided by South Atlantic Division.

- b. Beach Nourishment. To ensure protection to nesting sea turtles the following conditions would be adhered to:

- I. Overview.

1. If the project is constructed during the turtle nesting season, a turtle nest monitoring program should be conducted to ensure protection of turtles that try to nest on the existing or newly formed beach.
2. The beach would be monitored during the first winter/spring following completion of construction to determine post-nourishment compaction. This would be performed to ensure that the newly constructed beach provides suitable nesting material for endangered sea turtles. If the examination finds sand compaction within 50 feet of the toe of the dune to be greater than 500 cone penetrometer units (cpu), and the US FWS confirms that plowing is necessary, the compacted area will be plowed to a depth of at least 36 inches.
3. The beach would be monitored for three nesting seasons after beach placement for escarpments. Any escarpments in excess of 18 inches high, extending more than 100 feet in length and exceeding 500 cpu would be mechanically leveled to the natural beach contour.

4. When dredged materials are placed on Tybee Island, the city's light ordinance for protection of sea turtles would be enforced.

II. Turtle Nest Monitoring Program. The following work would be implemented when dredged materials are placed on the Tybee Island (or Daufuskie Island with appropriate changes) beach during the sea turtle nesting season. The work would include monitoring the beach for nesting sea turtles and relocation of nests found in the disposal areas or within 500 feet of the limits of the disposal area which are likely to be impacted by future disposal and/or related construction activities.

SCOPE OF WORK
FOR
MONITORING LOGGERHEAD SEA TURTLE NESTING
TYBEE ISLAND

1. PURPOSE: The City of Tybee Island, in cooperation with the Georgia Department of Natural Resources, will monitor loggerhead sea turtle nesting efforts on Tybee Island. Such a monitoring program is necessary due to disposal of dredged material obtained from the Savannah Harbor Navigation Project along the beach during the sea turtle nesting season. The entire construction area on the island will be monitored. All nests, false crawls and strandings will be recorded and nest relocations, if necessary, will be performed within 6 hours of the completion of the daily patrol. Monitoring under this work activity will commence on May 1 and will continue on a daily basis through the end of the nesting season (August 15). Any unhatched nests remaining on the beach after August 15 will continue to be monitored to determine hatching success and orientation of emerging hatchlings.

2. WORK EFFORTS: The following work efforts will be undertaken as a part of this activity:

- a. Patrol of the survey area will be made at sunrise each morning from 1 May through August 15. The survey area incorporates all the ocean beach construction area. It will be the responsibility of the surveyor to clear the use of survey vehicles with applicable State agencies and local authorities.
- b. A daily log sheet (obtained from GA DNR Marine Resources Division) will be filled out for each day. All applicable parts of the log sheet should be completed.

c. Should a stranded sea turtle be encountered on the beach, a stranding form (obtained from GA DNR Marine Resources Division) will be completed. If a stranded Kemp's ridley, Green, Hawksbill or Leatherback is encountered, the GA DNR, Marine Resources Division sea turtle coordinator will be contacted at (912/264-7218) on the day of discovery. Dead loggerhead turtles should be buried on the beach after all measurements are taken. Other species should not be buried until clearance is obtained from the sea turtle coordinator.

d. A turtle nest data sheet (obtained from GA DNR Marine Resources Division) will be completed for all turtle nests found. The locations of all nests discovered during the beach monitoring program will be carefully described and recorded in relation to existing structures. A wooden stake, marked with the nest number and date, will be placed a known distance landward of the nest. A map showing the nest location will be sketched on the back of the nest data sheet.

e. All nests which are located in the disposal area or within 500 feet of the limits of the disposal area which are likely to be impacted by future disposal and/or related construction activities will be relocated to an undeveloped portion of the beach north of the disposal site. This includes nests which are laid in the disposal area and are located so that the nest is likely to be destroyed by erosion prior to hatching. All relocated nests will be staked as described in paragraph "d" above. Relocations will be conducted in accordance with the attached guidelines.

f. Efforts should be made to obscure evidence of loggerhead nesting where desirable and practicable. Tracks of crawls leading to a nest are best erased by sweeping or kicking sand. If questioned by onlookers, the nesting surveyor will state that he is performing environmental surveys associated with beach disposal operations.

g. Nests will be observed daily to monitor disturbance and predation. When nests show signs of emergence, the sand around the nests will be smoothed to improve observations of hatchling tracks. For those nests where hatchling tracks can be distinguished, the number and orientation of hatchlings which emerged from the nest will be determined and enumerated. If hatchlings are disoriented, an effort will be made to identify lights which appear to have caused disorientation.

h. Nests will be excavated 3 days following signs of emergence or 65 days following deposition to determine hatchling success. The number of unhatched eggs, egg shells, and dead hatchlings will be determined and recorded.

3. REPORTING: In addition to the reporting requirements mentioned above, a report of findings which incorporates the daily log sheets, stranding forms, turtle nest data sheets and other pertinent field data will be prepared and furnished to the Savannah District within 4 weeks of the completion of beach nourishment. If necessary, a revised report will be furnished to the Savannah District within 2 weeks of receipt of any District comments on the original report.

4. SCHEDULE: The City of Tybee Island would be on site at sunrise on or about May 1 and will monitor daily through August 15 for each year of disposal. Relocation of nests within the impact areas will continue until the nesting season is completed or on August 15. Nest monitoring would continue until all nests have been hatched or until 65 days after the last nest was laid.

GUIDELINES FOR SEA TURTLE NEST RELOCATION

Nests which are located in the disposal areas or within 500 feet of the limits of the disposal area which are likely to be impacted by future disposal and/or related construction activities must be relocated to the designated relocation area. Also, nests which are laid in the newly created beach in areas where they are likely to be destroyed by erosion before incubation is complete will be relocated. The following guidelines should be used:

1. Loggerhead eggs are frequently located on the seaward side of the nest, approximately one-half meter beneath the surface of the sand. Extreme care must be used in attempting to locate eggs. Eggs should be located by hand excavation whenever possible. A probe should be used only by experienced personnel and only after extensive digging by hand has failed to locate the nest (probe should be a wood

or metal rod about 0.75 centimeters in diameter and about 1 to 1 1/2 meters in length). If a probe is used, any broken eggs and spilled contents should be removed and discarded to prevent the clutch from rotting.

2. Once the eggs are located excavate them by hand quickly and carefully. The size (depth, width, etc) of the nest chamber and its location in relation to the primary dune and high tide line should be recorded. Eggs should be placed in a rigid container, such as a Styrofoam or wooden box or a plastic bucket on a layer of moist sand from the nest. The container should be large enough to allow for a sand "buffer" between the eggs and the side of the container to prevent physical damage to the eggs during transportation. Eggs should be shaded from the heat of the sun during relocation. Do not allow the eggs to become dry.

3. The hatching success of nests relocated within 6 hours of laying is higher than that for older nests. Efforts should be made to relocate nests as soon as possible after laying, and care should be used in moving nests to maintain the axial orientation of the egg.

4. The relocation site should be located at a site which closely resembles the natural nest site (i.e. beach profile, relationship to the high tide line and primary dune, etc.). A nest chamber should be excavated with shape and dimensions similar to that of the natural nest. (The pear-shaped configuration of a natural nest can be most easily achieved by using posthole diggers to excavate the "neck" and then scraping out the egg chamber with a sea shell or other small digging implement). Once the eggs have been carefully placed in the chamber and the sand from the original nest put on top, the neck of the chamber should be filled and packed firmly.

5. A turtle nest data sheet should be completed for all relocated turtle nests. The locations of all original and relocated nest sites should be recorded by the method(s) described in the Scope of Work. The street addresses of residences structures used to describe the nest location should be recorded and used in the location map for each nest (the map can be drawn on the back of the nest data sheet). A wooden stake, marked with nest number and date, will be placed a known distance landward of the nest.

0.3.03 Right Whales. The District committed to the following measures to protect Right whales:

a. Each contractor will be required to instruct all personnel associated with the dredging/construction project about the possible presence of endangered right whales in the area and the need to avoid collisions. Each contractor will also be required to brief his personnel concerning the civil and criminal penalties for harming, harassing or killing species that are protected under the Endangered Species Act of 1973 and the Marine Mammal Protection Act of 1972. Dredges and all other disposal and attendant vessels are required to stop, alter course, or otherwise maneuver to avoid approaching the known location of a right whale. The contractor will be required to submit an endangered species watch plan that is adequate to protect right whales from the impacts of the proposed work.

b. The conditions in the current regional opinion, applicable to hopper dredging and which the District would also abide by as long as the opinion is in effect, include the following: Monitoring by endangered species observers with at-sea large whale identification experience to conduct daytime observations for whales between December 1 and March 31. During daylight hours, the dredge operator must take necessary precautions to avoid whales. During evening hours or when there is limited visibility due to fog or sea states of greater than Beaufort 3, the dredge must slow down to 5 knots or less when transiting between areas if whales have been spotted within 15 nm of the vessel's path within the previous 24 hours. (Contractors will be required to use daily available information on the presence of right whales in the project area.) One hundred percent dedicated daytime whale observer coverage is required between December 1 and March 31. Monitoring by sea turtle observers is allowed between April 1 and November 30. At the present time, no aerial surveys are required for the Savannah Harbor area. If a Right Whale Early Warning System (RWEW) is put in place in the future, contractors would be required to use it during dredging operations in acquiring information on the daily presence of whales.

NOTE: * These are the conditions in the NMFS 1995 Biological Opinion for Navigation Channels in the Southeast, and additional guidance provided by South Atlantic Division. Should a new Biological Opinion be issued, the District would consider the conditions listed here void, and would instead abide by the conditions as stated in that Opinion and any further guidance provided by South Atlantic Division.

O.3.04 Manatees. The District committed to the following measures to protect manatees:

- a. The contractor will instruct all personnel associated with the dredging of the presence of manatees and the need to avoid collisions with the manatees.
- b. All personnel associated with the dredging will be advised that there are civil and criminal penalties for harming, harassing, or killing manatees which are protected under the Endangered Species Act of 1973 and the Marine Mammal Protection Act of 1972.
- c. Any collision with a manatee will be immediately reported to the Corps of Engineers' Contracting Officer's Representative (912) 652-5958, The Charleston Ecological Services Office of the Fish and Wildlife Service (803) 724-4707, and the Georgia Department of Natural Resources (weekdays 8:00 a.m. - 4:30 p.m.; (912)2647218 or 1-800-272-8363; nights and weekends: 1-800-241-4113.
- d. All construction activities in open water will cease upon sighting of manatees within 100 yards of the project area. Construction activities will not resume until the manatee has not been seen in the project area for at least 30 minutes.
- e. The contractor will keep a log detailing sightings, collisions, or injury to manatees which occur during the dredging operations.
- f. A report summarizing the above incidents will be provided to the Savannah District for coordination with the U.S. Fish and Wildlife Service, Charleston Ecological Services Office.
- g. All vessels associated with the project will operate at "no-wake" speeds at all times while in the water where the draft of the vessel provides less than four feet of clearance from the bottom and that vessels will follow routes of deep water to the extent possible.

O.3.05 Fisheries. In recent years, Striped bass have experienced significant declines in their population level. This species is known to be sensitive to particular environmental parameters, especially salinity. Savannah District is funding studies to determine the timing, distribution and numbers of Striped bass eggs and larvae in the harbor. Those studies began in 1994 and will be complete in 1998. Until those field studies

are complete and the results fully analyzed, questions will still remain about potential impacts to Striped bass eggs and larvae from dredging operations. Therefore, to remain in compliance with the Georgia Water Quality Certification and address concerns about impacts to the Striped bass population of the Savannah River, dredging will continue to be restricted to the lower harbor (River Mile 5.0 to 0.0) and the Bar Channel during the period from March 15 to May 31 of each year, until this condition in the state water quality certifications is altered. Case-by-case exceptions to that condition require prior approval from GA DNR and the SC DHEC-OCRM. Should future research indicate that this restriction is unnecessary to protect Striped bass, the District would follow procedures agreed to by the state resource agencies.

0.3.06 Migratory Birds. Nesting migratory birds receive protection under the Migratory Bird Treaty Act. Under that Act, nests, eggs, or individual birds cannot be destroyed unless a depredation permit is obtained from the US FWS. Some species of migratory birds do nest on the Savannah Harbor disposal area dikes and could be impacted by dike maintenance activities, particularly mowing. To ensure that these birds receive the protection required while nesting, a change in the maintenance procedures will be instituted in 1995. This change calls for the dike side slopes and other non-travelled surfaces to not be mowed from March 1 to July 15. The traveling surface (roadway) on the dike crest would continue to be mowed when necessary to allow safe movement around the dikes for inspection and disposal area use purposes. Mowing of dike side slopes would only be performed outside the March 1 to July 15 period.

0.3.07 At the present time, strict compliance with the Migratory Bird Treaty Act requires an assessment of each dredging project to determine if the project would impact nesting migratory birds. This includes an assessment of whether head section and subsequent discharge of dredged material will take nesting migratory birds, their nests, eggs, or young. If impacts to nesting birds appear unavoidable, the District must secure a Depredation Permit from the US FWS (Atlanta Regional Office) before construction activities could occur. The District has requested an opinion from the US FWS that, with implementation of the wildlife management mitigation strategy to enhance bird habitat, overall management of the disposal areas would have a net positive impact on nesting migratory birds, with no requirement that particular minor takes associated with dredging operations would require separate authorization.

0.3.08 Ocean Disposal. This EIS contains an update of the Section 103 Evaluation which Savannah District prepared to determine the acceptability of channel sediments for ocean disposal. That evaluation concluded that bar channel sediments are suitable for placement at the Ocean Dredged Material Disposal Site (ODMDS). The District has received concurrence from EPA in that determination by letter dated March 23, 1995.

0.3.09 One commitment included in that document consisted of the time period before another Section 103 Evaluation would be conducted. That duration was 3 years.

0.3.10 That document included a commitment concerning the source (channel stationing) from which the sediments would be dredged that would be transported and placed in the ODMDS. The Section 103 Evaluation stated that Bar Channel (oceanward of Station 0+000) sediments would normally be excavated and placed at the ODMDS.

0.3.11 Management of the Savannah ODMDS. Several commitments were included in the Site Management Plan for the Savannah Harbor ODMDS, which is found in Appendix I. Those commitments are described in the following paragraphs.

0.3.12 Material Suitability. The District would document the material suitability for dredging events proposed for ocean disposal when more than 3 years have passed since the last verification. The Section 103 Evaluation in this EIS contains an assessment of the material suitability. An exchange of letters between the Corps and EPA would suffice for that verification. If more than 5 years have passed since the last verification, the District would perform a new Section 103 Evaluation and issue a Public Notice concerning the action.

0.3.13 Disposal Technique. When normal Bar Channel maintenance material or other suitable material is available, the District agreed to have that material placed so that the mound existing in the northeast quadrant of the site will be continued to the south to provide a barrier to large northeasterly waves. Should predominantly fine-grained dredged materials need to be disposed in the site, they would be placed within just west of the mound, where they would be more sheltered from large storm waves.

0.3.14 Placement of Materials. The District agreed to consult with EPA prior to placing dredged material at the site other than the normal Bar Channel maintenance sediments.

0.3.15 Disposal Monitoring. The District agreed that the dredging contractor would prepare and operate under an approved electronic verification plan for all disposal operations. As

part of this plan, the contractor will use an automated system that will continuously track the horizontal location and draft condition (vertical) of the disposal vessel from the point of dredging to the disposal area, and return to the point of dredging. Accuracy and precision of the locational system will be at least as good as provided by Loran C. Required digital data are as follows:.

- (a) Date;
- (b) Time;
- (c) Vessel Name;
- (d) Dump Number;
- (e) Map Number on which dump is plotted;
- (f) Horizontal location and draft of disposal vessel each 30 minutes;
- (g) Beginning and ending coordinates of the dredging area for each load, and the beginning and ending coordinates for each dump and the compass heading at the beginning of each dump;
- (h) Channel stations from which dredged material came; and
- (i) Volume and brief description of material disposed.

0.3.16 Savannah District will require such information in digital form from all dredging contractors and will compile and continuously update computer plots depicting placement of dredged material. Plotted coordinates will be in GPS-corrected latitude/longitude to enhance use by all associated monitoring agencies.

0.3.17 Prior to commencement of disposal operations, a baseline bathymetric survey will be conducted of the disposal area and adjacent areas by the site user. The survey will be taken along lines spaced on 500-foot intervals and be of sufficient length to adequately cover the area. Accuracy will be +/- 1.0 feet. The survey will be referenced to MLW and corrected for tide conditions at the time of the survey. The Savannah District ARTIS tide gauge will be used for tidal corrections. As a follow-up to the baseline bathymetric survey, the District will conduct a similar survey after disposal. The number of transects and accuracy required will be the same as in the baseline survey.

0.3.18 Sediment Mapping and Site Bathymetry. Close grid hydrographic surveys will be conducted at least annually to monitor the site's bathymetry. The sediment mapping effort should encompass the entire area of the ODMDS designated for maintenance disposal and a 0.25 NM buffer zone around that site. The spacing of the grid may be increased on the southern half of the ODMDS if disposal activities occur only in the northern half of the site. After more detailed surveys are performed which

confirm the overall direction of movement, the positioning of benthic sampling stations can be determined for a revised baseline assessment of benthic infaunal communities in the area (see next section).

0.3.19 Biological Impact Assessments. EPA will conduct benthic surveys both in the ODMDS and in the area immediately surrounding the site. The benthic data will allow determinations to be made concerning whether benthic resources outside the ODMDS are being affected by disposal of fine-grained materials, and determine whether these changes are detrimental. The primary focus of this monitoring effort will be to determine whether disposal operations cause a major change in the faunal composition of benthos (which could affect trophic functions) and/or whether there are significant alterations in species numbers or biomass. The benthic surveys will involve collecting benthic samples in and around the ODMDS using a stratified random sampling design. The general zones (strata) will include areas both within the ODMDS and adjacent to all boundaries of the ODMDS (Figure 3). The zones within the ODMDS would be used to document changes in the benthic communities following disposal operations for comparison with zones outside the ODMDS. The initial survey will involve sampling all of the zones, with several grab samples collected randomly in each zone. The number of samples obtained per zone will be determined from preliminary sampling or historical data, but will be sufficient to adequately represent the benthic community composition (based on species saturation curves) and detect moderate changes in faunal densities, biomass, and species numbers (based on power analyses). At least one sample will be taken within the area of steepest slope in the south-central portion of the ODMDS. Each benthic sample obtained for faunal assessment will be subsampled to determine sediment characteristics of the sample (eg, grain size, percent silt, clay, sand, CaCO_3 , etc.). The sediment samples will be used to (1) further characterize the composition of surficial sediments in and around the ODMDS, and (2) aid in interpreting changes in benthic infaunal composition.

0.3.20 Disposal Plume Dispersion. While no live bottom communities are known to be associated with the Savannah ODMDS, such communities, when present, are an important habitat for productivity and fish use. Should any significant benthic communities be identified in the area, an evaluation would be conducted to determine if they would be impacted by turbidity plumes. At that time, a typical turbidity plume generated by a major disposal event should be delineated and its areal distribution plotted. A ship-mounted transmissometer could be used to profile light attenuation at grid points encompassing the plume. The outer boundaries of the grid could be determined using an aircraft mounted GPS during an aerial reconnaissance of

the disposal operation prior to initiating the grid profiling. Information gleaned during this effort could be compared to plume turbidity/suspended solids concentrations for consideration of plume impact.

0.3.21 Sediment Turbidity Transport Studies. The primary task required for current data collection would be the deployment and retrieval of continuously recording current meters. Ideally, a long-term continuous data base obtained over a two-year period should be obtained to evaluate both seasonal and yearly variability in current patterns. Deployment of a Acoustic Doppler Current Profiler (ACDP) placed within or adjacent to the ODMDS would provide the best data base for this effort. Quarterly or semiannual retrieval of the data record would provide timely information on prevailing current patterns. Collection of such data should be coincident with a major disposal project during which sediment mapping, plume dispersion, and sediment sampling occurs. This would allow integration of current data into these programs, thus enhancing interpretation of plume dispersion, sediment transport and sedimentation.

0.3.22 Sediment Contaminant Monitoring. A critical component of the Site Monitoring Plan will be to periodically sample sediments in and adjacent to the ODMDS to monitor for changes in sediment contaminant levels. This sampling would be conducted by EPA using a tiered approach, where sites outside the ODMDS are not monitored until elevated levels are detected inside the ODMDS. A Tier I evaluation of the need for sediment chemical testing would be conducted every 3 years to coincide with a similar evaluation of sediments in the Bar Channel. More frequent sampling of the sediments may be warranted if elevated levels of certain contaminants are found, but the analysis could be restricted to only those constituents which are above acceptable levels.

0.3.23 Section 404 Evaluation For Dredge And Fill Actions.

0.3.24 Wetland impacts in South Carolina from diking of Disposal Area 14A and other proposed work described in the EIS, as well as wetland impacts in Georgia resulting from miscellaneous disposal area operations and construction of an access road to Disposal Area 2A, are all addressed in the Section 404(b)(1) Evaluation for this project. A Mitigation Plan for South Carolina wetland impacts has been completed. The District agrees to develop a mitigation plan for wetland impacts in Georgia. The mitigation plans are discussed below.

0.3.25 Stormwater Runoff. As a component of the Section 404 Evaluation, the District considered the potential for adverse impacts resulting from the stormwater runoff from dikes at the confined disposal facilities during their periodic improvement

(raising) projects. In that evaluation, the District committed the sponsor to use "Best Management Practices", as defined in the Manual For Erosion And Sediment Control In Georgia or the South Carolina Stormwater And Sediment Control Handbook For Land Disturbance Activities, whichever is appropriate, during those construction events. Uncontrolled discharges associated with stormwater runoff from within the CDFs are considered transient events for which regular monitoring is not possible. Controlled discharges associated with dredge disposal management operations and wildlife management would be regularly controlled and monitored.

0.3.26 The District's monitoring program would include weekly monitoring of the level of suspended solids in the effluent. The District will use a standard for acceptability of its weir effluents of 500 mg/l. That standard would be used for the weir discharge, with no consideration of a mixing zone, to make monitoring easier to perform. The suspended solids level at the edge of a normal mixing zone is likely to be much lower than that measured at the weir. Water levels would be managed within the confined disposal facilities to obtain the settling time necessary to produce an effluent with suspended solids less than the standard of 500 mg/L. The maximum design height at which water can be held, in conformance with present dike construction practices, is 2 feet below the dike crest. Water held at those levels would result in maximum retention time of the sediment/water slurry, and thereby, maximum removal of the suspended solids.

0.3.27 Erosion Control And Sedimentation Plan. The District prepared an Erosion and Sediment Control Plan, which can be found in Appendix N. That plan described actions which would be taken to minimize adverse impacts resulting from non-point source pollution from construction projects at the dikes at the confined disposal facilities (dike raising projects). In that document, the District committed the sponsor to use "Best Management Practices", as defined in the Manual For Erosion And Sediment Control In Georgia or the South Carolina Stormwater Management And Sediment Control Handbook For Land Disturbance Activities, whichever is appropriate, during those construction events. The local sponsor will prepare and submit documents to the SC OCRM for the purpose of obtaining a Stormwater Permit for the initial construction of the Disposal Area 14A dikes. Implementing the procedures described in the Erosion and Sediment Control Plan contained in Appendix N of this EIS will provide environmental clearance for subsequent Project dike raising activities in South Carolina.

0.3.28 Section 106 Compliance (Cultural Resources). The District made four sets of commitments concerning cultural resources. Two concern significant cultural resources -- the CSS GEORGIA and Old Fort Jackson -- and are included in separate appendices in this EIS. The third set of commitments concern additional evaluations which must be conducted prior to construction at specific sites to ensure significant cultural resources would not be impacted. The fourth set of commitments concern the Cultural Resource Management Plan prepared as part of the EIS, and also contained in a separate appendix. These commitments are summarized in paragraphs 0.3.29 through 0.3.35.

0.3.29 Old Fort Jackson. In the Memorandum of Agreement (MOA), the District agreed to (1) study the streambank erosion problem at Old Fort Jackson to determine the nature, extent, and cause(s) of the problem, and (2) determine the contributing effect of the construction and/or maintenance of the Savannah Harbor Navigation Project on bank erosion. If the conclusion from those studies is that construction and/or maintenance of the Savannah Harbor Navigation Project contributes to the bank erosion problem at the Old Fort Jackson Historic Site, then Savannah District will implement the following further actions.

- a. Savannah District shall identify and evaluate alternatives to eliminate, minimize, and retard the contribution to bank erosion problem at the Old Fort Jackson Historic site, caused by the construction and/or maintenance of the Savannah Harbor Navigation Project.
- b. Savannah District shall develop a mitigation plan to minimize the adverse effects of streambank erosion on Old Fort Jackson, resulting from the construction and/or maintenance of the Savannah Harbor Navigation Project, in accordance with 36 CFR Part 800.5.
- c. The District's studies, study results, evaluations and determinations shall be documented in a report. The report will include a discussion of various erosion control alternatives, the merits, efficacy, and projected costs of each alternative, and make recommendations as to the optimal erosion control alternative(s). The optimal erosion control plan shall be incorporated into a draft mitigation plan for mitigating the adverse effects to the Old Fort Jackson Historic site resulting from the Savannah Harbor Navigation Project.

- d. The draft mitigation plan shall be provided to the GA SHPO, the Council, the Coastal Heritage Society, and interested local historical groups for comment. A final mitigation plan, including mitigation recommendations and projected costs of implementation, shall be developed following receipt and consideration of all comments.
- e. Savannah District shall, in consultation with the property owner, the State of Georgia, and the property lessee and operator, the Coastal Heritage Society, develop a cost-sharing program by which the mitigation measures recommended as the optimal solution to the bank erosion problem at the Old Fort Jackson Historic Site may be implemented.
- f. Savannah District, in conjunction with the GA SHPO and the Coastal Heritage Society, shall implement the recommended plan subject to the availability of funds. Savannah District shall function as the lead party in coordinating and implementing the work necessary to implement the mitigation plan.
- g. Should the mitigation plan entail the alteration or destruction of any features associated with the Old Fort Jackson Historic Site, such that data recovery of buried archeological deposits/artifacts might be recovered, a research design for the necessary data recovery shall be developed by the Savannah District and coordinated with the GA SHPO and the Coastal Heritage Society, who shall have the opportunity to review and comment on the proposed data recovery plan.
- h. The final mitigation plan shall be submitted by Savannah District to the GA SHPO and the Council for a 45-day review period. Unless the GA SHPO or the Council objects during the review period, the mitigation plan shall be considered approved.
- i. Savannah District shall ensure that any archeological data recovery carried out pursuant to this Agreement is carried out by, or under, the direct supervision of an individual meeting, at a minimum, the standards for an archeologist as set forth in the Department of the Interior's Archeological and Historic Preservation: Secretary of the Interior's Standards and Guidelines (48 FR 44716-42) for a historic archeologist. Any and all materials and records resulting from any such data recovery are curated in accordance with 36 CFR Part 79.

O.3.30 Savannah District will also ensure that all final reports resulting from the MOA will be provided to the GA SHPO and the Council, and to the National Park Service, Southeast Regional Office for possible peer review and submission to the National Technical Information Service (NTIS). The District shall ensure that all such reports are responsive to the contemporary professional standards, and to the Department of Interior's "Format Standards for Final Reports of Data Recovery Programs" (42 FR 5377-5379).

O.3.31 CSS GEORGIA. In the Memorandum of Agreement (MOA), the District made the following commitments:

1. Conduct such studies as are necessary to determine the present condition of the vessel, its stability as a historic site/object, any factors which may threaten its present condition or stability, and restrictions which the vessel places on present harbor operations.
2. Determine the contributing effect of the construction and/or maintenance of the Savannah Harbor Navigation Project on the CSS GEORGIA, in accordance with 36 CFR Parts 800.5 through 800.9.
3. If the conclusion from the studies is that construction and/or maintenance of the Savannah Harbor Navigation Project contributes to the degradation or reduced stability of the CSS GEORGIA, then the District would take the following actions:
 - a. Identify and evaluate alternatives to eliminate, minimize, and retard the Savannah Harbor Navigation Project contribution to factors which may threaten the vessel's present condition or stability. If the vessel is restricting present harbor operations, alternatives shall be evaluated which would allow those restrictions to be eliminated or minimized.
 - b. Develop a mitigation plan to minimize the adverse effects on the CSS GEORGIA resulting from the construction or maintenance of the Savannah Harbor Navigation Project, in accordance with 36 CFR Part 800.5.
 - c. Document the District's studies, study results, evaluations and determinations in a report. The report will include a discussion of the present condition of the vessel, factors which may threaten the vessel's

present condition, adverse effects which construction and/or maintenance of the Project has had on the vessel, and restrictions which the vessel has on present harbor operations, the merits, efficacy, and projected costs of each alternative, and make recommendations as to the optimal alternative(s). The plan shall be incorporated into a draft mitigation plan for mitigating the adverse effects to the CSS GEORGIA resulting from the Savannah Harbor Navigation Project.

- d. The draft mitigation plan shall be provided to the GA SHPO, the SC SHPO, the Council, and interested local historical groups for comment. A final mitigation plan, including mitigation recommendations and projected costs of its implementation shall be developed following receipt and consideration of all comments.
- e. Implement the recommended plan, subject to the availability of funds.
- f. Should the mitigation plan entail the alteration or destruction of any features associated with the CSS GEORGIA, such that data recovery of buried archeological deposits/artifacts might be recovered, a research design for the necessary data recovery shall be developed by the Savannah District and coordinated with the GA SHPO and the SC SHPO, who shall have the opportunity to review and comment on the proposed data recovery plan.
- g. Submit the final mitigation plan to the GA SHPO, the SC SHPO, and the Council for a 45-day review period. Unless the GA SHPO, the SC SHPO, or the Council objects during the review period, the mitigation plan shall be considered approved.
- h. Ensure that any archeological data recovery carried out pursuant to this Agreement is carried out by, or under the direct supervision of, an individual meeting, at a minimum, the standards for an archeologist as set forth in the Department of the Interior's Archeological and Historic Preservation: Secretary of the Interior's Standards and

Guidelines (48 FR 44716-42) for a historic archeologist. Curate in accordance with 36 CFR Part 79 any and all materials and records resulting from any data recovery investigations

O.3.32 The District will also ensure that all final reports resulting from the MOA will be provided to the GA SHPO, the SC SHPO, and Council, and to the National Park Service for possible peer review and submission to the National Technical Information Service (NTIS). Savannah District shall ensure that all such reports are responsive to the contemporary professional standards, and to the Department of Interior's "Format Standards for Final Reports of Data Recovery Programs" (42 FR 5377-5379).

O.3.33 Cultural resource surveys (side scan and magnetometer surveys) would be conducted at each new disposal area located in the nearshore area. This includes the island to be constructed off Turtle Island, the submerged berms, and the feeder berm. The District's evaluation and findings would be provided to the SHPO for approval prior to initial sediment deposition at each site,

O.3.34 Construction of underdrains could potentially impact cultural resources located along the pipe alignment. Prior to installation, archival information would be reviewed to determine if any proposed underdrain alignment had the potential for impacting any known cultural resource sites in the confined disposal areas. If there was a significant potential for adverse impact to a known site, a cultural resource survey would be performed of the underdrain alignments and approval of the study's findings from the SHPO would be obtained prior to excavation.

O.3.35 Cultural Resource Management Plan. The District also prepared a plan which describes how future actions related to other cultural resources will be addressed. This includes both (1) sites which are currently known, but which are not expected to be impacted by harbor operations, and (2) sites whose existence is not currently known, but becomes evident in the future. As part of that Plan, the District will study the cumulative impacts which harbor operations and issuance of Department of the Army permits has had upon cultural resources in the harbor.

O.3.36 South Carolina Wetland Mitigation Plan. Wetland impacts in SC would result from the diking of Disposal Area 14A (305 acres) and miscellaneous disposal area operations (6.0 acres). The District will maintain records of the actual acreage of wetlands impacted as those impacts occur over the project life. Commitments made in the LTMS Mitigation Plan for addressing those

impacts include several items: water level management for bird use, clearing and maintenance of a bird nesting area on Jones/Oysterbed Island, construction of nesting islands within disposal areas, construction of a bird nesting island offshore of Turtle Island, establishment of an escrow account with the SC OCRM for in-kind mitigation, and construction of a water control structure at the Savannah NWR for fisheries benefits. The plan employs a rotating disposal area use schedule of about 2 years, with modifications for bird use. In this scenario, each disposal area would be available for use in disposal operations for two years, followed by two years of drying. The rotation period may vary from 2 years, but one CDF from each pair must be available at all times for disposal/wildlife management purposes. A 26-acre bare ground nesting area would be cleared and maintained on high ground outside the dike at the Jones/Oysterbed Island Disposal Area for use by colonial nesting birds. Two 1.0-acre isolated nesting islands would be constructed and maintained in each area for use by nesting migratory shorebirds. An island would be established offshore of the South Carolina Turtle Island Wildlife Management Area. This bare ground bird nesting area would be constructed using open water placement of dredged material obtained from within, below, or adjacent to the navigation channel. The island would have a 2.0-acre crown located at +14 feet MLW. Disposal areas would be managed during each scheduled 2-year use period for the most environmentally appropriate outcome following each disposal operation. Dredging needs would have top priority concerning the scheduling of disposal events, while management of the disposal areas for wildlife would be a secondary consideration. The goal would be to have at least one disposal area each year functioning for each of the following four major categories of bird use: (1) spring migrants, (2) summer nesting shorebirds, (3) fall migrants, and (4) wintering shorebirds and waterfowl. Note that a disposal area may provide more than one function within a given year. For example, an area held wet for wintering shorebirds and waterfowl could be slowly dried during the spring for spring migrants. An escrow account would be established by the non-Federal sponsor or his agent to restore/create/protect 25 acres of tidal wetlands in South Carolina. The account would be administered by the SC DHEC-OCRM. The water control structure would be constructed at a 228-acre impoundment on the Savannah National Wildlife Refuge. Currently, a daily connection with the Savannah River is not maintained at the impoundment. This structure would allow a continuous connection with the river, thus establishing the impoundment as fish feeding, spawning, and nursery habitat.

0.3.37 Special considerations would apply to disposal operations taking place during the nesting season. Sand mounds would be constructed in each confined disposal area for use by nesting birds such as least terns, Wilson's plovers, killdeer and nighthawks. Portions of these or other mounds would be constructed for use by black-necked stilts. Two bird nesting

mounds would be constructed and maintained in each of the confined disposal areas in the rotational program (Disposal Areas 12A, 12B, 13A, 13B, 14A, 14B, and Jones/Oysterbed Island). Each mound would have an area above the potential flood height of 1 acre. The crest of the mounds would be constructed above the height of the flooded pool to avoid inundation during disposal operations. Once these mounds are in place, it would be judged beneficial to flood the surrounding areas in the spring and early summer for both protection of the mounds from predators and stimulation of invertebrate prey populations. A disposal operation could proceed early in a nesting season where impacts to nesting individuals are judged to be minor in comparison to the later benefits expected to accrue to the species involved.

O.3.38 Management of a disposal area for birds would depend on the month in which the disposal operation is scheduled to end. Management options available after a disposal operation ended would be chosen based on the situation in other disposal areas and the availability of habitat for each major category of bird use (spring migrants, summer nesting shorebirds, fall migrants, and wintering shorebirds and waterfowl). Maintenance of a constant water level within a disposal area may not be possible for extended periods due to the natural effects of evaporation and infiltration. However, discharges from the site through the weirs and underdrains could be stopped to retain as much water as possible. The disposal operation would be managed to ensure the successful attainment of the scheduled management scenario. This would include management of weir discharges to ensure a full pool upon completion of the disposal operation. Since water would be held in the disposal areas for longer periods than presently occurs, there is a potential for increased mosquito breeding. To address that possibility, purple martin nesting houses and bat houses would be installed at each of the disposal areas included in the rotation program to provide a biological control for that situation. Table 1 displays the actions which would be taken after completion of disposal operations. The critical factor used to decide which management technique would be implemented is the date when disposal operations are complete.

O.3.39 Mitigation for Other Wetland Losses. Other wetlands would be lost in the State of Georgia as a result of the construction of an access road to Disposal Area 2A and miscellaneous disposal area operations. Mitigation for those losses consists of the restoration of 6.4 acres of tidal marsh in the harbor area. The plan would replace 3.2 acres of wetlands which would be permanently lost at a 2:1 rate. The Plan will be coordinated with the GA DNR Coastal Resource Division and the US FWS for approval. In light of the relatively small number of acres involved, it is expected that a site can be identified in the general Savannah Harbor area where the sponsor or the GA DOT can restore previously impacted marsh as a component of another

TABLE 1

CONFINED DISPOSAL AREA MANAGEMENT TECHNIQUE

Date Disposal Operation Ends	Proposed Management Technique
1 Jan - 15 Mar	Hold water level as high as possible. Beneficial to waterfowl and wintering shorebirds. Draw down in the spring for migrating shorebirds.
15 Mar - 15 Jul	<u>Option 1.</u> Hold water as protection for nesting terns, plovers, nighthawks, and in preparation for fall draw down for fall migrating shorebirds. <u>Option 2.</u> Draw water down slowly for spring migrating shorebirds and nesting black-necked stilts and vegetation growth if flooded later for wintering waterfowl.
15 Jul - 15 Nov	<u>Option 1.</u> Draw down slowly for fall migrating shorebirds. <u>Option 2.</u> Hold for wintering waterfowl and shorebirds.
15 Nov - 31 Dec	Hold water level as high as possible for wintering waterfowl and shorebirds, and in preparation for spring draw down for spring migrating shorebirds.

construction project. Construction of the access road to Disposal Area 2A would result in the permanent loss of approximately 2.9 acres of tidal wetlands. Approximately 0.14 acres would be lost as a result of pipe ramp expansions and an additional 0.04 acres would be lost from weir/discharge pipe replacements. Implementation of this wetland mitigation plan would occur before the access road is placed in service.

0.3.40 Tidegate Construction and Deepening. In 1965, improvements to the Savannah Harbor Navigation Project were authorized by Congress. Those improvements included deepening of the shipping channel, as well as construction of the Tidegate and freshwater control features. The freshwater control features were constructed to reduce salinity impacts to the Savannah National Wildlife Refuge expected from the combined harbor deepening and Tidegate construction project. The District Engineer's report, dated October 24, 1964, included the following conclusion:

"The most feasible plan for preventing damage to the refuge operations would be the construction of channels for fresh water diversion from Front River to Middle and Little Back Rivers through McCoombs Cut and the construction of a fresh water canal and control structures to supply fresh water to refuge lands."

0.3.41 The freshwater supply system had the following five components:

- (1) a 5,500-foot long canal through McCoombs Cut to provide freshwater to the Savannah NWR (Figure 4). The canal was constructed with a 200-foot bottom width at EL -7' MLW and 2H:1V side slopes. The design flow through McCoombs Cut was 4,000 CFS.
- (2) a channel in Middle River with a 90-foot bottom width at EL -6' MLW and 2H:1V side slopes. The design flow in Middle River was 1,500 CFS.
- (3) a channel in Little Back River with a 200-foot bottom width at EL -5.1' MLW and 2H:1V side slopes. The design flow in Little Back River was 2,500 CFS.
- (4) a 28,000-foot long freshwater supply canal with a 28-foot bottom width at EL -4' MLW, 2H:1V side slopes, and water control structures.
- (5) a 3,700-foot long connecting canal with a 6-foot bottom width at EL -4' MLW, 2H:1V side slopes.

O.3.42 A canal to provide freshwater to private lands located adjacent to and downstream of the Refuge was determined by the District Engineer to not be economically justified, but was added to the project by Congress. That canal was designed with a 6-foot bottom width at EL -4' MLW and 2H:1V side slopes.

O.3.43 The Federal government is responsible for maintenance of the Diversion Canal, the channels in Little Back River and Middle River, and the canals and control works for the Refuge. Maintenance of the canal to reduce salinity impacts to adjacent private lands is the responsibility of the non-Federal sponsor. Since the Tidegate is not currently in use, no maintenance of those canals by the sponsor is necessary.

O.3.44 Tidegate/New Cut Project. Several commitments were made in the 1991 Section 1135 Feasibility Report and Environmental Assessment for the filling of New Cut. Most of those commitments concerned how the dredging and disposal operations would be conducted to minimize impacts to water quality during the construction of that project. Other commitments were related to cultural resources. Investigations were to be conducted to assess and document any impacts to cultural resources in Back River. Those investigations were conducted and a report was completed by Savannah District in August 1994 which documented those studies. The report, titled "Archival Research, Archaeological Survey, and Site Monitoring; Back River, Chatham County, Georgia and Jasper County, South Carolina", was coordinated with both the Georgia and South Carolina SHPO.

O.3.45 The 1991 Feasibility Study also identified the potential for impacts to Old Fort Jackson and the CSS GEORGIA from changes in river hydraulics resulting from project implementation. The report stated that "Since these resources have been, and continue to be, impacted by maintenance dredging under the Savannah District's Operations and Maintenance (O&M) Program, studies of the impacts to these resources will be funded with O&M funds as part of our proposed development of a Long Term Management Strategy for the Savannah Harbor. Any mitigation needs for these resources identified in the study of these sites would also be completed with O&M funds." A Programmatic Agreement was signed by the District in January 1992 to document what studies would be conducted. Summaries of pertinent sections of that agreement are as follows:

- a. Savannah District shall ensure that an archeological survey of the areas of primary and secondary effect is conducted. The survey shall be conducted in

consultation with the GA SHPO and the SC SHPO, and reports of the survey, meeting the standards of the GA SHPO and the SC SHPO, shall be submitted to the GA SHPO and the SC SHPO for review and approval.

- b. Savannah District shall determine the effect of the Section 1135 Project upon properties determined eligible for inclusion in the National Register of Historic Places.
- c. Savannah District shall identify and evaluate alternatives to avoid and/or mitigate adverse effects to properties determined eligible for inclusion in the National Register of Historic Places.
- d. Savannah District shall ensure that data recovery plans are developed in consultation with the GA SHPO and SC SHPO for the recovery of archeological data from properties determined eligible for inclusion in the National Register of Historic Places. The plans shall specify, at a minimum:
 - a. the property, properties, or portions of properties where data recovery is to be carried out;
 - b. any property, properties, or portions of properties that will be destroyed without data recovery;
 - c. the research questions to be addressed through the data recovery, with an explanation of their relevance and importance;
 - d. the methods to be used, with an explanation of their relevance to the research questions;
 - e. the methods to be used in analysis, data management, and dissemination of data, including a schedule;
 - f. the proposed disposition of recovered materials and records;
 - g. proposed methods for involving the interested public in the data recovery;
 - h. proposed methods for disseminating results of the work to the interested public;

1. proposed methods by which local historic sites and historic preservation agencies and individuals will be kept informed of the work and afforded the opportunity to participate;
- j. a proposed schedule for the submission of progress reports to Savannah District, the GA SHPO, SC SHPO, and Council, and
- e. The data recovery plans shall be submitted by the Savannah District to the GA SHPO, SC SHPO, and Council for 45 days review. Unless the GA SHPO, SC SHPO, or the Council objects within 45 days after receipt of a data recovery plan, the Savannah District shall ensure that it is implemented.
- f. Savannah District shall ensure that all archeological survey, testing, and data recovery work carried out pursuant to this Programmatic Agreement is carried out by or under the direct supervision of a person or persons meeting at a minimum the standards for archeologist set forth in the Secretary of the Interior's Standards and Guidelines for Archeological Documentation (48 FR 44716-42);
- g. Savannah District shall ensure that all materials and records resulting from survey, testing, and data recovery are curated in accordance with 36 CFR Part 79;
- h. Savannah District shall ensure that all final archeological reports resulting from actions pursuant to this agreement will be provided to the GA SHPO, the SC SHPO, and Council, and to the National Park Service for possible peer review and submission to the National Technical Information Service (NTIS). The Savannah District shall ensure that all such reports are responsive to the contemporary professional standards, and to the Department of Interior's "Format Standards for Final Reports of Data Recovery Programs" (42 FR 5377-79).
- i. The Savannah District will ensure that information resulting from the archeological surveys, testing, and data recovery efforts provided for in this agreement are provided to the Georgia and South Carolina State Site Files for inclusion in the State site file systems.

- j. In consultation with the Council and the GASHPO, Savannah District will prepare a Memorandum of Agreement to outline procedures for identifying, evaluating, and mitigating and/or removing adverse effects of the Savannah Harbor Navigation Project upon Old Fort Jackson, a property listed in the National Register of Historic Places;
- k. In consultation with the Council, the GA SHPO, and the SC SHPO, Savannah District will prepare a Memorandum of Agreement to outline procedures for identifying, evaluating, and mitigating and or removing adverse effects of the Savannah Harbor Navigation Project upon the CSS GEORGIA, a property listed in the National Register of Historic Places;

0.3.46 1993/1994 Deepening Project. Several commitments were made in the 1991 Feasibility Report and EIS for the Deepening Project. Many of those commitments concerns how the dredging and disposal operations would be conducted to minimize impacts to water quality during the construction of that project. A standard water quality monitoring plan was established. Other commitments, related to cultural resources, are described in the following paragraphs. The commitments center around two significant cultural resources, Old Fort Jackson and the CSS GEORGIA. Concerning the CSS GEORGIA, paragraph 5.79 of the EIS stated that "Impacts to the wreck could be mitigated by mapping, recovery, and conservation of the wreckage on the channel bottom and the 100-foot stand-off restrictions to dredging in this area. Deepening to 42 feet would require archaeological excavation of the wreck site. Excavation of the site has an estimated cost in excess of five million dollars. One alternative being considered in lieu of excavation would be to narrow the channel in this area and allow one-way harbor navigation in the wreck vicinity. Mitigation alternatives are being developed and will be coordinated with proper State and Federal agencies". Concerning Old Fort Jackson, paragraph 5.84 of the EIS stated that "The river bank at Old Fort Jackson has been riprapped; however, erosion has continued. Narrowing of the north side of the channel and allowing only one-way traffic in this vicinity is being considered to avoid impacts to the CSS Georgia. Additional narrowing may be needed on the south side of the channel to reduce impacts to Old Fort Jackson. The exact amount of channel narrowing that would be needed will be the subject of future studies".

O.3.47 A Programmatic Agreement was prepared between Savannah District, the Georgia State Historic Preservation Officer (GA SHPO), the South Carolina State Historic Preservation Officer (SC SHPO), and the Advisory Council on Historic Preservation (ACHP) as signatory partners. The PMOA stipulated that Savannah District will fulfill the requirements of 36 CFR Part 800 by implementing the following actions:

- a. Conduct archival and literature research of the deepening impact areas (including disposal areas);
- b. Conduct underwater remote sensing (magnetometer, fathometer, side scan sonar, and sub-bottom profiler) surveys;
- c. Conduct a low-water shoreline survey;
- d. Map the side slopes and channel bottom in the areas of Old Fort Jackson and the CSS GEORGIA;
- e. Test and recover ordnance from the portions of the CSS GEORGIA wreck located within the new authorized channel prism;
- f. Coordinate all survey and testing results with the GA SHPO, SC SHPO, and ACHP in order to make definitive determinations of eligibility for inclusion in the National Register of Historic Places and determine the effect of the deepening project upon each resource;
- g. In coordination with the GA SHPO, SC SHPO, ACHP, and other interested parties identify and evaluate alternatives for avoiding and/or mitigating impacts to significant resources;
- h. Implement the avoidance/mitigation program; and
- i. Conduct a study of the long and short term impacts of the Federal operation and maintenance activities, removal of the Tidegate from operation, and issuance of Department of the Army permits within the harbor on cultural resources.

O.3.48 All cultural resources studies were to be coordinated with the Georgia and South Carolina State Historic Preservation Officers, and, when appropriate, with the Advisory Council on Historic Preservation. An attempt was to be made to complete all of this work prior to construction of the project; however, if construction of the project was authorized and could be accomplished prior to completion of the above described studies

and coordination, initial construction of the project would proceed, but would be limited to construction of a project with a bottom width which would not result in side slope sloughing. This would avoid impact to all cultural resources which could potentially be impacted by full project construction. Construction of the remaining portions of the project would be completed once the above described process is completed and all resources have been mitigated.

0.3.49 A 100-foot standoff is to be used at the site of the CSS GEORGIA. That restriction was implemented during the project construction through a total restriction on dredging for the 1,000 foot channel reach (Stations 58+000 to 59+000) which encompass the wreck.

0.3.50 A significant amount of work has been accomplished on these items. Extensive data recovery efforts were performed as part of the Deepening Project. Additional studies were performed at that same time which were funded by the LTMS Study. Item a. has yet to be completed, but will soon be performed using funds from the Deepening Project. Items b. and c. have been completed and the results have been coordinated in accordance with items f and g. Remaining work items will be accomplished and are included in the separate Memorandums of Agreement for Old Fort Jackson and the CSS GEORGIA, and the Cultural Resource Management Plan.

0.4.00 APPROVALS AND CERTIFICATIONS RECEIVED.

0.4.01 Introduction. This section of the document contains all the environmental approvals and certifications for the Savannah Harbor Navigation Project which were received as a result of review of the draft EIS.

0.4.02 Water Quality Certification, State of Georgia. In a letter dated September 5, 1995, the State of Georgia, Department of Natural Resources, Environmental Protection Division (GA DNR-EPD) issued a Section 401 Water Quality Certification for the Long Term Management Strategy. Conditions in the certification are listed below. The District received clarification from the State by letters dated February 6 and 28, 1996, on three of the

conditions and has requested a modification on one condition. The conditions below reflect those which have been clarified by the State. Further discussions with GA DNR staff confirm that conditions 5 and 6 apply only to hopper dredges.

0.4.03 The Georgia certification was issued contingent on the following conditions:

1. All work performed during construction will be done in a manner so as not to violate applicable water quality standards.
2. No oils, grease, materials or other pollutants will be discharged from the construction activities which reach public waters.
3. No dredging operations will be conducted during the striped bass spawning period from March 16 to May 31.
4. Prior to initiation of dredging activity between July 1 and September 30, the dredge operator must establish the following procedures. Dissolved oxygen levels in the Savannah River contiguous with the immediate dredging activity will be determined at a depth of one meter above the hard bottom or 2 to 3 meters above an indeterminate bottom. This determination must be made within 24 hours prior to the commencement of dredging activity. If dissolved oxygen levels are less than 3.0 mg/l dredging activity will not be permitted.

Monitoring of the dredging activity will be conducted within 4 hours of the commencement of dredging, but no earlier than 2 hours after the commencement of dredging. In the event of 24 hour operation (around the clock) of the dredge, dissolved oxygen will be determined daily. The monitoring station will be located at mid-channel, 500 feet downstream of the ongoing dredging activity. Dissolved oxygen levels will be determined at a depth of one meter above a hard bottom or 2 to 3 meters above an indeterminate bottom. If dissolved oxygen levels fall below 3.0 mg/l dredging will be suspended until dissolved oxygen levels are 3.0 mg/l or greater.

Results of this monitoring must be submitted to the Georgia Environmental Protection Division, the Georgia Wildlife Resources Division, and the Georgia Coastal Resources Division within 30 days of the completion of each dredging operation. Failure to maintain

satisfactory compliance with these conditions may result in prohibition of dredging operations in the Savannah River during the period of July 1 to September 30 upon written notice to the applicant.

5. Dredging should be conducted during December through March. These are the times when sea turtles are least abundant in the area of the Savannah Ship Channel. Dredging outside these months should be coordinated with the Georgia Department of Natural Resources (DNR) Nongame Wildlife Program. Dredging in May will require the implementation of a conservation plan approved by the Georgia DNR. This plan should include trawling to remove turtles from the path of the dredge.
6. During December through March, dredge and support vessels should have a trained whale observer on watch during daylight hours. At night, or when visibility is reduced by fog or sea states greater than Beaufort 3, dredges must slow to 5 knots or less if whales have been spotted within 15 nm of the vessel's path within the previous 48 hours. Normal operational speeds can be resumed after 48 hours if visibility has not improved and no whales have been observed by dredge observers. These procedures are consistent with the "Recommended Safe Operating Procedures for Large Vessels Transiting the Right Whale Calving Area Critical Habitat Off Georgia and Florida During March-December" that have been developed by the Southeastern U.S. Implementation Team for the Recovery of the Northern Right Whale.

0.4.04 Water Quality Certification, State of South Carolina. In a letter dated May 10, 1996, the State of South Carolina, Department of Health and Environmental Control (SC DHEC) issued a Section 401 Water Quality Certification for the Savannah Harbor Long Term Management Strategy (LTMS) Project. Conditions in the certification are listed below.

0.4.05 The South Carolina certification was issued contingent on the following conditions:

1. To insure water quality standards are maintained, the Division of Water Quality and Shellfish Sanitation must be notified and any alternate disposal site must be reviewed and approved prior to its use if the proposed disposal areas can not be utilized by the COE or the GA DOT.

2. The applicant must implement a water quality monitoring plan to insure that the effluent is in compliance with state water quality standards and to coordinate with the Department if any discharge is violating any state water quality criteria, as proposed. The applicant must conduct monitoring in accordance with an approved sampling plan specifying the location of sampling stations, parameters sampled, when samples will be collected, and how the sampling data will be reported. Appropriate ambient data from the Wright River must also be submitted.
3. The applicant must install flap gates at underdrain discharge points so that no effluent is discharged during low flow periods in receiving waters.
4. The applicant must monitor water quality 100 feet downstream of underdrain discharges to test for water quality standards compliance, as proposed. In addition, the applicant must conduct monitoring in accordance with an approved sampling plan specifying the location of sampling stations, parameters sampled, when samples will be collected, and how the sampling data will be reported.
5. The applicant must adhere/comply with recommendations of the SC DNR regarding the timing of placing dredged material for beach nourishment to insure continued protection of various species of sea turtles.
6. The applicant must provide compensatory mitigation for wetlands impacts associated with the proposed work. All wetlands impacts must be compensated for on at least a 1:1 basis. If mitigation includes creation, restoration, or enhancement, the plan must include monitoring. This mitigation plan must be submitted to the Water Quality Division for review and approval within 6 months of Section 404 permit issuance.

0.4.06 Compliance With Section 401 Water Quality Certifications

0.4.07 A Water Quality Monitoring Program would be implemented to ensure the confined disposal facilities (CDFs) are functioning properly and discharges conform to the state water quality standards. To monitor the dissolved oxygen levels and pH in discharges from the CDFs, weekly monitoring of controlled releases associated with dredge disposal management operations or

wildlife management would continue to be performed. To address potential impacts to aquatic species from the release of effluent with low dissolved oxygen levels or adverse pH, the following water quality monitoring program would be followed:

WATER QUALITY MONITORING PLAN

SAVANNAH HARBOR OPERATION & MAINTENANCE PROJECT

I. MONITORING OF CDF DISCHARGES

Water quality data will be taken on a weekly basis when controlled releases occur from dredged disposal management operations or wildlife mitigation operations. Sampling would be performed in accordance with the schedule indicated below by a qualified independent laboratory or Savannah District employee. If a laboratory is used, the contractor will be responsible for providing this data to the Contracting Officer's Representative (COR). The laboratory selected must be approved by the South Atlantic Division Laboratory of the Corps of Engineers. Testing and sampling shall be in accordance with "Standard Methods of the Examination of Water and Waste Water," 16th Edition, published by APHA-AWWA-WPCF. Test results indicating a violation of State Water Quality Standards shall be reported immediately to the COR. All other available test results should be sent telephonically on the day the samples are taken. Written confirmation of all the test results shall be provided to the COR within 7 days of the sampling.

The data collection will be for the following water quality parameters: salinity (ppt), pH, dissolved oxygen (mg/l & salinity corrected), and total suspended solids (mg/l). The following general information will be recorded when each sample is taken:

- (1) Date, time, location, tidal stage, and current direction.
- (2) Depth of water over the weir boards and ponding depth at the weir.

The above data will be collected at the outfall of each weir from which there is a discharge. In Disposal Areas 2A and 12A where the weirs empty into a drainage ditch, the data will be collected where the discharge leaves the ditch and enters the receiving water body.

If, during sampling, any of the tests reveal a violation of the state water quality standards listed below, the investigator will complete the testing at that station in accordance with this monitoring plan. Data would also be collected of the ambient condition in the receiving water near the discharge point. The investigator or the Contractor shall then immediately, within the hour, contact the COR and report the test results. The standard criteria in the State of Georgia for dissolved oxygen is a minimum instantaneous concentration and applies throughout the water column. The dissolved oxygen values in the State of South Carolina can be averaged, but no one value can be lower than 4.0 mg/l. The standards are as follows.

<u>State</u>	<u>Parameter</u>	<u>Standard</u>	<u>Month</u>
Georgia	dissolved oxygen	3.0 mg/l	Jun - Oct
Georgia	dissolved oxygen	3.5 mg/l	May & Nov
Georgia	dissolved oxygen	4.0 mg/l	Dec - Apr
Georgia	pH	6.0 - 8.5	All year
South Carolina	dissolved oxygen	daily ave. of 5.0 mg/l with minimum of 4.0 mg/l	
South Carolina	pH	6.0 - 8.5	All year

The following procedures would be followed should violation of a state water quality standard be detected:

- (1) If a measurement at a weir indicates potential violation of a state water quality standard, another measurement would be taken where the discharge enters the receiving water. The value found where the discharge enters the receiving water would be used to determine compliance with the state standard.
- (2) Should low dissolved oxygen levels (below state water quality standards) or adverse pH (outside state water quality standards) be observed during the weekly monitoring of weir effluent overflows, daily monitoring would begin.
- (3) Should sustained low dissolved oxygen levels or adverse pH (three consecutive days outside state water quality standards) be observed in weir effluent overflows, the pool elevation would be raised to the maximum height allowed by the condition of the dike (designed for full pool to be 2 feet below the dike crest),

- (4) The pool elevation would be held at that height until the effluent dissolved oxygen and pH levels conform to state water quality standards for three consecutive days.
- (5) The pool elevation may then be reduced as long as state water quality standards are maintained in the effluent.
- (6) If the dissolved oxygen or pH levels continue to remain outside state water quality standards even with full pool conditions, the appropriate state water quality office would be notified by telephone (by District Environmental staff) and in writing (from the District Engineer or Contracting Officer's Representative) of the situation and what further actions were being taken to bring the Project back into compliance with its Water Quality Certification.
- (7) After dissolved oxygen and pH levels conforming to state water quality standards are recorded for 14 consecutive days, the monitoring frequency would be shifted back to a weekly basis.

II. MONITORING DISSOLVED OXYGEN IN THE SAVANNAH RIVER

Prior to initiating dredging between July 1 and September 30, dissolved oxygen (D.O.) levels would be monitored in the Savannah River. Monitoring would be performed when dredging is conducted during that period. Measurements would be taken at mid-channel, 500 feet downstream of the ongoing dredging activity. D.O. levels will be determined at a depth of one meter above a hard bottom or 2 to 3 meters above an indeterminate bottom.

Sampling would be conducted within 24 hours prior to the commencement of dredging. If D.O. levels are less than 3.0 mg/l, dredging activity will not be permitted. During continuous dredging operations, sampling would occur on a weekly basis as long as the river D.O. remains above 3.5 mg/l. Should the D.O. at the bottom drop below 3.5 mg/l, the District would initiate daily monitoring until the river D.O. again reaches 3.5 mg/l for three consecutive days.

Sampling would be performed by a qualified independent laboratory or Savannah District employee. If a laboratory is used, the contractor will be responsible for providing this data to the COR. The laboratory selected must be approved by the South Atlantic Division Laboratory of the Corps of Engineers. Testing and sampling shall be in accordance with "Standard

Methods of the Examination of Water and Waste Water," 16th Edition, published by APHA-AWWA-WPCF. Test results indicating a violation of State Water Quality Standards shall be reported immediately to the COR. Written confirmation of all the test results shall be provided to the COR within 7 days of the sampling.

If, during sampling, any of the tests reveal a violation of the state water quality standards listed below, the investigator will repeat the sampling at that station. Data would then be collected of the ambient -- upcurrent -- condition outside the influence of the dredging operation. When those two stations have been sampled, the investigator or the Contractor shall immediately, within the hour, contact the COR and report the test results. The standard criteria in the State of Georgia for D.O. is a minimum instantaneous concentration.

Within 15 days of the conclusion of the monitoring, a written report consisting of all D.O. data obtained during performance of that dredging contract would be provided to the COR. The District would provide that information to the Georgia DNR - Environmental Protection Division, Georgia DNR - Wildlife Resources Division, and Georgia DNR - Coastal Resources Division within 30 days of the completion of the dredging operation.

O.4.08 The Water Quality Monitoring Program described above will be reCOORDINATED with SC DHEC to ensure that this program fulfills the monitoring requirements stated in their certification. Although this coordination has not yet occurred, the District believes it can reach a satisfactory agreement with the SC DHEC on water quality monitoring.

O.4.09 The Mitigation Plan contained in Appendix G will be reCOORDINATED with SC DHEC to ensure that this plan fulfills the mitigation requirements included in their certification. The SC DHEC-OCRM has approved the Mitigation Plan through their CZM certification of the LTMS Project.

O.4.10 An Underdrain Effluent Monitoring Program would be implemented to ensure those discharges are not adversely affecting aquatic species in the receiving water. A Monitoring Plan would be developed and submitted to SC DHEC for approval prior to initiating use of underdrains. A chemical evaluation would be performed of the underdrain discharges every three years to ensure that all state water quality standards are being met in the receiving water at the edge of a 100-foot mixing zone.

0.4.11 South Carolina Coastal Zone Management Certification. In a letter dated January 8, 1996, the State of South Carolina, Department of Health and Environmental Control, Office of Ocean and Coastal Resource Management (SC DHEC-OCRM) found the LTMS Project consistent with the policies of the South Carolina Coastal Zone Management Program. No conditions were explicitly stated in the letter, but the finding was based on revisions and clarifications made to the draft EIS that are contained in the Final EIS.

0.5.00 REQUIRED TIMING OF NON-ANNUAL ACTIONS.

0.5.01 Introduction. This section of the document contains the non-annual actions required for the Savannah Harbor Navigation Project to remain in environmental compliance.

0.5.02 Threatened And Endangered Species. The Biological Assessment of Threatened and Endangered Species (BATES) determined both (1) the impacts which the Project was likely to have on threatened and endangered species, and (2) what measures were appropriate to minimize the risk of impact to those species.

Sea Turtles. To ensure protection to nesting sea turtles as a result of beach disposal operations, the following conditions would be adhered to:

1. A turtle nest monitoring program would be implemented when dredged materials are placed on the Tybee or Daufuskie Island beach during the sea turtle nesting season to ensure protection of turtles that try to nest on the existing or newly formed beach. The work would include monitoring the beach for nesting sea turtles and relocation of nests found in the disposal areas or within 500 feet of the limits of the disposal area which are likely to be impacted by future disposal and/or related construction activities.
2. The beach would be monitored during the first winter/spring following completion of material deposition to determine post-nourishment compaction. This would be performed to ensure that the newly constructed beach provides suitable nesting material for endangered sea turtles. If the examination finds sand compaction within 50 feet of the toe of the dune to be greater than 500 cone penetrometer units (cpu), and the US FWS confirms that plowing is necessary, the compacted area will be plowed to a depth of at least 36 inches.

3. The beach would be monitored for three nesting seasons after beach placement for escarpments. Any escarpments in excess of 18 inches high, extending more than 100 feet in length and exceeding 500 cpy would be mechanically leveled to the natural beach contour.
4. When dredged materials are placed on Tybee Island, the city's light ordinance for protection of sea turtles would be enforced.

O.5.03 Ocean Disposal. The Section 103 Evaluation which received concurrence from EPA in a letter dated March 23, 1995, is valid for a period of three (3) years. The District will need to perform another Evaluation prior to that time. That evaluation would include at least a Tier 1 assessment of the quality of the maintenance sediments proposed for deposition at the ODMS. If information indicates there is a "reason to believe" the sediments are contaminated, the District would need to perform sediment testing. The District would likely issue a Public Notice as part of its Section 103 Evaluation.

O.5.04 Section 404 Evaluation For Dredge And Fill Actions. The Section 404 Evaluation documents several commitments which were included to minimize impacts to wetlands and the aquatic environment. Those commitments consist of the following:

- (1) Perform a side scan sonar investigation, magnetometer survey and benthic survey prior to the initial use of each new nearshore disposal site. This includes the island to be constructed off Turtle Island as a wetland mitigation feature. The side scan sonar investigation and magnetometer survey would be performed to ensure no significant cultural resources would be impacted by the proposed sediment deposition. The District's conclusions and the results of those investigations would be provided to the SHPO for approval. The District's conclusions and results of the benthic surveys would be provided to the US FWS and the NMFS, and the SC DHEC-OCRM in the case of the nearshore bird island, for approval. Approval from these regulatory agencies must be received prior to deposition of dredged material on those sites.
- (2) Detailed designs of riprap to be placed on the shoreline of Jones/Oysterbed Island to protect that eroding bank must be submitted for approval to the SC DHEC-OCRM. The SC DHEC-OCRM will make a field inspection to confirm that the design minimizes the loss of wetlands along that shoreline. Mitigation for

the loss of 2.6 acres of wetlands resulting from this activity was included in the approved Mitigation Plan for the LTMS Project.

- (3) Vegetation would be controlled inside the CDFs. Extensive vegetation existing on the floor of a CDF is to be removed prior to the site's flooding for disposal use. Removal of the vegetation is required to ensure that degradation of the vegetation within the CDF would not produce a large dissolved oxygen demand resulting in poor water quality in the effluent. Burning of the vegetation is allowed.
- (4) To minimize impacts to fishery resources, nearshore placement of dredged sediments in open water is to be conducted during early winter, if possible. There would be no nearshore placement of dredged sediments in open water during the period of 1 March to 1 June, if possible.
- (5) Dredged sediments to be deposited at open water sites must be excavated from the Bar Channel and upstream to Station 28+000. The average fines content of sediments from the inner harbor (Stations 0+000 to 28+000) to be deposited at such sites must not exceed 15 percent.
- (6) Deposition on beaches would be monitored to document the volume of sediments dredged, the volume deposited on the beach, and the volume retained on the beach. This information would be compared with the physical characteristics of the dredged sediments (percent fines) to allow a better prediction of the impacts and success of future beach placement activities. If sediments upriver of Station 0+000 are to be deposited on a beach, the average fines content of those sediments must not exceed 15 percent. The retention of deposited sediments on a beach must exceed 50 percent when construction is complete.

0.5.05 Erosion Control And Sedimentation Plan. Prior to initiating construction of the dikes at Disposal Area 14A, the local sponsor will prepare and submit to the SC DHEC-OCRM an Erosion Control And Sedimentation Plan to obtain a Stormwater Management Permit. That plan will describe actions to be taken to minimize adverse impacts resulting from non-point source pollution during that construction project.

0.5.06 Cultural Resources (Section 106 Compliance). The District made three sets of commitments concerning significant cultural resources. Each is contained in a separate appendix in this EIS, but two are also summarized in the following paragraphs. The third set of commitments stem from the Cultural Resources Management Plan (Appendix J), which describe procedures which would be followed on a continual basis. Another set of commitments concerns additional studies which would be conducted after additional design information is available to ensure that significant cultural resources are not impacted. Those commitments are included in Sections 0.5.09 and 0.5.10.

0.5.07 Old Fort Jackson. In the Memorandum of Agreement (MOA), the District agreed to (1) study the streambank erosion problem at Old Fort Jackson to determine the nature, extent, and cause(s) of the problem, and (2) determine the contributing effect of the construction and/or maintenance of the Savannah Harbor Navigation Project on bank erosion. If the conclusion from those studies is that construction and/or maintenance of the Savannah Harbor Navigation Project contributes to the bank erosion problem at the Old Fort Jackson Historic Site, then Savannah District will implement further actions, as summarized in the following paragraphs:

- a. Identify and evaluate alternatives to eliminate, minimize, and retard the Navigation Project's contribution to bank erosion problem at the Old Fort Jackson Historic site.
- b. Develop a mitigation plan to minimize the adverse effects of streambank erosion on Old Fort Jackson, caused by the Navigation Project.
- c. Prepare a report which documents the District's studies, study results, evaluations and determinations. Identify the optimal erosion control plan, including a draft mitigation plan for mitigating the Project's adverse effects to the Old Fort Jackson.
- d. Obtain public review of the draft mitigation plan. Consider all comments in development of the final mitigation plan. The final mitigation plan must be approved by the GASHPO and the Advisory Council.
- e. Develop a cost-sharing program to implement the mitigation plan.
- f. Implement the recommended plan subject to the availability of funds. Function as the lead party in coordinating and implementing the work necessary to implement the mitigation plan.

O.5.08 CSS GEORGIA. In the Memorandum of Agreement (MOA), the District agreed to the certain actions, as summarized in the following paragraphs:

1. Conduct studies to determine the present condition of the vessel, its stability as a historic site/object, any factors which may threaten its present condition or stability, and restrictions which the vessel places on present harbor operations.
2. Determine the effects of the Savannah Harbor Navigation Project on the CSS GEORGIA.
3. If the conclusion from the studies is that the Navigation Project contributes to the degradation or reduced stability of the CSS GEORGIA, then the District would take the following actions:
 - a. Identify and evaluate alternatives to eliminate, minimize, and retard the Project's adverse impacts. If the vessel is restricting present harbor operations, alternatives would be evaluated to allow those restrictions to be eliminated or minimized.
 - b. Develop a mitigation plan to minimize the Project's adverse effects on the CSS GEORGIA.
 - c. Prepare a report documenting the District's studies, evaluations and determinations, including recommendations as to the optimal alternative(s). The District would prepare a draft mitigation plan for mitigating the Project's adverse effects to the CSS GEORGIA. That plan would be available for public review.
 - d. Implement the recommended plan, subject to the availability of funds.
 - e. Develop a proposed data recovery plan if the mitigation plan entails the alteration or destruction of any features associated with the CSS GEORGIA, such that data recovery of buried archeological deposits/artifacts might be recovered. A research design would be developed by the District and coordinated with the GA SHPO and the SC SHPO for comment.

- f. Submit the final mitigation plan to the GA SHPO, the SC SHPO, and the Council for review.
- g. Curate any and all materials and records resulting from any data recovery investigations.

0.5.09 Cultural resource surveys (side scan and magnetometer surveys) would be conducted at each new disposal area located in the nearshore area. This includes the island to be constructed off Turtle Island, the submerged berms, and the feeder berm. The District's evaluation and findings would be provided to the SHPO for approval prior to initial sediment deposition at each site.

0.5.10 Construction of underdrains could potentially impact cultural resources located along the pipe alignments. Prior to excavation, archival information would be reviewed to determine if any proposed underdrain alignment had the potential for impacting any known cultural resource sites in the confined disposal areas. If there was a significant potential for adverse impact to a known site, a cultural resource survey would be performed of the underdrain alignments and approval of the study's findings from the SHPO would be obtained prior to excavation.

0.5.11 South Carolina Wetland Mitigation Plan. The Mitigation Plan for impacts to wetlands in South Carolina include several items, some of which require action only periodically. Those recurring -- but not annual -- requirements consist of the following construction-type items: (1) maintenance of the bare ground bird nesting area on Jones/Oysterbed Island, (2) maintenance of nesting islands within disposal areas, (3) maintenance of the bird nesting island offshore of Turtle Island.

0.5.12 Maintenance on the 26-acre bare ground nesting area outside the dike at the Jones/Oysterbed Island Disposal Area would be performed when site inspections reveal that emergent vegetation has covered substantial portions of the site, rendering it unusable for colonial nesting birds.

0.5.13 The 1.0-acre isolated nesting islands inside the confined disposal areas would be maintained when dike raising occurs to ensure the crown of each island remains above the height of the surrounding dikes. Should emergent vegetation cover substantial portions of the site, actions would be taken to re-establish bare ground to restore the usefulness of the site to nesting migratory birds and shorebirds. Those actions would include removal of the vegetation or deposition of additional dredged material.

0.5.14 The design dimensions of the nearshore island off Turtle Island would be restored when the island has been reduced by 50 percent below the specified design size. This restoration would be accomplished by deposition of additional dredged material. Should emergent vegetation cover substantial portions of the site, actions would be taken to re-establish bare ground to restore the usefulness of the site to migratory birds and shorebirds.

0.5.15 Periodic replacement of the purple martin nesting houses and bat houses would be needed at the disposal areas in the rotation program to continually provide a measure of biological control for potential increased mosquito breeding.

0.5.16 Mitigation for Other Wetland Losses. A detailed mitigation plan has not been developed for wetlands that would be lost in the State of Georgia as a result of the Project. As detailed designs become available on the items which will destroy wetlands in Georgia, actions must also be taken to mitigate for those new construction features. Those items consist of the following: (1) construction of an access road to Disposal Area 2A, (2) pipe ramp expansions, and (3) weir/ discharge pipe replacements. Mitigation would occur at a 2:1 rate for wetlands which would be permanently lost. The mitigation plan will be coordinated with the GA DNR Coastal Resource Division and the US FWS for approval. Implementation of the wetland mitigation plan would occur before the construction feature causing the wetland loss is placed in service.

0.5.17 Tidegate Construction and Deepening. Improvements to the Savannah Harbor Navigation Project were authorized by Congress in 1965. Those improvements included construction of the Tidegate and fresh water control features, as well as deepening of the shipping channel. The fresh water control features were constructed to reduce salinity impacts to the Savannah National Wildlife Refuge from the combined harbor deepening and Tidegate construction project. The freshwater control system included the following components:

- (1) a 5,500-foot long canal through McCoombs Cut to provide freshwater to the Savannah NWR (Figure 4). The canal was constructed with a 200-foot bottom width at EL -7' MLW and 2H:1V side slopes. The design flow through McCoombs Cut was 4,000 CFS.
- (2) a channel in Middle River with a 90-foot bottom width at EL -6' MLW and 2H:1V side slopes. The design flow in Middle River was 1,500 CFS.
- (3) a channel in Little Back River with a 200-foot bottom width at EL -5.1' MLW and 2H:1V side slopes. The design flow in Little Back River was 2,500 CFS.

O.5.18 The Federal government is responsible for maintenance of the Diversion Canal, the channels in Little Back River and Middle Rivers, and the control works to the Refuge. The non-Federal sponsor has maintained the freshwater canals in the Refuge and on private lands outside the Refuge.

O.5.19 1993/1994 Deepening Project. Several commitments were made in the 1991 Feasibility Report/EIS for the Deepening Project and the Programmatic Agreement signed by the District in January 1992. The remaining non-annual commitments center around two significant cultural resources; Old Fort Jackson and the CSS GEORGIA. Specific studies include: (1) mapping the side slopes and channel bottom in the areas of Old Fort Jackson and the CSS GEORGIA, and (2) testing and recovering ordnance from the portions of the CSS GEORGIA wreck located within the new authorized channel prism. The studies were to determine the effect of the Deepening Project upon each resource, identify and evaluate alternatives for avoiding and/or mitigating impacts to significant resources. An avoidance/mitigation program was also to be implemented. The 1992 PMOA also called for development of individual Memorandums of Agreement (MOAs) for Old Fort Jackson and the CSS GEORGIA. Those documents are contained in this EIS and will be signed after the EIS is finalized.

O.5.20 Compliance With Section 401 Water Quality Certifications. Non-annual water quality monitoring activities would consist of a chemical evaluation every three (3) years of underdrain discharges to ensure that all state water quality standards are being met in the receiving water at the edge of a 100-foot mixing zone.

APPENDIX F

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APPENDIX Q

COMMENTS RECEIVED FROM PUBLIC REVIEW OF THE DRAFT EIS
AND DISTRICT RESPONSES TO THOSE COMMENTS



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION IV

345 COURTLAND STREET, N.E.
ATLANTA, GEORGIA 30365

JAN 27 1995

Savannah District, Corps of Engineers
P.O. Box 889
Savannah, GA 31402-0889

ATTN: Dr. William Bailey
Planning Division

Subject: Draft Environmental Impact Statement (EIS) for Long-term Management Strategy (LTMS) for the Savannah Harbor Navigation Project Chatham County, Georgia and Jasper County, South Carolina

Dear Sir:

Pursuant to Section 309 of the Clean Air Act and Section 102 (2)(C) of the National Environmental Policy Act, EPA, Region 4 has reviewed the subject document which describes the measures and methods being implemented to make the harbor operation more efficient and presumably less damaging environmentally. While not characterized as an upgrade, the management measures effectively yield this result by increasing the total capabilities of the Savannah facility. Seven action management strategies were eventually developed and serve as a basis to compare and contrast with the current operational procedures.

The tentatively selected option, Alternative 8, is essentially a composite of the individual numbered management strategies. Nearly all of the proposed modifications to the present operational procedures are very comprehensive in scope; nonetheless, the former are uniformly forecasted to have nominal adverse environmental ramifications. Notwithstanding this depiction, we have a degree of concern about how all the elements of this very involved plan will actually function. The details of these concerns are expressed in the attached comments.

While the future can not be known with precision, certain broad principles form the basis for this proposal. Foremost among these tenets is the proposition that shipping volumes will increase and the trade will be plied with ever larger, deep-draft vessels. Hence, the need for increasing navigation and berthing depths along with more disposal sites and the management thereof to accommodate the material excavated to secure the enlarged bottom profiles. We have no reason to doubt this premise, but observe that there is an immediate correlation between these

facility upgrades and the attendant environmental costs necessary for their implementation.

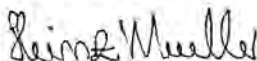
While there are a multitude of future scenarios as to how the federal and local sponsor partnership will proceed in the future, there is the distinct and increasing probability that the local sponsor will have to assume a larger role. This would be particularly true in terms of funding capital improvements as well as the administrative costs of administering the management plan. Given this potential, it is important that all the elements of Alternative 8 have independent utility in the event the local sponsor elects not to fund its increased share of the plan and a smaller or modified plan becomes necessary. From our perspective this potentiality requires that the mitigation elements of the plan occur before or concurrently with any of the construction necessary for the proposed structural measures. It has been our experience that this sequence makes it more likely that proposed mitigation would not be substantively modified/deferred by funding constraints.

Adding to the difficulties in this regard is the fact that there are a number of studies which will be factored into the operation of the subject long-term plan. For example, the effect of weir discharges into the Wright River and specialized measures to insure dike stability are not available for immediate evaluation. Hence, there are some important data gaps associated with this proposal which add to our uncertainty about the plan's environmental costs and the mitigation necessary to compensate for the losses.

On the basis of our review a rating of EC-2 has been assigned. That is, we have some reservations regarding the long-term consequences of how all of the proposed elements of the management plan will mesh and subsequently function. Further, additional information necessary to more precisely define the uncertainties associated with proposed management/operational changes needs to be acquired. To the extent practicable these unknowns should be assessed in the final document.

Thank you for the opportunity to comment. If we can be of further assistance in the meanwhile, Dr. Gerald Miller (404-347-3776) will serve as initial staff contact.

Sincerely,



Heinz J. Mueller, Chief
Environmental Policy Section
Federal Activities Branch

SPECIFIC COMMENTS

Alternative disposal ("beneficial") uses, viz., construction of feeder berms and beach renourishment, are proposed for material excavated from the bar channel and other source areas. We generally have no pronounced objections to these activities, if biologically sensitive resources are not adversely affected in either a direct or indirect fashion. However, you will recall that a recent episode of beach renourishment on Tybee Island resulted in large amounts of fines being placed on the shore rather than good quality sand as had been portrayed in the environmental documentation.

While this material has subsequently dispersed, its fate and consequences remain unknown. Construction of feeder berms should be undertaken with even more caution since the quality of the sediments involved would be less apparent than the material used for beach nourishment. Use of sediments from the inner harbor near Jones/Oysterbed Islands could also be problematic from a contaminant standpoint. While no hard bottom communities are known to exist within the berm construction site, care must be taken during the side scan sonar investigation to insure that this is in fact the case.

There should be a formalized procedure to address unexpected incidents such as the Tybee Island beach nourishment situation. To this end a mechanism needs to be implemented that will more precisely obtain and characterize pertinent data, e.g., sediment classes, and allow cessation of construction activities without delay when unanticipated events which could have significant adverse environmental consequences occur. This issue needs to be discussed and resolved in the final document.

In a related matter "Bird Island" will not be stabilized; hence, in the absence of renourishment its longevity will be relatively short. This and other elements of the long-term plan will potentially result in a great deal of sediment movement in the system. The text does not project any adverse long-term repercussions from these measures. However, because of the magnitude of this construction, we suggest that some modelling be accomplished prior to plan implementation and a carefully developed monitoring plan started afterward to ascertain if indeed there were only minor consequences.

The present method of maintaining operational depths in many of the berthing areas through the use of agitation has been a matter of contention for a number of reasons, e.g., water quality degradation. The results of several recent studies examining this excavation technique stated that its effects were minor and short-lived. However, since dredging must occur so routinely, we

remain unconvinced that agitation dredging is so benign. Hence, the proposal to replace agitation with hydraulic dredging appears to have merit. While the latter technique might appear to immediately increase the volume of material (ca. 800,000 cy) added to the confined disposal cells, this addition is actually just material which must be moved (dredged) twice under current procedures. Nonetheless, we agree that the berth sediments should be analyzed on an annual basis especially during the initial excavation when the overall depths will be maximized.

The wetland and upland habitats which will be sacrificed to dike disposal area 14A exceed 800 acres. While some variability was noted in the functional value(s) of the different habitats which comprise this total, this loss will still have some important localized effects. We have no quarrel with the major mitigation element, viz., 2-year rotational use of disposal areas with management options/modifications to benefit birds (composite strategy 3). It appears to be a satisfactory approach to benefit targeted avian populations.

Staff is not as familiar with the relationship of the subject mitigation sites to adjacent habitat as other agency representatives, but it appears that the nesting areas which are within the disposal cells (Figure 1, Appendix G) could be at risk from ground predators unless care is taken to maintain a water barrier between the dike wall and island. Unfortunately, all the nesting areas may be the targets of vandalism and/or trespass unless there is some means to enforce relative isolation during critical nesting phases.

This value of enhancing nesting success notwithstanding, we believe that some in-kind mitigation should be included in the long-term plan for the wetlands lost to dike and road construction. In concept, we favor restoration of previously degraded wetlands to compensate for functional values lost from fill activities. Unfortunately, for a number of reasons this tact does not have an outstanding degree of long-term success. Alternatively while some existing wetlands and fringe uplands remain in the estuary system and can be purchased at a reasonable price, they should be bought and preserved. The accelerating developmental pressures in this immediate area and, in fact, the entire coastal plain is devastating to the natural environment. Hence, there is an urgency to acquiring these habitat types before they are converted to residential/commercial/industrial sites. We would like to see this issue assessed in the final EIS.

There are two unconfined upland disposal areas (1S on Onslow Island and 14A on Elba Island) with at least the potential for use. Regardless of whether or not dikes could be constructed at these locations, we believe that their habitat value is such that their future use should be precluded. The preservation of these two features could be made part of the in-kind mitigation efforts for the habitat lost in the upgrade of disposal sites and

associated access features.

The use of underdrains to facilitate dewatering of the maintenance material is an important part of the management strategy. The effluent from the underdrains will be directed to either the Savannah or Back River. While these water bodies have a large dilution capacity compared to Wright River, we are concerned about localized water quality degradation. The potential for problems is an obvious function of the composition of the material being drained. However, a determination of the potential for water quality degradation and how contaminant problems could be addressed is not so apparent, but needs to be discussed in the final EIS.

In a related matter effluent data (Appendix C, page 9) collected from the CDFs reveal that outflow suspended solid levels are between 2 and 10 times background levels of the Savannah River. However, it was indicated that water quality standards could readily be met with a minimal mixing zone. The basis for this statement and why turbidity does not adversely affect local water use designation should be given in the final EIS.

While we have no interest in economics, per se, economic justifications are used as the basis for proposals of this nature. Therefore, we wondered why if the hinterlands served by containerized cargo are much more extensive due to the effects of intermodal containerized rail rates, how can there be an economic justification for deepening ports such as Jacksonville, Savannah, and Charleston which are so proximate to one another from a shipping (origin distance) perspective? The idea of bulk cargo being captive to Savannah as opposed to nearby ports is also perplexing unless it were demonstrated that this material is essentially consumed within the Savannah economic area.

As a result of interagency coordination, a number of measures (cessation of tide gate operation and closure of New Cut) were recently implemented to improve water quality and fisheries with the harbor environs. It is important that the proposed structural/operational measures in this strategic plan do not lessen the long-term benefits of these improvement efforts. This plan should have sufficient flexibility such that if an element proves problematic to another priority interest, the former can be deleted or modified. For example, deepening of the berthing areas, turning basins, etc. to serve as storage for sediment has an obvious appeal, but should be monitored to determine whether there will be unintended consequences.

Section 2.25 (Page 17) as regards the Savannah River Basin Watershed Project would be more accurately characterized as follows: EPA is currently facilitating a study of the Savannah River basin watershed (from the headwaters in North Carolina and Georgia to the Atlantic Ocean). It will examine environmental impacts to the river and its tributaries as well as develop an

interagency action plan to address significant impacts. Participants in the project include a broad spectrum of federal, state, and local agencies and interest groups. With state assistance EPA is developing and will implement a monitoring plan for the basin that will assess the condition of basin resources with a known statistical confidence. A geographical information system is also being developed with project participants to serve as a basin-wide data management tool. A baseline assessment of six basin resource areas is being developed by project participants which will serve as the basis of a Watershed Assessment and Prioritization Plan (WAPP). The WAPP will identify and prioritize watershed impairments and recommend appropriate solutions. The total study is in its initial stages; however, the WAPP is expected to be complete by mid-1995.

Comments on the Section 103 evaluation of ocean disposal as well as the site management monitoring plan will be sent directly from our Coastal Regulatory Unit. Mr. Doug Johnson (404-347-1740) will serve as initial staff contact.

RESPONSE -- Environmental Protection Agency;
Environmental Policy Section,
Federal Activities Branch,
January 20, 1995.

FUTURE WITHOUT PROJECT CONDITIONS. The Without Project Condition in the Savannah Harbor LTMS Study is based on a continuation of existing navigation, dredging, and disposal practices. The analyses are not based on future increases in vessel size or channel/berth dimensions. The study makes no assumptions on "facility upgrades and the attendant environmental costs necessary for their implementation."

TIMING OF MITIGATION ACTIONS. Mitigation actions would be performed before or concurrently with any of the construction necessary for the proposed measures. The project/construction feature requiring mitigation would not be placed in operation until the mitigation was completed, or underway if long-term operational procedures were used as mitigation.

BENEFICIAL DISPOSAL USES IN NEARSHORE AREA. The proposed nearshore disposal alternatives are not expected to have a significant adverse impact on biological resources. The material removed from the Bar Channel is believed to be similar to that which moves along the ocean floor in that area. Therefore, exposure of nearshore biota to those sediments is not expected to be markedly different from what they experience on a daily or periodic basis. Investigations will be performed prior to construction to ensure that no highly sensitive hard bottom communities exist within the impact area. The District typically has an inspector on-site on a continuous or daily basis to observe, among other things, the results of the contractor's actions. The inspector is aware of conditions, including environmental limitations, that the construction must meet to be acceptable. That inspector provides the District with an observer who continuously monitors on-site conditions. The District believes that such observation, combined with the coordination it performs and good working relationships it maintains with resource agencies is adequate to address unexpected incidents. Prior to deposition in the nearshore area, the sediments will be sampled to ensure they are predominantly sands or shell. Contracts for removal of sediments which are predominantly fine-grained materials would not allow deposition in nearshore areas.

NEARSHORE BIRD ISLAND. The Bird Island will be maintained when its size has been reduced by 50 percent. Use of the alternate sites proposed for placement of sediments in the nearshore area is expected to result in the retention of more sediments in the nearshore area, rather than their present deposition further from

the coastline at the Savannah ODMDS. The District does not believe that modelling would add significant information required to assess the impacts of nearshore placement. Since there are no known hard bottom communities within the immediate vicinity of the proposed nearshore dredged material placement sites, the District does not believe that post-construction monitoring is necessary to document the minor level of impacts which are expected.

AGITATION DREDGING. Placement of berth sediments directly into the confined disposal facilities would not substantially increase the total volume deposited in those sites since berth sediments already comprise a portion of the sediments removed from the navigation channel.

LOSS OF HABITATS AT DISPOSAL AREA 14A. We concur that the loss of 305 acres of wetland habitat and 510 acres of upland habitats which would be lost as a result of diking and use of this site would have some localized effects. The proposed Mitigation Plan was designed to compensate within the immediate vicinity for the functional values which would be lost.

INTERIOR NESTING MOUNDS. Care would be taken to maintain a flooded area around the mounds while they are in use to maintain a water barrier between the dike wall and the nesting site. The water barrier would also provide protection from vandalism and/or trespass during the critical nesting phases.

IN-KIND MITIGATION. Mitigation for wetland impacts in Georgia will be accomplished by restoration of degraded wetlands or creation of new salt marsh. The Mitigation Plan for losses of South Carolina wetlands consists of several features. The final Mitigation Plan does include in-kind mitigation for 25 acres of saltwater wetlands through an agreement with the SC DHEC-OCRM. That agency will administer an escrow account established by Chatham County -- or the GA DOT as its designee -- to fund wetland restoration, creation, or protection projects in South Carolina.

UNCONFINED DISPOSAL SITES. The District's development of mitigation actions is complicated by the states' position that impacts occurring in their state must be compensated for through actions implemented in their state. Since mitigation for wetland impacts in Georgia will be accomplished by restoration of degraded wetlands or creation of new salt marsh in Georgia, protection of Disposal Area 1S -- located in Georgia -- is not warranted at this time. The remaining unconfined upland disposal area -- Disposal Area 14A -- is proposed for diking and use for the Navigation Project in the LTMS Management Plan and EIS.

UNDERDRAIN DISCHARGES. The potential for water quality degradation from underdrains was addressed in the draft EIS in Sections 7.31 through 7.35 and Appendix E, RESULTS OF WRIGHT RIVER WEIR AND SEDIMENT TESTING. The potential for contaminant problems after underdrain installation was addressed in the draft EIS in Section 7.34. The SC DHEC has provided water quality certification for the proposed project -- including releases from the underdrains. The Draft EIS stated that monitoring of the underdrain effluent would be performed every 5 years to ensure that water quality standards are being met. The interval between chemical evaluations of underdrain effluents has been revised to every 3 years in the Final EIS.

OVERFLOW WEIR DISCHARGES. Suspended solids in overflow weir effluents was addressed in the draft EIS in Sections 7.21 through 7.26. As stated in Section 7.26, research indicates that water with suspended solids levels of 500 mg/l or less would not produce impacts to estuarine-dependent and anadromous fish. The District will use a 500 mg/l threshold at the weir as its measure of acceptability of suspended solids in its weir overflows. Mixing zones are commonly accepted for discharges from confined dredged material disposal areas (reference June 1994 draft EPA/Corps Inland Testing Manual). At the edge of a reasonable mixing zone, the suspended solids level would be lower -- with less potential aquatic impacts -- than that discharged at the weir.

CARGO MOVEMENT. The LTMS does not propose any improvements to the navigation channel which are dependent on additional cargos moving through the port. The EIS only assumes that funds will be available when needed to both maintain the Navigation Project and operate and improve the confined disposal facilities. The concepts of port competition and captive cargos are beyond the scope of this EIS. Improvements to the Navigation Project, both landside and channel maintenance-related, which are proposed in the LTMS are designed to improve the operational or economic efficiency of actions which have already been authorized by Congress.

FLEXIBILITY OF NEW MEASURES. The sediment control measures and nearshore disposal options proposed in the Management Plan and EIS would be implemented where economically justified and environmentally acceptable. After further studies indicate a specific measure would be effective in a certain location, the measure would be implemented at that location, then the actual effectiveness and resulting impacts would be evaluated by the District to ensure continued maintenance of that application would be both economically warranted and environmentally acceptable.

SECTION 2.25 (Page 17) - SAVANNAH RIVER BASIN WATERSHED PROJECT. Concur. Suggested changes to better describe this study have been incorporated in the Final EIS.



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION IV

345 COURTLAND STREET, N.E.
ATLANTA, GEORGIA 30365

MAR 23 1995

4WM-WOW

Mr. Richard A. Hill
Acting Chief, Planning Division
Department of the Army
Savannah District, Corps of Engineers
P.O. Box 889
Savannah, GA 31402-0889

Dear Mr. Hill:

We have completed our review of the Draft EIS for the Savannah Harbor Long Term Management Strategy (LTMS) Study, dated November 1994. We are providing comments on the 103 Evaluation, the Site Management and Monitoring Plan, and the Sediment Quality Evaluation.

We agree with your determination that maintenance material to be excavated from the Savannah Harbor Bar Channel is suitable for ocean disposal. We are granting a three-year concurrence from the date of this letter for the placement of dredged maintenance material from the Savannah Harbor Bar Channel in the Savannah Ocean Dredged Material Disposal Site (ODMDS).

Appendix D Comments

Please note that on Page 2 of Appendix D, "Section 103 Evaluation of Ocean Disposal for the Savannah Harbor Navigation Project," the update of 103 Evaluation will be for three (3) years only, not five (5) years.

Paragraph D.4.01, Appendix I (not H). We consider this management and monitoring plan to be a draft document, open to future discussions and development. A likely approach would be to develop an Implementation manual that will be flexible and open to modification as necessary.

Appendix F Comments

Paragraph F.2.01, line 5, What is "(EPA, 1992)" referencing?

Paragraph F.2.05-F.2.08, the "Evaluation of the Region 4 Coastal Sediment Quality Inventory" was prepared under contract by SAIC for EPA. It represents the contractor's evaluation of the data according to their interpretation of the work assignment. This document has not undergone a rigorous review or critique by the Agency and, therefore, does not reflect the

opinions or conclusions of the EPA. The document should not have been released without such a disclaimer, and all copies dated December 3, 1992 should be considered as a "DRAFT" document. Conclusions drawn from this evaluation are to be considered preliminary and subject to revision. In its present form the document has limitations on its use as a predictive tool, particularly in assessing areas as "clean." The major limitation is a lack of synoptic data. This document, therefore, cannot be used to establish a "lack of concern."

Appendix I Comments

WRDA requires that the Site Management and Monitoring Plan (SMMP) be reviewed and revised not less frequently than every ten (10) years. We agree that five (5) years is a more prudent time frame, but would like the SMMP to be open to revisions and modifications as deemed appropriate by the Site Management and Monitoring Team (SMTT).

We would like to schedule a meeting to review and discuss this Site Management and Monitoring Plan before it is finalized, since we have not previously seen this document. WRDA establishes the EPA, in consultation with the ACOE, as the responsible Agency for the development and implementation of Site Management and Monitoring Plans for ODMDSS. Our main concern is to develop SMMPs for all ODMDSS that are consistent in content and approach, meet the requirements of WRDA, reflect the details of EPA's "Managing Ocean Disposal of Dredged Material - Ocean Dredged Material Disposal Site Designation, Management, and Monitoring Manual," and are effective in protecting our coastal environment.

Should you have any questions concerning this letter, please contact Douglas K. Johnson of my staff at (404) 347-1740, extension 4297.

Sincerely,



E. Stallings Howell, Chief
Wetlands, Oceans and Watersheds
Branch

RESPONSE -- Environmental Protection Agency;
Wetlands, Oceans and Watersheds Branch,
March 23, 1995.

SUITABILITY OF BAR CHANNEL MATERIAL FOR OCEAN DISPOSAL, EPA concurs in the suitability of Bar Channel sediments for ocean disposal and extends their approval of ocean disposal for three years from the date of their letter.

APPENDIX D

Section D.3.01. Concur. This section has been revised to show that the Section 103 Evaluation would be reevaluated every three years, rather than every five years.

Section D.4.01. Concur. The Site Management Plan has been revised as a result of further discussions between the Corps and EPA. The final signed Site Management Plan can be modified over time as both parties agree that revisions are appropriate to better manage the site.

APPENDIX F

Section F.2.01. Appendix P REFERENCES includes a reference to "U.S. Environmental Protection Agency, 1992. Draft Evaluation of the Region 4 Coastal Sediment Quality Inventory. Prepared by Science Applications International Corporation for EPA, 3 December 1992."

Sections F.2.05 to F.2.08. This section has been revised to state that the 1992 report was only a draft and that conclusions drawn from the contractor's evaluation are to be considered preliminary and subject to change.

APPENDIX I

Revision/Modification of the SMMP. A section has been added to state that the Site Management Plan may be modified by joint agreement of the signatory parties to reflect the views of the SMMP team.

Meeting to Discuss the SMMP. A meeting was held between the District and EPA Region IV on July 12, 1995. That meeting resulted in revisions to the SMMP which have been incorporated into the SMMP included in the Final EIS.



United States Department of the Interior

OFFICE OF THE SECRETARY

OFFICE OF ENVIRONMENTAL POLICY AND COMPLIANCE

Richard B. Russell Federal Building

75 Spring Street, S.W.

Atlanta, Georgia 30303

February 23, 1995

ER-95/14

Mr. William Bailey
U.S. Army Engineer District, Savannah
P.O. Box 889, Attn: CESAS-PD-EI
Savannah, Georgia 31402-0889

Dear Mr. Bailey:

The Department of the Interior has completed its review of the Draft Environmental Impact Statement (DEIS) for the Savannah Harbor Long Term Management Study, Chatham County, Georgia and Jasper County, South Carolina. We have the following general and specific comments.

General Comments

The DEIS contains a comprehensive review of the Savannah Harbor operation and a plan for future operation and maintenance of the project. We are pleased that the Corps of Engineers has addressed many of our concerns and interests in the Savannah Harbor study area. However, some of the alternatives discussed below need further study or refinement before being implemented.

The Department is particularly supportive of the plan to use off-channel storage of sediments to reduce the amount of agitation dredging in Savannah Harbor. We believe that this alternative is preferable to the use of agitation dredging for maintaining berthing areas in the harbor. The plan proposed in the DEIS should substantially reduce the amount of agitation dredging and therefore improve fish and wildlife resources in Savannah Harbor.

The Department also supports the concept of managing the dredged material disposal areas for shorebirds and waterfowl. We have had discussions with the Corps over many years exploring this management concept. However, before we can fully support this alternative, the dredged material should be sampled to insure that the birds would not be subject to increased contaminant exposure. While we are hopeful that contaminants in the disposal areas are not a threat, we believe that attraction of additional birds without this precaution would be imprudent. Further, we believe that testing could be completed in a cost effective manner with cooperative support from the Fish and Wildlife Service (Service) and other agencies.

We also support the creation of a new bird nesting island and creation of a nesting area on Tybee National Wildlife Refuge. We recommend that the number one priority for dredged material be for environmental benefits, primarily bird habitat management. This use should take priority over such uses as beach nourishment or berm creation. Also of concern to the Department is the proposal to deepen the Back River sediment basin. The removal of the tide gate from operation and closure of New Cut has improved salinity levels and tidal freshwater marsh. However, recovery of the striped bass population is not evident. Modifications of the Back River due to shoaling upstream of the tide gate and the current deep water sediment basin could be contributing factors hindering striped bass recovery. An on-going striped bass study, to be completed within three years, will provide information to help evaluate the problem. We recommend that a decision on deepening the sediment basin be deferred until the study is completed and an assessment can be made.

The DEIS failed to discuss the feasibility of recovering the heavy mineral and phosphate fractions of the dredged material. The Department has no objection to the proposed project in this regard. However, we suggest that subsequent reports and other documents prepared describing this project discuss all mineral resources and impacts to them.

Specific Comments

Paragraph 2.08. These comments in response to the DEIS do not constitute a Fish and Wildlife Coordination Act report as stated in the document. This response is made under authority of the National Environmental Policy Act (NEPA).

Paragraph 5.08. The mitigation plan for loss of wetlands associated with diking of disposal area 14A is proposed to include increased management of disposal areas for shorebirds and waterfowl and creation of an offshore bird nesting island. Although this is not "in-kind" mitigation, shorebird nesting and feeding habitat is extremely limited and under increasing threat due to coastal development. The disposal areas and nesting island have the potential to provide significant habitat for these species.

The plan should include a long term, binding, management commitment. Management decisions should be made by qualified biologists and be flexible in nature. The Department has no objection to the plan provided that it is further coordinated with the Service to clarify and/or refine details prior to implementation.

Paragraph 5.36 and 5.40. The Department is concerned with the direct placement of maintenance material on Tybee Beach and Daufuskie Island. It is our understanding that during harbor deepening, several extensive pockets of fine sediments were dredged, resulting in high turbidity levels and unsuitable material

on Tybee beach. Placement of such incompatible material on the beach has the potential to impact fishery resources. These concerns need to be addressed in the DEIS. A monitoring plan to document the level of impact would also be appropriate.

Paragraph 5.42. The Department strongly supports coordinating dredging of the berthing areas with the navigation channel to reduce the amount of agitation dredging.

Paragraph 5.46. The Department supports the need to test berthing areas for contaminants before dredging.

Paragraph 5.48. Recovery of the striped bass population after removal of the tide gate from operation has not been documented. Configuration changes in the Back River such as the tide gate structure, shoaling upstream of the gate, and shoaling in the sediment basin may be impacting striped bass recovery. We recommend that a decision on deepening of the sediment basin be deferred until current striped bass studies are completed.

Paragraph 5.69 (Table 5). The proposed management techniques should be modified and stated as general guidelines. There needs to be flexibility of management depending on weather conditions and status of bird populations. For example, in some winters the shorebird population is high and the waterfowl population is low. Under these conditions it would be best to draw down the disposal area for shorebirds. Therefore, the techniques for January 1 - March 15 and November 15 - December 31 should be changed to: "Optimum water level will be determined by qualified biologists and coordinated with the Service. At a minimum, a water depth of one (1) inch will be maintained in the area."

Paragraph 6.31. Studies by the State of South Carolina have documented low dissolved oxygen levels in the Back River sediment basin during the summer. These studies and the implications for harbor management should be discussed.

Paragraph 6.40. There is only one active eagle nest on Savannah National Wildlife Refuge. Another active nest is located on private land near the refuge in South Carolina.

Paragraph 6.59. The Tybee National Wildlife Refuge is about 400 acres in size rather than 100 acres as stated in the document.

Paragraph 6.157. The Tybee National Wildlife Refuge is about 400 acres in size.

Paragraph 7.34. The Department concurs with relocation of the underdrains to the Back River, provided that the discharge is adequately monitored. We believe that discharges should be monitored every three (3) years rather than every five (5) years.

We understand that you are proposing a 10-foot mixing zone, **not** a 100-foot mixing zone.

Paragraph 7.57. The striped bass in the Savannah system spawned primarily in the Back River prior to tide gate construction. However, recent studies found very few eggs in the Back River with most eggs being collected in the Front River. The present status of striped bass recovery and habitat use in the lower Savannah are unclear.

Paragraph 7.146. An offshore bird nesting island would also require adequate posting and law enforcement to prevent disturbance of nesting birds by people and/or their pets. An agreement with the South Carolina Department of Natural Resources or the Service may be appropriate to accomplish this protection.

Paragraph 7.151. We believe that the proposed nesting island and 26-acre nesting area on Tybee National Wildlife Refuge have the potential to provide valuable habitat for nesting shorebirds. However, we are concerned that the proposed 2-acre crown on the nesting island will be too small. We recommend at least a 5-acre crown to provide sufficient habitat and protection from erosion. Provision also needs to be made for periodic sand nourishment to control vegetation succession and replace habitat lost to erosion. Use of dredged material to create and maintain bird nesting areas should be a higher priority than beach nourishment or berm creation.

Summary Comments

The Corps of Engineers is to be commended for preparing a comprehensive statement that attempts to address the major environmental problems associated with operation and maintenance of Savannah Harbor. The Department does not fully concur with the selected alternative, but would support the selected alternative if modified in accordance with the following changes.

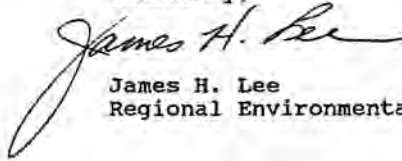
- (1) The mitigation plan will be further coordinated with the Service to clarify details such as disposal area water depth and draw down rates.
- (2) In cooperation with the Service, a contaminant survey of disposal materials to be managed for birds will be accomplished.
- (3) The crown area of the offshore bird nesting area will be increased to five (5) acres and provisions for periodic renourishment will be added.
- (4) The plan to deepen the sediment basin will be deferred until current striped bass studies are complete in two years.

(5) The underdrain discharge will be monitored every three years rather than every five years.

If you have any questions pertaining to Fish and Wildlife aspects of this project, please contact Jon Andrew, Fish and Wildlife Service, at (404) 679-7123, or Mr. Ed Eudaly at (803) 727-4707. Please feel free to contact Mr. Robert Wood of the Bureau of Mines if you have any questions concerning mineral resources. Mr. Wood can be reached at (303) 236-0428, ext. 294.

Thank you for the opportunity to comment.

Sincerely,



James H. Lee
Regional Environmental Officer

RESPONSE -- US Department of Interior,
Office of Environmental Policy And Compliance,
February 23, 1995.

AGITATION DREDGING. The District concurs that the proposed use of off-channel storage of sediments should reduce the amount of agitation dredging in Savannah Harbor, thereby improving fish and wildlife resources.

TESTING OF DISPOSAL AREA SEDIMENTS. The District has agreed to test sediments in the confined disposal areas which will be used in the rotational program to ensure that increased use of the sites by migratory birds would not result in adverse impacts to those species.

BENEFICIAL USE OF DREDGED MATERIAL. An evaluation is made prior to each dredging contract to determine the best location for disposal of the sediments. Three steps are generally followed in this evaluation:

- (1) Identify a need for dredged sediments,
- (2) Evaluate the suitability of the specific sediments to be dredged for that need,
- (3) Identify sources and obtain funding for incremental costs.

The District does not anticipate conflicts to commonly occur when multiple uses for sediments obtained during a particular contract would successfully complete each of the steps listed above.

SEDIMENT BASIN DEEPENING. The District had initially concurred that construction of an advance maintenance deepening section at the Sediment Basin would not be performed until an ongoing striped bass egg and larval study was completed. However, the 3-year study which the District was conducting has been concluded. Since preliminary results from that study were inconclusive, the District recently funded an additional 1-year of effort on that study.

Using data obtained during the 3-year study as well as other available information on the species, the environmental impacts of deepening the Sediment Basin are adequately identified and evaluated in this FEIS, and delaying the decision on the acceptability of those impacts is unwarranted. The 1-year extension to the striped bass egg and larval study may provide new information on the status of striped bass in the estuary, but the evaluation contained in the FEIS of potential impacts of deepening the Sediment Basin assumes that striped bass are present in the estuary and using Back River to spawn. This is a conservative position from which to assess potential project impacts to striped bass. If adverse impacts to that species were to result from deepening the Sediment Basin, they would occur primarily from increases in salinity in Back River. The Tidegate

structure which crosses Back River acts as a sill, limiting the movement of salinity upstream of that location. Since the proposed action is the creation of a localized hole downstream of the Tidegate, the hydraulic impacts of such construction are not expected to extend upstream of that structure or increase salinity upstream of that location. Based on those physical restrictions, the proposed advance maintenance deepening of the Sediment Basin is not expected to adversely affect striped bass using Back River. Therefore, the District believes that an evaluation of potential environmental impacts of the proposed Sediment Basin deepening would not be substantively altered by waiting for the results of the extended striped bass study. The data obtained during the 1-year extension of that study could be as inconclusive as that obtained during the foundational 3 years of the study.

Although the FEIS obtains environmental clearances for the proposed advance maintenance at the Sediment Basin, authorization from higher headquarters for such construction has not yet been sought by the District. This project feature could not be implemented until such authorization has been received.

RECOVERY OF CONSTITUENTS FROM DEPOSITED SEDIMENTS. There are presently no proposals to recovery any constituents from deposited sediments. Current proposals include beneficial use of sediments through alternate placement strategies and use of bulk sediment to make construction aggregate. The EIS contains and evaluation of those proposals, as much as possible given the design information available at the time. Should proposals be made to recover specific fractions of the sediments, future environmental documents would include evaluations of those proposals when the decision being made could be affected.

Paragraph 2.08. Concur. This paragraph has been revised to state that the FWS comments are made under authority of the National Environmental Policy Act (NEPA).

Paragraph 5.08. - **MITIGATION PLAN.** Concur. The Mitigation Plan would be a long term, binding, management commitment. Specific water level management decisions would generally follow Table 6, but could be adjusted on a case-by-case basis if the District's biologist believed a variation would be more beneficial and concurrence was obtained from the US FWS prior to implementation. The Mitigation Plan has been revised and coordinated with the Service to clarify and/or refine specific details.

Paragraph 5.36 and 5.40. **DIRECT PLACEMENT ON BEACHES.** A mixture of sediments are typically encountered in all dredging contracts. The environmental evaluations conducted as part of this EIS consider a dredging contract as a whole. There would be times during a contract when more fines are encountered than the average, and times when fewer fines would be experienced. To define the sediment characteristics of small segments of a

dredging area with the goal of placing different material types in different disposal areas would not be efficient or cost effective. The time required to shift to an alternate disposal area would sometimes equal the time to dredge the volume of sediment of specific concern. This would increase the dredging unit cost to unacceptable levels. Monitoring would be performed to document the volume of sediments dredged and the volume retained on the beach. This would be compared with the physical characteristics of the dredged sediments (percent fines) to allow a better prediction of the impacts and success of future beach placement activities.

Paragraph 5.42. Concur.

Paragraph 5.46. Concur.

Paragraph 5.48. Deepening of the Sediment Basin was deferred until the foundational 3-years of the Corps striped bass studies were completed. Based on physical restrictions at the site, as well as other available information on the species, the proposed advance maintenance deepening of the Sediment Basin is not expected to adversely affect striped bass using Back River. Therefore, the District believes that an evaluation of potential environmental impacts of the proposed Sediment Basin deepening would not be substantively altered by waiting for the results of the extended striped bass study and that delaying until ongoing or yet-to-be-initiated studies concerning the disposition of the Tidegate structure are completed is not warranted.

Paragraph 5.69 (Table 5). As suggested, the proposed management techniques have been revised to add flexibility. The following sentence has been added to the Mitigation Plan: "If District biologists believe it would be beneficial to use a management technique which is different than that prescribed in Table 6, approval from the US FWS would be required prior to implementation."

Paragraph 6.31. Another paragraph has been added to include this information.

Paragraph 6.40. This paragraph has been revised as suggested.

Paragraph 6.59. This paragraph has been revised as suggested.

Paragraph 6.157. This paragraph has been revised as suggested.

Paragraph 7.34. The District agrees to perform a chemical evaluation of underdrain effluents every three years rather than every five years. The District will use the mixing zone distance specified by the SC DHEC in their Water Quality Certification

Paragraph 7.57. This paragraph has been revised as suggested.

Paragraph 7.146. NEARSHORE NESTING ISLAND. Concur. The District expects the state of South Carolina to be the owner of the created nearshore island, since such land is claimed by the state. Restrictions to limit human access and disturbance would support the purposes for which the island would be created and maintained.

Paragraph 7.151. NEARSHORE NESTING ISLAND. The proposed nearshore island would have a 2-acre crown at EL 14 MLW. Due to the sloping sides, 11 acres are expected to be present at EL 8 MLW, the elevation above which nesting should successfully occur. The proposed Mitigation Plan also includes maintenance of both the nearshore island and upland nesting area through periodic sand nourishment and/or scraping to remove vegetation. The use of suitable dredged material for beneficial purposes will be made based on the physical site needs at the time and availability of needed funding.

SUMMARY COMMENTS. The Corps has performed, or agrees to perform the following actions:

- (1) A revised Mitigation Plan has been coordinated with the FWS.
- (2) Sediment testing would be performed of surface material at the confined disposal areas to be managed for birds.
- (3) While the island crown at the proposed nearshore bird island would be two acres, the area above high water available for nesting would be eleven acres. Periodic maintenance through placement of additional dredged material and/or scraping of vegetation are included.
- (4) The striped bass study which the Corps was conducting has been extended and the evaluation contained in the FEIS of potential impacts of deepening the Sediment Basin identified no substantive adverse impact on that species. Therefore, the Corps believes that delaying a decision on the acceptability of such deepening until the extended Corps striped bass study is complete is not warranted.
- (5) Underdrain discharges would be chemically evaluated every three years.



United States Department of the Interior



FISH AND WILDLIFE SERVICE
P.O. Box 12559
217 Fort Johnson Road
Charleston, South Carolina 29422-2559

November 29, 1995

Colonel Grant M. Smith
District Engineer
U.S. Army Corps of Engineers
Post Office Box 889
Savannah, Georgia 31402-0889

Dear Colonel Smith:

Please reference the revised draft Mitigation Plan for Diking and Use of Disposal Area 14A provided to our office from Mr. Bill Bailey of your staff. The mitigation plan was revised by the Corps based on concerns and recommendations provided by various resource agencies. The revised mitigation plan will become part of the Long Term Management strategy Study for Savannah Harbor, Chatham County, Georgia and Jasper County South Carolina. The Fish and Wildlife Service (Service) has reviewed the revised mitigation plan and offers the following comments.

The revised mitigation plan is generally acceptable to the Fish and Wildlife Service. However, we have some specific comments and concerns on the revised plan. The following comments are referenced to paragraph designations used in the revised mitigation plan.

Paragraph G.2.26. We are pleased that the Corps has agreed to perform contaminant sampling in the disposal areas and agree that most sampling should be performed on soil material within one foot of the surface. We recommend that a limited number of water samples also be tested. Some shorebirds use water carried by the breast feathers to cool eggs during incubation and this is a potential source of fetal bird contamination.

Paragraph G.3.07 b. If the nesting mounds are located near the dikes they need to be surrounded by water or mud during the nesting season. We recommend that you determine the location of the mounds in consultation with the Fish and Wildlife Service.

Paragraph G.3.07 d. We concur with the plan to have the South Carolina Office of Coastal Resource Management (OCRM) implement restoration or creation of a minimum of 25 acres of tidal wetlands in South Carolina. We recommend that OCRM coordinate the restoration or

creation plans with interested resource agencies (Service, National Marine Fisheries Service, South Carolina Department of Natural Resources) as the plans become available.

Paragraph G.3.07e. We concur with the plan to add a water control structure on the 228 acre impoundment at Savannah National Wildlife Refuge. The structure will improve water circulation through the impoundment and enhance fish habitat.

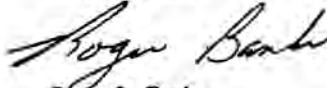
Paragraph G.4.01. Part of this section discusses the creation of the near shore bird nesting island and states that benthic surveys will be conducted on the site prior to construction. Part or all of the proposed bird nesting island site may be located within unit SC-10P of the Coastal Barrier Resources System. Therefore, a determination is needed from the Service that the project is consistent with purposes of the Coastal Barrier Improvement Act (CBIA). Our preliminary determination is that the project, as a conservation measure for the enhancement of wildlife habitat, would be an exception to the act, and would be consistent with purposes of the CBIA. When benthic surveys are completed and the project design is finalized the Corps should consult with the Service for our final determination.

Paragraph G.4.05. The revised plan states that, because beneficial migratory bird impacts of the plan will outweigh any negative impacts on these birds, that the plan would be in compliance with the Migratory Bird Treaty Act (MBTA) and that no further clearances would be necessary to implement the actions described in the plan. We concur that the mitigation plan, as proposed, is in compliance with the MBTA. However, this concurrence does not extend to specific management or disposal actions that may be implemented in accordance with the plan. Issuance of blanket permission to take birds, nests or eggs under the MBTA would not be appropriate. If a potential take situation develops during use of the disposal areas, the Service will work closely with the Corps to obtain any needed permits under the MBTA. We recommend that you coordinate, on a continuing basis, management of the disposal areas with the Service to avoid any unnecessary delays.

Based on the biological assessment of threatened and endangered species (BATES) provided by the Savannah District in February 1994, we will concur with your determination that the project is not likely to adversely affect the species listed in your BATES which are under our jurisdiction. In view of this, we believe that the requirements of Section 7 of the Endangered Species Act have been satisfied with regard to these species. However, obligations under Section 7 of the Act must be reconsidered if (1) new information reveals impacts of this identified action that may affect listed species or critical habitat in a manner not previously considered, (2) this action is subsequently modified in a manner which was not considered in this assessment, or (3) a new species is listed or critical habitat determined that may be affected by the identified action. Further consultation under the Endangered Species Act may be necessary if significant levels of contaminants are found in the disposal areas. We will review the planned contaminant test data, when available, and advise you as to any potential impacts to threatened or endangered species.

We appreciate the cooperation of your staff during planning efforts for the Long Term Management Strategy Study. We request that you continue close coordination with the Service throughout development of detailed construction and management plans, contracting and construction.

Sincerely yours,

A handwritten signature in black ink, appearing to read "Roger Banks", written in a cursive style.

Roger L. Banks
Field Supervisor

RLB/EE/km

cc:

Savannah Coastal Refuge, Savannah, GA (John Robinette)
NMFS, Charleston, SC (David Rackley)
SCDNR, Charleston, SC (Ed Duncan)
OCRM, Charleston, SC (Rob Mikell)

RESPONSE -- US Department of Interior,
Ecological Services Office,
November 29, 1995.

ACCEPTABILITY OF REVISED MITIGATION PLAN. Concur.

Paragraph G.2.26. CONTAMINANT TESTING. Concur.

Paragraph G.3.07b. NESTING MOUNDS. Concur.

Paragraph G.3.07d. SC DHEC-OCRM IMPLEMENTATION OF WETLAND RESTORATION. Concur.

Paragraph G.3.07e. WATER CONTROL STRUCTURE. Concur.

Paragraph G.4.01. NEARSHORE BIRD ISLAND. Coordination between the District and the FWS after this letter has resulted in clarification that the proposed location of the nearshore bird island is not under the oversight of the FWS under the Coastal Barrier Improvement Act. Instead, control of that area rests with the State of South Carolina as it is (1) adjacent to a state wildlife management area, and (2) in subtidal coastal waters within the three-mile state jurisdiction line.

Paragraph G.4.05. COMPLIANCE WITH THE MIGRATORY BIRD TREATY ACT. The District concurs that the Mitigation Plan is in compliance with the Migratory Bird Treaty Act (MBTA). Subsequent to this letter, the District has written to the FWS Regional Office in Atlanta which administers permitting for incidental takes of migratory birds to further discuss this issue. The District continues to believe that the large-scale valuable benefits for migratory birds which biologists uniformly expect to be produced through implementation of the Mitigation Plan should outweigh the take of a limited number of individuals which may occur as a result of scheduled disposal operations.

IMPACT TO THREATENED AND ENDANGERED SPECIES. The District concurs that the project is not likely to adversely impact these species.



UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
 NATIONAL MARINE FISHERIES SERVICE

Southeast Regional Office
 9721 Executive Center Drive N.
 St. Petersburg, Florida 33702

January 13, 1995

Colonel Wayne W. Boy
 District Engineer, Savannah District
 Department of the Army, Corps of Engineers
 P.O. Box 889
 Savannah, Georgia 31402-0889

Dear Colonel Boy:

The National Marine Fisheries Service (NMFS) has reviewed the Draft Environmental Impact Statement (DEIS) for the Savannah Harbor Long Term Management Strategy (LTMS) Study. The DEIS was conveyed by cover letter dated November 20, 1994, from Mr. M.J. Yuschishin of your staff and is advertised by a November 30, 1994, unnumbered Public Notice.

Overall, we find that the document is well written and parts of the proposed mitigation are good. Unfortunately, several significant deficiencies exist in the analysis and data presented as well as parts of the mitigation package. Key components of the project for which the environmental consequences are insufficiently documented and remediation is insufficient include the conversion and elimination of shallow water habitat for building the "bird island" and creating nearshore berms near the entrance channel. The NMFS also believes that the planned mitigation for eliminating 260 acres of estuarine habitat is inadequate because it does not address the loss of living marine resource habitat and functions that will result from enclosing Disposal Site 14A.

The shallow depth and relatively protected nature of submerged bottoms near the proposed "bird island" are characteristic of areas suitable for colonization by invertebrates and demersal fish that are of ecological, recreational, and commercial importance. Because of this, confirmation is needed on the status of the benthos and whether the area can be filled without harm to important living marine resources. Confirmation is possible through analysis of recent sample data from the site, if available, or through a specific sampling effort. Creation of the nearshore berms is also of concern. Recent investigations in other areas of the South Atlantic show that bottom configuration and currents in the immediate seaward zone of ocean inlets are major determinants for ingress, into estuarine waters, of planktonic fish and invertebrates that are spawned offshore. Consequently, the modification of nearshore currents through berm creation could affect finfish and shellfish abundance.



The elimination of agitation dredging, as proposed in conjunction with the selected alternative, could have a substantial net benefit with regard to protection of living marine resources. The study results presented in the DEIS pertaining to the environmental consequences of agitation dredging, are inconclusive in that they examined only a fraction of the total amount of agitation dredging occurring in Savannah Harbor. For example, the EMC study cited in the DEIS examined the effects of resuspending less than 14,000 cubic yards of material, yet annual dispersion of over one million cubic yards of material was authorized for work proposed by the Georgia Ports Authority and other dock operators. The NMFS has consistently maintained that the cumulative effect of annually resuspending and redepositing in excess of one million cubic yards of bottom sediments has not been determined and could be adverse. Accordingly, we conclude that the benefits related to this aspect of the project may be understated in the DEIS.

In the absence of full disclosure of impacts associated with filling submerged bottoms and constructing offshore berms; and in the absence of suitable mitigation for eliminating 260 acres of estuarine emergent, scrub, and submerged bottoms resulting from diking Disposal Site 14A, the DEIS is seriously inadequate. More importantly, the undescribed impacts are potentially significant in their effect on the long-term health and survival of living marine resources that utilize the project area. The NMFS believes strongly that these deficiencies warrant remedy through preparation of a supplemental DEIS. Absent suitable disclosure of impacts associated with these aspects of the project, construction should not be implemented.

Specific Comments:

1.00 Areas of Controversy

Page 9, para. 1.27. This section should be modified to note that the mitigation plan provides no replacement for wetland functions that are of benefit to living marine resources.

2.00 Need for and Objectives of Action

Page 12, Section 2.08. This section should be modified to include the National Marine Fisheries Service and the heads of the state fish and wildlife agencies for South Carolina and Georgia as contact points for coordination required under the Fish and Wildlife Coordination Act.

Page 17, Section 2.23. As noted in the preceding general comments, studies on the effects of agitation dredging were extremely limited in scope and did not examine the effects of the large-scale maintenance dredging that actually occurs in Savannah Harbor. This section should be modified to state that the studies were extremely limited when compared to the total amount of agitation dredging that actually occurs and that the effect of this dredging is undetermined and potentially significant and adverse.

5.00 Alternatives

Page 56, Section 5.08. This section should be modified to note that the mitigation plan provides no replacement for wetland functions that benefit living marine resources. The planned mitigation should be highly beneficial to birds and possibly sea turtles if the proposed "bird island" is relatively stable and suitable for use as a nesting site for sea turtles.

Pages 56 and 57, Section 5.09. The NMFS should be contacted with regard to development of a mitigation plan for wetland losses in Disposal Area 2A. A plan to offset wetland losses using a 2:1 (minimum) replacement to loss rate and in-kind replacement should be evaluated.

Page 71, Section 5.27. Evidence of the determination that variation in bottom contours will increase the habitat value of the site is needed. It is also possible that modification of bottom contours could affect local currents that affect ingress of sub-adult fish through the inlet and into estuarine waters. In this regard, hydrographic studies are needed to determine probable effects of the proposed berms.

Pages 90 and 91, Section 5.69. This section should be modified to include mitigation for lost wetland functions beneficial to living marine resources. The determination that such mitigation is too costly to allow remediation is unacceptable. At a minimum, off-site but in-kind habitat replacement should be provided. The NMFS should be added to the list of agencies to be consulted regarding wetland mitigation for "other wetland impacts."

7.00 Environmental Consequences

Page 169, Section 7.56; Page 171, Section 7.59. The determination that the numbers of fish entrained through dredges "has no measurable impact on population levels" needs documentation and further explanation with regard to the meaning of "population." No measurable impact on certain populations could represent a significant number of organisms. This also fails to address the affect of such take on endangered species such as the shortnose sturgeon.

Pages 175 and 176, Section 7.73. The absence of suitable mitigation sites in the immediate vicinity of Disposal Site 14A does not preclude responsibility for offsetting the loss of fishery resource functions and benefits provided by the 280 acres of wetlands to be filled. Creation or restoration of estuarine emergent wetlands at other locations is acceptable and should be implemented.

Page 178, Section 7.81. Although creation of an island for use by colonial nesting waterbirds and other avian species could be environmentally innocuous, the shallow water and protected nature of the site are indicative of locations that support diverse and highly productive benthic communities. Consequently, a survey of the existing benthic community is needed before it can be concluded that this aspect of the project can be undertaken without causing further environmental damage. Eliminating or converting one habitat to create another is usually unacceptable except in situations where the functional value of the affected site for desirable flora and fauna is exceptionally low.

Page 198, Section 7.106. This section should be modified to state that wetland functions of significant benefit to living marine resources will be lost if Disposal Site 14A is diked and filled; especially if a similar quality and amount of in-kind habitat is not created or restored.

Page 210, Section 7.138. Significant differences may exist in the substrate and depth of submerged bottoms that would be filled versus those created along the edges of the bird island. Consequently, the newly established benthos may differ from that presently found on site. While this change would be insignificant if the existing benthos is ecologically unimportant, the status of the existing benthos must be determined before the environmental effects are known. Accordingly, and as previously stated, a survey is needed of the benthos inhabiting submerged bottoms to be filled.

Page 217, Section 7.153. The disposal of dredged material in the nearshore zone could have a substantial effect on larval fish and invertebrates. This area is an important staging site for larval organisms that must traverse the inlet to reach estuarine waters where development and maturation takes place. This section should be modified to acknowledge the importance of nearshore areas in the vicinity of ocean inlets as locations where subadult fish and invertebrates congregate. It should also be noted that activities causing significant elevation of turbidity levels and modification of local currents could adversely affect recruitment of aquatic organisms into estuarine waters.

Pages 217 and 218, Section 7.154. Plans to conduct side-scan sonar surveys to confirm the presence or absence of hard bottoms is highly desirable and should be implemented. As noted previously, the status of soft bottom infauna and epifauna should also be determined in the vicinity of the proposed bird island. We question the determination that the proposed berms will stabilize the ocean shoreline enough to increase the stability of benthic communities occupying this zone. Documentation is needed.

Page 218, Section 7.156. The assertion that the berms will increase fishery habitat values should be documented.

8.00 Public Involvement

Page 239, Section 8.01. Delete "U.S." from in front of National Marine Fisheries Service.

Appendix C

Page 10, Section C.2.44. The decision to deposit dredged materials in the nearshore environment in early winter is based on the fact that overall biological activity is relatively low during this period. As noted previously, waters near ocean inlets are important staging sites for estuarine-dependent organisms that are spawned offshore. Since spawning of many of these species occurs in early winter, the assumption that disposal during this time of year is desirable may not be valid. To address this, we recommend that the Savannah District examine relevant

literature or data regarding larval migration into Georgia estuaries. In the absence of this information, investigations (sampling) should be performed to determine the occurrence and abundance of sub-adult fish and invertebrates during disposal operations.

Page 11, Section C.2.46. The assessment provided is essentially a "best case" scenario. Since the composition of the benthos is unknown, it cannot be assumed that lasting changes in the benthic community will not occur. Considering the size of the disposal area and volume of material to be deposited, we also question the determination that burrowing organisms "should survive." As noted previously, a benthic survey is needed before the effects of filling the area are known.

Pages 13 and 14, Sections C.2.56 and C.2.57. All previous comments pertaining to effects on plankton (sub-adult fish and invertebrates) and benthos apply. As presented, the analysis is flawed since the determination that the work will not significantly and adversely affect those resources is unsubstantiated.

Pages 14, Section C.2.60. This section states that separate mitigation ("restoration and creation of saltwater wetlands") would be performed in the Savannah Harbor area to offset wetland losses other than those associated with diking and filling Disposal Site 14A. Assuming that "saltwater wetlands" are estuarine intertidal emergent wetlands, we support this concept and encourage similar action for wetland losses associated with Disposal Site 14A. As previously noted, we acknowledge the limited availability of wetland creation and restoration sites in the vicinity of Disposal Site 14A. This, however, does not preclude the use of other locations. The detailed mitigation plan to be submitted in for this aspect of the project also should be coordinated with the NMFS.

Appendix G.

Page 3, Section G.2.08. Explanation should be given for the apparent discrepancy or differences with respect to the effect of filling shallow water habitat for creation of bird habitat and marsh. Specifically, how was it determined that filling submerged estuarine bottom for marsh creation is unacceptable, yet filling to create bird habitat is acceptable.

Pages 3 and 4, Sections G.2.09 and G.2.10. The NMFS was not consulted regarding determination of functional values associated with Disposal Site 14A. We do not support the apparent determination that the site is unimportant and essentially valueless with regard to fishery resource functions. We also question the determination that the 260 acres of wetlands found on the site are unimportant as sites for floodwater storage since this area is subject to inundation by flood waters. As previously noted, consideration of mitigation options such as offsite marsh creation is needed. Another possible mitigation alternative is creation of oyster reefs in locations that are void of important benthic communities.

Finally, in accordance with the Endangered Species Act of 1973, as amended, it is the responsibility of the appropriate federal regulatory agency to review its activities and programs and to identify any activity or programs that may affect endangered or threatened species or their habitat. If it is determined that these activities may adversely affect any species listed as endangered or threatened, formal consultation with our Protected Species Management Branch must be initiated. The appropriate contact person for matters pertaining to protected species is Mr. Charles Oravetz who may be contacted at the letterhead address or at (813) 570-5312. Mr. David Rackley of our Charleston Branch Office should be contacted regarding technical aspects of the comments we have provided. He is also prepared to assist the Savannah District in efforts to develop a mitigation plan for lost fishery functions and values associated with the project.

We appreciate the opportunity to provide these comments.

Sincerely,

A handwritten signature in black ink, appearing to read "And Mager Jr", written in a cursive style.

Andreas Mager, Jr.
Assistant Regional Director
Habitat Conservation Division

RESPONSE -- NOAA, National Marine Fisheries Service,
Southeast Regional Office,
Habitat Conservation Division,
January 13, 1995.

GENERAL COMMENTS:

1. A revised Mitigation Plan was prepared and provided to the NMFS for review. The District met with the NMFS and other resource agencies on July 11, 1995 to discuss the revised Plan. At that meeting, the NMFS stated they felt some form of mitigation specifically for fishery resources was required. The Final Mitigation Plan includes two actions which enhance fishery habitat at 228 acres. The District believes this adequately compensates for the wetland functional values related to fishery resources which would be lost as a result of project implementation.

2. A side scan sonar investigation and benthic survey will be performed at all new nearshore areas prior to initial placement of dredged material to ensure that significant impact will not occur to important living marine resources.

3. Savannah District recognizes the possibility of adversely modifying nearshore currents through berm or island creation. That possibility formed the basis of the location and design criteria for those proposed nearshore structures. The bird island was sited in shallow water between two deeper channels which allow tidal exchange to marshes north and south of Turtle Island. The footprint of the island would not extend into the channels, so we do not expect the island to interfere with flows through those creeks. The underwater berms would be oriented at a sharp angle to the channel, rather than parallel, to minimize changes to flood tides approaching the channel. The 2,000-foot spacing between berms was specified to further reduce impacts to tidal currents. The District believes these design criteria ensure that finfish and shellfish abundance would not be adversely impacted by changes in nearshore currents resulting from the proposed actions.

4. Agitation dredging is not proposed for elimination in the Management Plan or this EIS. The EIS does recognize that the double handling of sediments caused by the initial agitation dredging at a berth and the subsequent hydraulic dredging from the channel results in more environmental impacts than does direct placement of berth sediments into a confined disposal facility.

5. This Final EIS contains a revised Mitigation Plan which was substantially provided to the NMFS in July 1995 for review. The NMFS provided verbal comments on that revision related to adding some component to mitigate specifically for fishery resources. The District subsequently included actions in the Mitigation Plan to more clearly compensate for impacts to fishery resources. With the final Mitigation Plan and other minor changes and clarifications made to the EIS, Savannah District believes that the Final EIS adequately documents the impacts associated with the proposed actions and that preparation of a supplemental Draft EIS is not warranted.

SPECIFIC COMMENTS:

1.00 Areas of Controversy

Page 9, para. 1.27. The revised Mitigation Plan has a component -- restoration/creation/protection of 25 acres of tidal marsh in South Carolina -- which would ensure the continued protection of an acreage of Spartina marsh, thereby benefiting living marine resources. Mitigation for adverse impacts to Georgia wetlands would be provided through restoration/creation of wetlands in the harbor area at a 2:1 ratio.

2.00 Need for and Objectives of Action

Page 12, Section 2.08. This section has been modified to include the state fish and wildlife agencies for South Carolina and Georgia as contact points for coordination required under the Fish and Wildlife Coordination Act.

Page 17, Section 2.23. Savannah District believes that the studies of agitation dredging adequately examined the impacts of those dredging events.

5.00 Alternatives

Page 56, Section 5.08. The revised Mitigation Plan has a component -- the restoration/creation/protection of 25 acres of tidal marsh in South Carolina -- which would ensure the continued protection of an acreage of Spartina marsh, thereby benefiting living marine resources. Another component of the Mitigation Plan -- the water control structure at the Savannah National Wildlife Refuge -- was included to provide benefits to fishery resources. The proposed "bird island" is expected to be relatively stable and suitable for use as a nesting site for sea turtles.

Pages 56 and 57, Section 5.09. The Mitigation Plan for wetland losses in Georgia will use a 2:1 (minimum) replacement ratio and in-kind replacement (marsh creation/restoration). The Mitigation Plan will be coordinated with the NMFS.

Page 71, Section 5.27. Data recently gathered in Mobile Harbor on submerged berms constructed by the Corps revealed higher densities of fish around the berms than at adjacent ocean sites. The structures proposed for the nearshore environment are designed to minimize effects on tidal currents and, thereby, effects on the ingress of sub-adult fish through the inlet and into estuarine waters. The District believes that hydrographic studies would not provide additional information on the likely effects of the proposed berms.

Pages 90 and 91, Section 5.69. Resource agencies, including the NMFS, were reconsulted to identify sites within the project area which could be used for wetland restoration/creation purposes. As before, no sites of sufficient size could be identified at this time. Funds will be placed in escrow for the SC OCRM to restore/create protect 25 acres of tidal wetlands as in-kind mitigation.

7.00 Environmental Consequences

Page 169, Section 7.56: Page 171, Section 7.59. The statement that fish entrainment through dredges has no measurable impact on population levels was taken from information contained in Technical Report D-91-1 published in July 1991 by the Waterways Experiment Station titled "A Framework For Assessing The Need For Seasonal Restrictions On Dredging And Disposal Operations." The District has not previously observed, nor do we anticipate future dredging will produce a measurable impact on either fish populations or significant numbers of individual fish. The District is aware of no known documented adverse impact of dredging in Savannah Harbor on Shortnose sturgeon. Impacts to endangered species are described in more detail in Appendix B BIOLOGICAL ASSESSMENT OF THREATENED AND ENDANGERED SPECIES (BATES).

Pages 175 and 176, Section 7.73. The revised Mitigation Plan includes two components -- the 25 acres of in-kind mitigation administered by the SC OCRM and the water control structure for the 228-acre impoundment at the Savannah National Wildlife Refuge -- which would benefit fishery and other living marine resources.

Page 178, Section 7.81. A side scan sonar investigation and a benthic survey would be conducted at all new nearshore areas prior to placement of dredged material to ensure that hard-bottom communities or other highly productive and ecologically valuable benthic communities are not eliminated.

Page 198, Section 7.106. The EIS has been revised as suggested.

Page 210, Section 7.138. A side scan sonar investigation and a benthic survey would be conducted at all new nearshore areas prior to initial placement of dredged material to ensure that hard-bottom communities or other highly productive and ecologically valuable benthic communities are not eliminated.

Page 217, Section 7.153. Concur.

Pages 217 and 218, Section 7.154. Concur, a benthic survey would be conducted at all new nearshore areas prior to initial placement of dredged material to ensure that highly productive and ecologically valuable benthic communities are not eliminated. Any decrease in the wave climate at the ocean shoreline would stabilize the benthic communities residing at the shorelines to some degree.

Page 218, Section 7.156. Data recently gathered in Mobile Harbor on submerged berms constructed by the Corps revealed higher densities of fish around the berms than at adjacent ocean sites. The berms provided a variation in bottom contours that was not present in the immediate vicinity. Such should be the case with the proposed berms in the nearshore area off Tybee Island.

8.00 Public Involvement

Page 239, Section 8.01. Concur.

Appendix C

Page 10, Section C.2.44. Sediments are presently dredged from the Bar Channel during the winter and deposited at the Savannah ODMDS. The District believes that deposition in shallower nearshore waters, which are naturally turbid, would not create conditions which would cause significant impacts to the movement of estuarine-dependent organisms that are spawned offshore. Therefore, the District believes that investigations (sampling) to document the occurrence and abundance of sub-adult fish and invertebrates during disposal operations is not warranted.

Page 11. Section C.2.46. Neither the Corps nor resource agencies are aware of any hard-bottom communities existing in the nearshore areas proposed for deposition. However, a side-scan sonar investigation and a benthic survey would be conducted at all new nearshore areas prior to initial placement of dredged material to ensure that highly productive and ecologically valuable benthic communities are not eliminated.

Pages 13 and 14, Sections C.2.56 and C.2.57. The District continues to believe that the proposed work will not significantly and adversely affect benthic resources. That determination is based on a "reason to believe" rather than being "proven" through documentation and evaluation of previous actions at the same location. The District is aware of no information which indicates either (1) that unique or sensitive benthic resources are present in the potential impact area, or (2) that impacts likely to occur from open-water placement would significantly affect those resources beyond the local and temporary levels. Neither the Corps nor Georgia Department of Natural Resources is aware of any hard-bottom communities existing in the nearshore areas proposed for deposition. However, a side-scan sonar investigation and a benthic survey would be conducted at all new nearshore areas prior to initial placement of dredged material to ensure that highly productive and ecologically valuable benthic communities are not eliminated.

Pages 14, Section C.2.60. Resource agencies, including the NMFS, were reconsulted to identify sites within the project area which could be used for wetland restoration/creation purposes. As before, no sites of sufficient size could be identified in the project vicinity. The SC OCRM will restore/create/protect 25 acres of tidal wetlands as in-kind mitigation.

Appendix G

Page 3. Section G.2.08. Creation of an isolated island in the nearshore area would establish a habitat that is very rare in the project vicinity. Such habitat would be valuable for migratory birds, threatened and endangered species (piping plover and loggerhead sea turtles, and resident shorebirds. The US FWS and State resource agencies agreed that filling submerged estuarine bottom to create such habitat was desirable.

Pages 3 and 4. Sections G.2.09 and G.2.10. The NMFS was informed by the Corps and the US FWS of the plans the District was developing to mitigate for losses which would occur when Disposal Area 14A is used. The revised Mitigation Plan has two components -- the 25 acres of restoration/creation/protection of tidal wetlands to be administered by the SC OCRM and the water control structure for the 228-acre impoundment at the Savannah National Wildlife Refuge -- which would benefit fishery and other living marine resources.



UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
 NATIONAL MARINE FISHERIES SERVICE

Southeast Regional Office
 9721 Executive Center Drive N.
 St. Petersburg, Florida 33702

October 18, 1995

Colonel Grant M. Smith
 District Engineer, Savannah District
 Department of the Army, Corps of Engineers
 P.O. Box 889
 Savannah, Georgia 31402-0889

Dear Colonel Smith:

The National Marine Fisheries Service (NMFS) has reviewed the revised draft Mitigation Plan for Diking and Use of Disposal Area 14A (Plan). The Plan was provided to our Charleston Branch Office via facsimile dated September 25, 1995, from Mr. Bill Bailey of your staff. When finalized, it will become a component of the Savannah District's Long Term Maintenance Strategy Study for Lower Savannah Harbor, Chatham County, Georgia and Jasper County, South Carolina.

The Plan adequately addresses issues raised by the NMFS for mitigating adverse impacts to living marine resources. If implemented, fishery-related provisions would result in restoration of periodic (daily) tidal flow within a 228-acre impoundment located on the Savannah National Wildlife Refuge. The impoundment is presently managed so that periodic hydrologic connections with adjacent tidal waters are largely non-existent. Water management is limited to operation of a single control structure and management includes occasional flooding of impounded wetlands, extended water retention, and limited or complete drawdown prior to reflooding. Under the proposed plan of action, a second water control structure would be added and this structure would be operated to allow daily tidal exchange.

As discussed with Mr. Bailey, the Plan has considerable merit and its suitability for mitigation purposes will depend on the design and operation of the new water control structure. Accordingly, we are in general agreement with the proposed action. However, agreement regarding its technical and operational components are needed for conclusive determination that adverse impacts involving our trust resources will be sufficiently offset. In this regard, and in consideration of the fast track for completion of the Final Environmental Impact Statement for the project, I encourage prompt agreement on these key issues. To attain this, I request that the Savannah District initiate timely dialogue with my Charleston Branch Office, the U.S. Fish and Wildlife Service, and representatives from the South Carolina and Georgia natural resource agencies. With satisfactory progress, we can support the Savannah District's positive assessment regarding project related-fishery impacts.



With regard to other fishery-related components of the Plan, we are withholding judgement concerning proposed establishment of an escrow account to be used for tidal wetland restoration in South Carolina. Based on a cursory discussion with South Carolina Department of Health and Environmental Control personnel, it appears that general agreement regarding this matter has been reached and we look forward to reviewing the details of this agreement. We also maintain our desire to coordinate with Georgia State Ports Authority (GASPA) concerning possible fishery enhancement efforts in conjunction with shoreline stabilization work in the vicinity of existing disposal sites. This matter was discussed in considerable detail at a recent project meeting which included the GASPA and State and Federal agency representatives.

We appreciate the excellent work by your by your staff in addressing matters pertaining to fishery resource conservation. Please direct related questions or comments to the attention of David Rackley at our Charleston Branch Office. He may be reached at (803) 762-8574.

Sincerely,

A handwritten signature in dark ink, appearing to read 'Andreas Mager, Jr.', with a stylized flourish at the end.

Andreas Mager, Jr.
Assistant Regional Director
Habitat Conservation Division

RESPONSE -- NOAA, National Marine Fisheries Service,
Southeast Regional Office,
Habitat Conservation Division,
October 18, 1995.

ACCEPTABILITY OF REVISED MITIGATION PLAN. The District concurs that the revised Plan adequately addresses adverse impacts to marine resources.

ESCROW ACCOUNT FOR TIDAL WETLAND RESTORATION. The District will provide the NMFS with a copy of the agreement with the SC DHEC-OCRM for review when it is available.

SHORELINE STABILIZATION WORK. The District will coordinate with the NMFS when designs have been prepared for proposed shoreline stabilization work along the dike on Jones/Oysterbed Island.



UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
 NATIONAL MARINE FISHERIES SERVICE
 Southeast Regional Office
 9721 Executive Center Drive
 St. Petersburg, FL 33702

AUG 23 1995

F/SEO13-JEB

Mr. William Bailey
 Savannah District
 U.S. Army Corps of Engineers
 P. O. Box 889, Attn: CESAS-PD-EI
 Savannah, GA 31402-0889

Dear Mr. Bailey:

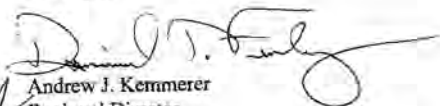
This responds to your request for comments on the November 1994 draft environmental impact statement (DEIS) for the Savannah Harbor Long Term Management Study. You also requested that the National Marine Fisheries Service concur with your determination that the long term management plan would not adversely affect threatened or endangered species under our jurisdiction. A biological assessment (BA), in the form of the DEIS was submitted pursuant to Section 7 of the Endangered Species Act of 1993 (ESA).

We have reviewed the BA and the information on pipeline dredge suction field strength supplied in your July 26, 1995 facsimile transmission. We concur with your determination that populations of threatened or endangered species under our purview would not be adversely affected by the proposed action. This concurrence assumes that the Corps of Engineers will carry out activities in accordance with the existing biological opinion addressing dredging activities along the southeast coast of the United States and any other applicable biological opinions that may be issued in the future.

This concludes consultation responsibilities under Section 7 of the ESA. However, consultation should be reinitiated if new information reveals impacts of the identified activity that may affect listed species or their critical habitat, a new species is listed, the identified activity is subsequently modified, or critical habitat is determined that may be affected by the proposed activity.

If you have any questions please contact Jeffrey Brown, Fishery Biologist, at (813) 570-5312.

Sincerely,


 Andrew J. Kemmerer
 Regional Director

cc: F/PR8
 F/SEO2



Printed on Recycled Paper



RESPONSE -- NOAA, National Marine Fisheries Service,
Southeast Regional Office,
Protected Species Management Branch,
August 23, 1995.

No response necessary to NMFS concurrence with Savannah
District's determination that the proposed LTMS actions would not
adversely affect threatened or endangered species under the
jurisdiction of the NMFS.



4130 Faber Place, Suite 300
Charleston, SC 29405

Commissioner: Douglas E. Bryant

Board: Richard E. Jabbour, DQS, Chairman
Robert J. Stripling, Jr., Vice Chairman
Sandra J. Molander, Secretary

Promoting Health, Protecting the Environment

John H. Burris
William M. Hull, Jr., MD
Roger Leaks, Jr.
Burnet R. Maybank, III

Office of Ocean and Coastal Resource Management

H. Wayne Beam, Ph.D., Deputy Commissioner

Christopher L. Brooks, Assistant Deputy Commissioner

(803) 744-5838

(803) 744-5847

January 20, 1995

Mr. Myron J. Yuschishin
Chief, Planning Division
U. S. Army Corps of Engineers
Savannah District
Post Office Box 889
Savannah, Georgia 31402-0889

Dear Mr. Yuschishin:

This letter is written in response to your request for consistency determination regarding the proposed Savannah Harbor Long Term Maintenance Strategy (LTMS). Under the Authority of 15:CFR 930.39, the staff of the Office of Ocean and Coastal Resource Management (OCRM) has received the document and determined that it is not consistent with the South Carolina Coastal Zone Management Program. The strategy does make several improvements which are needed; and while the OCRM applauds the District's efforts to resolve these issues, we continue to have problems with several of the plan's recommendations. We approve of the comprehensive planning methods that have been used to prepare the study and think that the plan well documents the problems and proposes some good solutions for the management of the harbor. There are specifically several individual elements which are not consistent with our management program. These could be made consistent with the provision of additional information or revising the management considerations listed in the study. These items are:

A) The mitigation plan submitted for the diking of area 14A is inadequate, as proposed. In 1982 the S.C. Coastal Council designated a line where the dike could be placed. However, the final construction design and permitting issues were not resolved at that time. The LTMS does not adequately address the wetland habitat resources and functional values that will be lost by this diking. While the Council has approved an alignment, this mitigation issue must be addressed. The report fully describes a wetland creation mitigation package for area 2A but fails to recognize or replace wetlands lost in the constructing and the diking of area 14A. Instead, the plan proposes as mitigation a wildlife management scheme for all of the dike disposal areas. Partial mitigation credit for wildlife management activities can be awarded; however, the acreage of wetlands lost by the dike must be replaced by a form of mitigation approved by the OCRM. In 1993 the OCRM (formerly the S. C. Coastal Council) amended the Coastal Zone Management

Mr. Myron J. Yuschishin
January 20, 1995

Page 2

Program to specify acceptable forms of mitigation and the procedures for constructing these mitigation efforts. The mitigation plan does not meet these requirements. (A copy of these regulations is provided.)

B) The creation of an offshore bird island as a mitigation measure is at this time inconsistent with the Coastal Zone Management Program. The OCRM might be able to approve creation of this type of habitat if a need is documented by the U. S. Fish and Wildlife Service and the S.C. Department of Natural Resources based upon the thorough and complete evaluation. This finding of need must be fully documented and the island sized to accommodate the affected wildlife population, and only large enough to accommodate that population. Replacement of one type of habitat (uplands) for another (open water bottoms) must be thoroughly considered and evaluated when a project is designed. The S. C. Coastal Zone Management Program policies concerning dredged material disposal presently discourage the use of open water spoil disposal. Those policies are listed below:

"VIII. Dredging

B. Dredged Material Disposal

2) In critical areas of the coastal zone, it is Council policy that:

a) Upland disposal of dredged material should always be sought in preference to disposal in wetlands. Where upland disposal is not possible, areas of relatively low productivity above mean high water mark should be utilized. Highly productive wetland areas or bottoms situated below the mean high water mark should not be utilized for disposal of dredged materials when other alternatives exist;

b) Open water and deep water disposal should be considered as an alternative if highland alternatives are not feasible. However, open and deep water disposal sites should be seriously considered only after careful consultation with the Council and other relevant State and Federal agencies;

c) Toxic and highly organic materials should be disposed of in highland areas behind impervious dikes;

d) Dikes surrounding disposal areas should be shaped and vegetated immediately to minimize erosion, with outfalls positioned to empty into non-wetland areas;

e) Future disposal sites shall be reviewed on a case-by-case basis;

f) Existing disposal areas should be utilized to the fullest extent possible; this utilization would include raising the height of the embankment to increase the holding capacity of the disposal area;

g) In evaluating potential sites for dredged material disposal, attention must be given to possible adverse impacts on public health

Mr. Myron J. Yuschishin
January 20, 1995

Page 3

and welfare as well as on critical fish and wildlife areas such as endangered species habitats, waterfowl wintering areas, and shellfish harvesting areas." [R. 30-12(l)]

The Council also recommends that the following policies be considered in planning for dredged material disposal:

a) Consideration for future maintenance of the spoil area, for example, development of spoil islands which have been found to be beneficial for terrestrial habitat and migratory waterfowl.

b) Abandoned sand or gravel pits in proximity to a dredge site, where spoil can be more adequately contained, should be used for disposal areas."

(S.C. Coastal Management Program, p. III-57)

C) With regard to the relocation of the underdrains to the Savannah/Back River side of the disposal areas, the OCRM supports this action. However, the report states that a mixing zone will be used to dilute levels of arsenic which do not meet South Carolina water quality standards. While South Carolina standards allow mixing zones, there must be a demonstration of no adverse effects on existing water uses. Because, in this situation, arsenic violates the human health standard which is based on the consumption of aquatic organisms, we recommend that the level of arsenic be reduced inside of the disposal site before release.

D) The report also notes that dissolved oxygen (D. O.) levels can be a problem, particularly in small creeks. As noted in the report many of the outfalls from the spoil areas do discharge into small creeks. The report proposes monitoring and management measures as a solution to this problem. We feel management measures are a solution but feel that the use of monitoring should be used to determine if a release should be allowed rather than use a weekly monitoring report to determine if the discharge should be allowed to continue. A release should not be allowed to begin if D. O. readings are below state water quality standards. The plan should be amended to reflect this management procedure.

E) The OCRM supports the efforts by the District to reduce the agitation dredging from the waters adjacent to private piers. However, we feel that with the provision of hydraulic dredging and disposal in the dike-contained areas, the practice of allowing agitation dredging should be completely prohibited. Several previous studies cited in the LTMS have documented D. O., turbidity and other problems with agitation dredging. It has long been our stated opinion that this practice should be prohibited. The LTMS seems to support this position but fails to address the problem. Agitation should be stopped rather than allowed to continue under a litany of unenforceable permit conditions.

F) The report indicates that one option for dredged material disposal would be to renourish Daufuskie Island beaches. We support this concept provided that all material

Mr. Myron J. Yuschishin
 January 20, 1995

Page 4

is of beach compatible grain size and the disposal is based upon a sound engineering plan to renourish the beach face rather than to simply remove the spoil material. However, please be aware that in order to use state funds for beachfront activities the entire beach receiving renourishment must be accessible to the public. Only a section of Daufuskie presently meets this definition (approximately 1/2 mile). The state participation in any funding arrangement for this project may be limited by this restriction.

The OCRM appreciates being able to provide these comments. In this letter I have tried to be specific as to what steps can be taken to make the LTMS consistent with our management program. We have enjoyed our working relationship with the District staff in the past and feel that these issues can be resolved with cooperation by all parties. Pursuant to 15 C.F.R. 930.110, secretarial mediation through the Secretary of Commerce may be utilized to resolve conflicting issues. If you desire to pursue mediation please contact me so that we may coordinate. We will be glad to pursue a resolution through either formal or informal mediation.

Sincerely,



Robert D. Mikell
 Director of Planning
 and Federal Certification

RDM:^{JW}uscomit2:g:jk

cc: Dr. H. Wayne Beam
 Mr. Christopher L. Brooks
 Mr. H. Stephen Snyder
 Ms. Sally Knowles
 Ms. Jane Settle
 Ms. Joelle Gore

RESPONSE -- SC Department of Health and Environmental Control,
Office of Ocean and Coastal Resource Management,
January 20, 1995.

MITIGATION PLAN FOR DISPOSAL AREA 14A. A revised Mitigation Plan was prepared and provided to the SC OCRM in July 1995. After a meeting with SC DHEC-OCRM staff in September 1995, the Plan was revised to include 25 acres of wetland restoration or creation as in-kind mitigation to address their concerns. As a result of the recent coordination, the District believes the Mitigation Plan contained in the Final EIS satisfies all mitigation concerns of the SC DHEC-OCRM.

NEARSHORE BIRD ISLAND. As in the Draft EIS, the Final EIS contains a nearshore bird island as a mitigation feature. The need for such habitat was documented in the EIS and is supported by the US FWS and the SC DNR. Isolated islands along the coast have become increasingly rare as development has occurred. As the SC DHEC-OCRM policies acknowledge, such islands have been found to be beneficial to shorebirds and migratory waterfowl. The island's size was selected based on a combination of the mitigation need and the technical aspects of the value of such habitats when constructed at other locations. The District will perform a benthic survey of the site where the island would be constructed to ensure highly productive hard bottom communities are not present. Recent coordination with SC DHEC-OCRM staff indicates that SC DHEC-OCRM now approves of this mitigation feature.

UNDERDRAINS. Savannah District met with the South Carolina DHEC and discussed this issue. The District will abide by the mixing zone and/or design parameters specified for the underdrains in the Water Quality Certification provided by the South Carolina DHEC.

DISSOLVED OXYGEN IN WEIR DISCHARGES. The District met with the South Carolina DHEC and discussed this issue. Data previously taken by Savannah District was provided to SC DHEC which documented that previous discharges which were below state water quality standards did not adversely affect the use of Wright River, the major receiving water. Savannah District will abide by the Water Quality Certification provided by the South Carolina DHEC.

AGITATION DREDGING. Implementation of the rotational use of the CDFs will result in a disposal area being available within a reasonable distance for use by berth owners. This will increase the economic feasibility of deposition of berth sediments in confined disposal areas. The deepening of berth areas to create off-channel sediment storage would reduce the need for agitation

dredging since adequate depths would be available at the berths for longer durations. Due to the high shoaling rate at the berths, circumstances may still arise where a hydraulic dredge cannot be used -- such as the March to June striped bass window -- when removal of sediments is necessary. Agitation dredging may serve as a viable option for those instances.

DIRECT PLACEMENT ON DAUFUSKIE ISLAND. Savannah District will consider direct placement of channel sediments on Daufuskie Island if (1) the material is determined suitable, and (2) an organization paid the additional incremental cost for such placement. The District will continue to work with the SC DHEC-OCRM to identify when such placement may be appropriate.



Commissioner: Douglas E. Bryant

Board: John H. Burrias, Chairman
Sandra J. Molander, Secretary

Promoting Health, Protecting the Environment

Richard E. Jabbour, DDS,
William M. Hull, Jr., MD
Roger Laska, Jr.

Office of Ocean and Coastal Resource Management

H. Wayne Beam, Ph.D., Deputy Commissioner

Christopher L. Brooks, Assistant Deputy Commissioner

(803) 744-5838

(803) 744-5847 (fax)

January 8, 1996

Mr. M. J. Yuschishin
Chief, Planning Division
U. S. Department of the Army
Savannah District, Corps of Engineers
Post Office Box 889
Savannah, Georgia 31402-0889

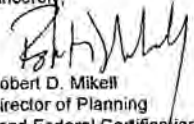
Re: Savannah Harbor Long Term
Management Strategy (LTMS)
Final Certification

Dear Mr. Yuschishin:

As you are aware, we have been working with your staff on the consistency determination for this document for several years. As a result of the revisions and clarifications made to the final draft document, our remaining concerns have been addressed. DHEC OCRM is now prepared to find this project consistent with the policies of the South Carolina Coastal Zone Management Program.

Should you have any questions on this matter please contact me.

Sincerely,


Robert D. Mikell
Director of Planning
and Federal Certification

cc: Dr. H. Wayne Beam
Mr. Christopher L. Brooks
Mr. H. Stephen Snyder
Mr. Tom Bolin
Ms. Rheta Geddings

RESPONSE -- SC Department of Health and Environmental Control,
Office of Ocean and Coastal Resource Management,
January 8, 1996,

CONSISTENCY DETERMINATION. The District is pleased that the
proposed project was found fully consistent with the policies of
the SC Coastal Zone Management Program.



Commissioner: Douglas E. Bryant

Board: Richard E. Jabbour, DDS, Chairman
Robert J. Stripling, Jr., Vice Chairman
Sandra J. Molander, Secretary

John M. Burris
William M. Hull, Jr., MD
Roger Leaks, Jr.
Burnet R. Maybank, III

Promoting Health, Protecting the Environment

January 4, 1995

Department of the Army
Savannah District, Corps of Engineers
Attn: Richard A. Hill, Acting Chief
Planning Division
P.O. Box 889
Savannah, GA 31402-0889

Dear Mr. Hill:

I am writing in response to your letter dated November 30, 1994, in which you requested comments regarding the Long Term Management Strategy (LTMS) Study for the Savannah Harbor Navigation Project, Chatham County Georgia, and Jasper County, South Carolina. You requested that our review of the enclosed Draft Environmental Impact Statement for this project include compliance of the tentatively selected plan with Section 401 of the Clean Water Act.

The Bureau of Water Pollution Control is currently evaluating the above referenced project as part of the technical review process for Water Quality Certification in accordance with Section 401 of the Clean Water Act, as amended. We will provide all comments to you in the Water Quality Certification and not comment separately on the Draft Environmental Impact Statement.

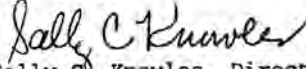
The Water Quality Certification process is governed by State Regulation 61-101. This process requires preparation of a written staff assessment evaluating potential effects of the proposed work on water quality. Written comments by interested parties will be considered in the review. This project will be certified if it is determined that there is a reasonable assurance that the proposed project will be conducted in a manner consistent with the Certification requirements, and is consistent with applicable provisions of Section 303 of the Federal Clean Water Act, as amended. It must also be determined that there are no applicable effluent limitations under Sections 301(b) and 302, and that there are no applicable standards under Sections 306 and 307.

Since the public comment period for this project has passed, we will complete our staff assessment as soon as possible. After the project review is complete, a Notice of Proposed Decision will be issued, including any proposed conditions. All aggrieved parties shall have rights to appeal the proposed decision by submitting a written request for an adjudicatory hearing before the Department within 15 days of notification of proposed certification.

Page 2
Richard Hill
January 4, 1994

If you have any questions please feel free to call Mark Giffin at
(803)-734-5302.

Sincerely,

A handwritten signature in cursive script that reads "Sally C. Knowles".

Sally C. Knowles, Director
Water Quality Division

RESPONSE -- SC Department of Natural Resources,
Bureau of Water Pollution Control,
Water Quality Division,
January 4, 1995.

No response necessary.



Commissioner: Douglas E. Bryant

Board: John H. Burris, Chairman
William M. Hull, Jr., MD, Vice Chairman
Roger Leaks, Jr., Secretary

Promoting Health, Protecting the Environment

Richard E. Jabbour, DDS
Cyndi C. Mosteller
Brian K. Smith
Rodney L. Grandy

May 10, 1996

Department of the Army, Savannah District, Corps of Engineers
Attn: Mr. William G. Bailey
P.O. Box 889
Savannah, GA 31402-0889

Re: Certification in Accordance with Section 401 of the
Clean Water Act, as amended.

Department of the Army, Savannah District, Corps of Engineers
Savannah Harbor Long Term Management Strategy
Savannah River, Back River, and Wright River
Jasper County
DHEC-94-C-SAV

Dear Mr. Bailey:

The Department issued a Notice Of Proposed Decision to issue a 401 Water Quality Certification for the project on October 27, 1995. James F. Missroon appealed this decision on November 7, 1995. The Department received an Order of Dismissal from Alison Renee Lee, Administrative Law Judge, on May 6, 1996, stating that Mr. Missroon has withdrawn his request for a hearing.

We have reviewed plans for this project and determined there is a reasonable assurance that the proposed project will be conducted in a manner consistent with the Certification requirements of Section 401 of the Federal Clean Water Act, as amended. In accordance with the provisions of Section 401, we certify that this project, subject to the indicated conditions, is consistent with applicable provisions of Section 303 of the Federal Clean Water Act, as amended. We also hereby certify that there are no applicable effluent limitations under Sections 301(b) and 302, and that there are no applicable standards under Sections 306 and 307.

This certification is subject to the following conditions:

1. To insure water quality standards are maintained, the Division of Water Quality and Shellfish Sanitation must be notified and any alternate disposal site must be reviewed and approved prior to its use if the proposed disposal areas can not be utilized by the COE or the GDOT.
2. The applicant must implement a water quality monitoring plan to insure that the effluent is in compliance with state water quality standards and to coordinate with the Department if any discharge is violating any state water quality criteria, as proposed. The applicant must conduct monitoring in accordance with an approved sampling plan specifying the location of sampling stations, parameters sampled, when samples will be collected, and how the sampling data will be reported.

Page 2
DHEC-94-C-SAV
May 10, 1996

Appropriate ambient data from the Wright River must also be submitted.

3. The applicant must install flap gates at underdrain discharge points so that so that no effluent is discharged during low flow periods in receiving waters.
4. The applicant must monitor water quality 100 feet downstream of underdrain discharges to test for water quality standards compliance, as proposed. In addition, the applicant must conduct monitoring in accordance with an approved sampling plan specifying the location of sampling stations, parameters sampled, when samples will be collected, and how the sampling data will be reported.
5. The applicant must adhere/comply with recommendations of the SCDNR regarding the timing of placing dredged material for beach nourishment to insure continued protection of various species of sea turtles.
6. The applicant must provide compensatory mitigation for wetlands impacts associated with the proposed work. All wetlands impacts must be compensated for on at least a 1:1 basis. If the mitigation includes creation, restoration, or enhancement, the plan must include monitoring. This mitigation plan must be submitted to the Water Quality Division for review and approval within 6 months of 404 permit issuance.

The S. C. Department of Health and Environmental Control reserves the right to impose additional conditions on this Certification to respond to unforeseen, specific problems that might arise and to take any enforcement action necessary to ensure compliance with State water quality standards.

Sincerely,



Sally C. Knowles, Director
Division of Water Quality
and Shellfish Sanitation
Bureau of Water Pollution Control

SCK:MAG

cc: Army Corps of Engineers,
Charleston District
Low Country District Office

RESPONSE -- SC Department of Natural Resources,
Bureau of Water Pollution Control,
Water Quality Division,
May 10, 1996.

WATER QUALITY CERTIFICATION.

This letter provides Water Quality Certification from the State of South Carolina for the Savannah Harbor LTMS. Savannah District intends to fully comply with all conditions contained in this certification. Condition 2 requires a water quality monitoring plan be submitted to the SC DHEC for approval within 6 months. The District believes it can reach agreement with the SC DHEC on an appropriate monitoring plan. Condition 6 requires a mitigation plan be submitted to the SC DHEC for approval within 6 months. The District intends to resubmit the Mitigation Plan contained in this EIS to the SC DHEC. The SC DHEC-OCRM, which is responsible for management of all South Carolina coastal resources, has approved the Mitigation Plan.

South Carolina Department of Natural Resources



James A. Timmerman, Jr., Ph.D.
Director

January 20, 1995

Mr. William Bailey
U.S. Army Engineer District, Savannah
P.O. Box 889, ATTN: CESAS-PD-EI
Savannah, GA 31402-0889

RE: Draft Environmental Impact State-
ment (EIS), Savannah Harbor Long
Term Maintenance Strategy (LTMS)

Dear Mr. Bailey:

Personnel of the S.C. Department of Natural Resources have reviewed the above referenced EIS and offer the following comments.

In general, it appears that the Long Term Maintenance Strategy (LTMS) has been thoroughly researched and addresses some of the problems which have been identified in the past in the Savannah Harbor system. Aspects of the strategy such as the removal of underdrains from the Wright River, the diking of Area 14A, and the proposals for better management of the Confined Disposal Facilities (CDF's) to enhance various aspects of bird use represent very positive considerations for the S.C. Department of Natural Resources (SCDNR). There are, however, some concerns which remain. These are addressed below in the order in which they appear in the Draft EIS.

Paragraph 2.05 (p. 13) identifies the natural resources of the Savannah Harbor. In our opinion, the listing presented is quite limited. Other natural resources which should be included are birds, threatened species, estuarine species of commercial and recreational importance.

Paragraph 3.10 (p.22) - The last statement regarding the increased cost of maintaining adequate depths in the Harbor as a result of the closure of New Cut and the removal of the Tide Gate from operation should have some documentation.

In paragraph 3.34 (p. 36), the "environmental documents which have already been prepared" to which the local sponsor will be required to adhere should be specified.

Paragraph 3.38 (p. 38) - The Wright River study summary is located in Appendix E, not Appendix N.

Rembert C. Dennis Building • 1000 Assembly St • P.O. Box 167 • Columbia, S.C. 29202 • Telephone: 803/734-4007

EQUAL OPPORTUNITY AGENCY

PRINTED ON RECYCLED PAPER 

Page 2, William Bailey, January 20, 1995

Paragraph 4.31 (p. 50) - Both of the assumptions included herein regarding threatened or endangered species may be appropriate. However, it is neither a foregone conclusion that no additional species will be listed as threatened or endangered or that no additional protective restrictive would be placed on actions which may impact species which are presently listed and, therefore, are already receiving protection. Additional information on the status of stocks of a given species is always a condition under which Section 7 consultations and negotiations can be reopened and would be the case here as well. This must be recognized.

Paragraphs 5.27 and 5.35 (pp. 71 and 73) - While side-scan sonar is an appropriate technology to determine the likelihood of the presence of hard-bottom communities, additional confirmation by underwater television provides a much more accurate portrayal of the bottom conditions. This technology should be incorporated as well, if possible, for these efforts.

Paragraph 5.48 (p. 78) - While the proposed deepening of the Sediment Basin is desirable from the standpoint of increasing its sediment detention capacity, it is of some concern to us given the data which has been generated regarding dissolved oxygen (DO) conditions at and near the bottom of it in its current configuration. A primary species of concern here is the striped bass (Morone saxatilis). Input from the U.S. Fish and Wildlife Service (FWS) and the Georgia Department of Natural Resources (GADNR) should be utilized in the determining the appropriateness of this aspect of the LTMS.

Paragraph 5.69 (p. 90) and other locations - Mitigation actions. Personnel of our Wildlife Diversity Division (formerly the Nongame and Endangered Species Division) were consulted in the development of the avian aspects of the mitigation plan for input. While the overall plan certainly represents a great enhancement of habitat for bird use in the Savannah Harbor area, there are several concerns which must be resolved. Of primary importance is an issue which has been discussed previously, that of contaminant levels in these confined disposal facilities (CDF's) and their potential impacts on avian life. Our review of Appendix F - Sediment Quality Evaluation does indicate that the likelihood of impacts to biota is limited. However, the proposed management techniques of enhancing avian feeding in these CDF's or the construction of bird islands in them, modified mowing of dike slopes, etc., to enhance the nesting of several species in and adjacent to them does raise the concern what is actually occurring or may occur at a particular location. Some bioassay work with avian species already utilizing these areas would better enable these uncertainties to be resolved. We would like to discuss this further to determine the details of what is needed to address this concern. Also, a monitoring program to evaluate various aspects of the success of this management technique should accompany this part of the proposed mitigation.

Page 3, William Bailey, January 20, 1995

Paragraph 6.23 (p. 110) - Mitigation Areas and paragraph 7.73 (p. 175). The first assumption in paragraph 6.23 and the discussion in paragraph 7.73 relates to the unavailability of sites which could be used for wetland mitigation, i.e., in-kind mitigation for lost wetland habitat values from dike placement, warrants further documentation. While this is likely to be the case, if there are any areas available which could be used for even partial mitigation for wetland losses, they should be considered. Even though the need exists for the enhancement of avian feeding and nesting habitat, it is our policy to seek in-kind replacement of habitat whenever possible. The values lost by the filling of wetlands are not replaced by the enhancement of bird use of these CDF's. We do agree that the filling of shallow subtidal areas to create intertidal wetlands is not an option which should be considered.

Paragraph 6.27 (p. 111) - Hazardous and Toxic Wastes. The Amazon Venture oil spill occurred on December 4, 1986.

Paragraph 6.28 (p. 111) - Water Quality. The information regarding South Carolina's classification of the Savannah River is incomplete. While that portion from Fort Pulaski to the Atlantic Ocean is classified as Class SA, the portion from the Seaboard Coastline RR to Fort Pulaski is classified as Class SB, and that portion from the headwaters of Lake Russell to the Seaboard Coastline RR is Class FW. The classification system was modified in 1991 and 1992 and this information is included in the manual published by SCDHEC entitled Water Classifications and Standards, Regulation 61-68 (includes all amendments through April 24, 1992).

Paragraph 7.05 (p. 153) - The statement that "Since the precautions to be observed in each of the detailed alternatives would result in construction occurring which does not harm either individual protected animals, fish etc., or their habitat, no plan would produce unacceptable adverse environmental impacts to threatened or endangered species," is not necessarily completely correct. As one example, it is entirely possible that a shortnose sturgeon (Acipenser brevirostris) could be harmed by dredging activities in turning basins as radio-tagged individuals have been documented to utilize these areas. Also, given this, the habitat which these individuals used would certainly be at least temporarily modified by dredging operations. While we understand that all possible precautions to avoid and/or minimize such impacts will be taken, it must be considered that some may occur.

Paragraph 7.30 (p. 161) - The DO problems in weir effluents which have been documented in the past should not be allowed to continue. We do not feel that the management measures which are proposed are adequate to address this issue. DO monitoring which is sufficient to prevent a release which would contravene either South Carolina or Georgia Water Quality Standards should be incorporated into the LTMS rather than management measures to determine whether a release should be allowed to continue.

Page 4, William Bailey, January 20, 1995

Paragraph 7.34 (p. 163) - The proposal to incorporate a 100-foot mixing zone at each of the underdrains from CDF's to enable arsenic levels to come into compliance with Water Quality Standards is unacceptable. Given that acute toxicity to estuarine organisms from these discharges has been demonstrated, other means of reducing this toxicity must be developed.

Paragraph 7.76 (p. 176) - Creating Nesting Islands. If the contaminants issues are satisfactorily resolved, these islands should be sized to provide 3 acres of area suitable for nesting to increase their likelihood of success.

Paragraph 7.79 (p. 177) - Slow Release of Ponded Water. This proposed management technique is dependent on rainfall and is, therefore, not a "sure thing". Limited credit for habitat enhancement can be given here.

Paragraph 7.81 (p. 178) - Construction of an Offshore Bird Island. It is our understanding that the need for this aspect of the proposed LTMS is based upon loss of similar habitat for shorebird nesting when the diking of Jones/Oysterbed Island enable predator access to a former shorebird nesting area, which was thus eliminated (Tom Murphy, personal communication). This needs to be documented better in the LTMS. Also, if this management technique is implemented, there is some concern regarding the high percentage of fine-grained sediments (50%) which is assumed to be lost during the construction process. This is not consistent with the higher percentages of sands indicated elsewhere in the LTMS to comprise the proposed source areas for this work.

Paragraph 7.150 (p.214) - The last portion of this paragraph addresses the means by which success of the proposed offshore nesting island would be measured. While we agree that predictions of the number of birds expected to nest on the island in different years would be speculative, this is, nonetheless, one of the measures of success. Additionally, with information regarding size, vegetation type, etc., it can be done with a greater degree of certainty than is indicated here. This should be done and included in the document.

Paragraph 7.152 (p. 215) through 7.166 (p.220) - berms and direct beach placement of sediments. While the specific locations of the proposed berms are in coastal Georgia waters, the quality of coastal South Carolina waters could be affected by this proposed activity. Related to both berm placement and direct beach placement is the aspect of turbidity. Only the locations with the highest percentages of coarse sediments should be used as sources for these proposed activities. Also, timing restrictions should be included for the protection of the various species of sea turtles known to inhabit the coastal waters of Georgia and South Carolina during the months of May through October.

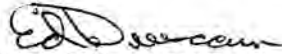
Page 5, William Bailey, January 20, 1995

It was not possible for us to adequately evaluate and provide input regarding the scoring process for the various alternatives which was used in the LTMS. No criteria were indicated on which the scores were based. Without these, the scheme seems to be very subjective and one which would result in very different scores for the same alternative when evaluated by different individuals. Therefore, its use is questionable.

Appendix E. Results of Wright River Weir Effluent and Sediment Testing. It would be helpful to the reviewer to have a map of sampling locations included.

We appreciate the opportunity to provide input into this planning process. We look forward to discussing our concerns and working toward their resolution. Please contact the SCDNR Project Manager for this project, Jane Settle (803-762-5068) for further information.

Sincerely,



Robert E. Duncan
Environmental Programs Director

cc: Jane Settle, SCDNR
Tom Murphy, SCDNR
Rob Mikell, OCRM
Sally Knowles, SCDHEC
Ed EuDaly, USFWS

RESPONSE -- SC Department of Natural Resources,
January 20, 1995.

Paragraph 2.05 (p. 13). Concur.

Paragraph 3.10 (p. 22). Savannah District has published no formal report on the increased cost of maintaining adequate depths in the Harbor as a result of the closure of New Cut and the removal of the Tidegate from operation. The documentation consists of internal District documents and information used for budget defense. However, the Operations & Maintenance budget now has a separate line item titled "Additional Dredging Cost Due To Keeping The Tidegate Open."

Paragraph 3.34 (p. 36). The Federal "environmental documents which have already been prepared" were listed in Section 2.15 and 2.19. Other documents would consist of those prepared as part of the permit process for non-federal construction actions.

Paragraph 3.38 (p. 38). Concur.

Paragraph 4.31 (p. 50). Concur.

Paragraphs 5.27 and 5.35 (pp. 71 and 73). Savannah District believes that underwater television would not be a useful technique to document the bottom conditions in this project area due to the highly turbid water which restrict visual observations to just a few feet. The District will conduct benthic sampling to document benthic communities in the affected areas.

Paragraph 5.48 (p. 78). The views of the US FWS and the Georgia Department of Natural Resources will be used in the determining the appropriateness of the proposed advance maintenance of the Sediment Basin.

Paragraph 5.69 (p. 90) and other locations - Mitigation actions. Chemical testing will be performed of sediments within the CDFs to confirm that contaminants do not exist at levels which would produce adverse impacts on wildlife using the sites. Monitoring of the District's compliance with its commitments and applicable laws is a normal part of daily operations. Since the basis of the proposed Mitigation Plan is the provision of certain types and amounts of various habitats, rather than development of certain types and amounts of various fish and wildlife usage, the success of the proposed Plan will be determined by the successful construction and subsequent maintenance of the habitats specified in the Plan.

Paragraph 6.23 (p. 110) - Mitigation Areas and paragraph 7.73 (p. 175). Resource agencies were reconsulted for identification of sites which could be used for wetland mitigation, i.e., in-kind mitigation. No agency suggested any potential sites of suitable size within the project area. The revised Mitigation Plan includes in-kind mitigation through the restoration/creation/protection of 25 acres of tidal wetlands, through an escrow account administered by the SC DHEC-OCRM.

Paragraph 6.27 (p. 111) - Hazardous and Toxic Wastes. Concur.

Paragraph 6.28 (p. 111) - Water Quality. Concur. This section of the EIS was revised.

Paragraph 7.05 (p. 153). Concur. The Biological Assessment of Threatened and Endangered Species (BATES) evaluates the effects of the proposed actions on protected species and their habitat. This section was revised to incorporate the SC DNR comment.

Paragraph 7.30 (p. 161). - Dissolved Oxygen Levels In Weir Discharges. The District met with the South Carolina DHEC and discussed this issue. Data previously taken by Savannah District was provided to SC DHEC which documented that previous discharges which were below state water quality standards did not adversely affect the use of Wright River, the major receiving water. Savannah District will abide by the Water Quality Certification provided by the South Carolina DHEC.

Paragraph 7.34 (p. 163) - Mixing Zone. Savannah District met with the South Carolina DHEC and discussed this issue. The District will abide by the mixing zone or design parameters specified for the underdrains in the Water Quality Certification provided by the South Carolina DHEC.

Paragraph 7.76 (p. 176) - Creating Nesting Islands. Nesting can be successful on small tracts of suitable land. The District does not believe that increasing the size of the proposed islands to 3 acres would significantly improve the quality of the nesting habitat produced, i.e. increase the nesting success ratio.

Paragraph 7.79 (p. 177) - Slow Release of Ponded Water. The CDFs have historically held water for extended periods when discharges were not allowed through the overflow weirs. The District believes that natural rainfall will be adequate to counter evaporative losses.

Paragraph 7.81 (p. 178) - Construction of an Offshore Bird Island. The need for isolated nesting shorebird habitat in the region is the primarily the result of increased development of barrier island beaches by man. The proposed bird island is not intended to compensate for the loss of any particular previous

nesting area. The percentage of fine-grained sediments (50 percent) which is assumed to be lost during construction is a design parameter. The percentage of fines in the sediments is lower (13 percent) and use of the higher value was (1) based on previous experience with retention of deposited dredged material on ocean beaches, and (2) intended to be a conservative feature in the analysis of dredged material needs, construction costs, and turbidity impacts.

Paragraph 7.150 (p.214) - Success of Nearshore Bird Island. The proposed Mitigation Plan is based on production of certain habitats. While the basis for producing an offshore bird nesting habitat is ultimately for use by birds, the District believes that the variables inherent in predicting the amount of bird use for such a unique area would indeed render a calculation of such use not much more than a speculation. The District believes that high use of the proposed island by nesting birds would likely make it an environmental success, but we believe the number and range of the variables are too great to predict with any confidence the number of birds which may nest there.

Paragraph 7.152 through 7.166 (p. 215 - 220) - Berms and direct beach placement of sediments. The Bar Channel sediments have been shown to be predominantly coarse-grained. Some fines are included and would be deposited with the coarser materials, as they are now at the Savannah ODMDS. The District recognizes the desirability of placing very high quality materials on public beaches and would try to reach that goal. However, use of only specific or intermittent locations could significantly increase the cost of dredging and could make these placement options economically impractical. Measures are incorporated in all dredging projects to protect threatened and endangered sea turtles.

The scoring process was intended to provide only a general method of comparison. Different evaluators may well produce different scores for specific impacts. However, the general ranking between the alternatives when all the impact types are included are expected to be similar. Therefore, the District believes the scoring process was adequate for the general evaluation purpose for which it was intended.

Appendix E. Results of Wright River Weir Effluent and Sediment Testing. The EIS does contain maps showing the location of the CDFs whose effluent was sampled. Maps of sampling locations are contained in the full report on this study and may be obtained from Savannah District. We believe that including maps of sampling locations in the Appendix would not provide information necessary to interpret the study results.



OFFICE OF PLANNING AND BUDGET

ZELL MILLER
GOVERNORHENRY M. HUCKABY
DIRECTOR

GEORGIA STATE CLEARINGHOUSE MEMORANDUM

TO: Mr. Nicholas Ogden, Chief
Regulatory Branch
Savannah District, Corps of Engineers
P.O. Box 889
Savannah, Georgia 31402

FROM: Charles H. Badger, Administrator
Georgia State Clearinghouse
Office of Planning and Budget

DATE: January 5, 1995

SUBJECT: RESULTS OF STATE LEVEL REVIEW

APPLICANT: Corps of Engineers

PROJECT: DEIS/Savannah Harbor LTM

STATE APPLICATION IDENTIFIER: GA 94 12 05-004

PUBLIC NOTICE REFERENCE NUMBER:

The State level review of the above referenced Public Notice/Permit Request has been completed. As a result of that review process, the issuance of this permit is approved with the following recommendation(s) for improving the proposed activity.

The Corps of Engineers is advised of the comments in the enclosure to this memorandum especially those clarifications from the State of Georgia DOT and the Georgia Ports Authority.

TR/blm

ENCL: DOT/Public Highways, December 8, 1994
DNR/Flood Plain Management, December 16, 1994
DOT/Office of Intermodal Programs, December 19, 1994
Georgia Ports Authority, December 27, 1994

AN EQUAL OPPORTUNITY EMPLOYER

254 WASHINGTON ST., S.W., + ATLANTA, GEORGIA 30334-8500

Form SV-4M

GEORGIA STATE CLEARINGHOUSE MEMORANDUM

TO: State Clearinghouse
Office of Planning and Budget
254 Washington St., S.W.
Atlanta, Georgia 30334

FROM: BOB BOWLING
DEPT OF TRANSPORTATION, PUBLIC HIGHWAYS

SUBJECT: RESULTS OF REVIEW

STATE APPLICATION IDENTIFIER: GA 94 12 05-004

DATE: 12-8-94

This notice is considered to be consistent with those State ~~(goals)~~, ~~(policies)~~, ~~(objectives)~~, (plans), ~~(programs)~~, and ~~(fiscal resources)~~ with which this organization is concerned. (Line through inappropriate word or words).

This notice is recommended for further development with the following recommendations for strengthening the project (additional pages may be used for outlining the recommendations).

This notice is not recommended for further development (accompanied by detail comments which explains the organization's rationale for this decision).

This notice does not impact upon the activities of this organization.

Form SC-3
March 1987

GEORGIA STATE CLEARINGHOUSE MEMORANDUM

TO: State Clearinghouse
Office of Planning and Budget
254 Washington St., S.W.
Atlanta, Georgia 30334

FROM: ALEXIS HARRIS
DEPT OF NATURAL RESOURCES, EPD, FLOOD PLAIN MANAGEMENT

SUBJECT: RESULTS OF REVIEW

STATE APPLICATION IDENTIFIER: GA 94 12 05-004

DATE: 12-16-94

This notice is considered to be consistent with those State (goals), (policies), (objectives), (plans), (programs), and (fiscal resources) with which this organization is concerned. (Line through inappropriate word or words).

AH

This notice is recommended for further development with the following recommendations for strengthening the project (additional pages may be used for outlining the recommendations).

This notice is not recommended for further development (accompanied by detail comments which explains the organization's rationale for this decision).

This notice does not impact upon the activities of this organization.

Form SC-3
March 1987

GEORGIA STATE CLEARINGHOUSE MEMORANDUM

TO: State Clearinghouse
Office of Planning and Budget
254 Washington St., S.W.
Atlanta, Georgia 30334

FROM: LUKE COUSINS, ADMINISTRATOR
DEPT OF TRANSPORTATION, OFFICE OF INTERMODAL PROGRAMS

SUBJECT: RESULTS OF REVIEW

STATE APPLICATION IDENTIFIER: GA 94 12 05-004

DATE:

This notice is considered to be consistent with those State (goals), (policies), (objectives), (plans), (programs), and (fiscal resources) with which this organization is concerned. (Line through inappropriate word or words).

✓ (See attached)

This notice is recommended for further development with the following recommendations for strengthening the project (additional pages may be used for outlining the recommendations).

This notice is not recommended for further development (accompanied by detail comments which explains the organization's rationale for this decision).

This notice does not impact upon the activities of this organization.

Form SC-3
March 1987

Comments attached



Department of Transportation

State of Georgia

2 Capitol Square, S.W.

Atlanta, Georgia 30334-1002

December 19, 1994

WAYNE SHACKELFORD
COMMISSIONER

FRANK DANCHETZ
CHIEF ENGINEER

G. CHARLES LEWIS
DEPUTY COMMISSIONER

ARTHUR A. VAUGHN
TREASURER

Mr. William Bailey
U.S. Army Corps of Engineers
P. O. Box 889
Savannah, GA 31402

Dear Mr. Bailey: _

My office has reviewed the Draft Environmental Impact Statement for the Savannah Harbor Long Term Management Strategy Study. The document appears to follow the outline the Corps initiated 2 years ago which we were allowed to participate in.

The management strategy recommended in the report should improve the long term environmental impact of harbor activities due to the potentially extended useful life of the disposal areas and reduced frequency of maintenance dredging. We support this strategy and the projects associated with it.

Our review of the document resulted in the following comments:

1. Page 16; Section 2.22. Ga. DOT owns approximately 60% of the acres in the disposal areas. DOT is not the sole "owner/operator of confined . . .".
2. Page 29; Section 3.20. A berthing area is defined as "the area between a dock and the navigation channel". This can be a large area if the docks are distant from the navigation channel. Is the definition accurate?
3. Page 79; Section 5.49. It is stated that the throat to the sediment basin would not be modified. It is our understanding that a clean deep throat is a main criteria to an efficient sediment trap. To deepen the basin and not the throat would not be as beneficial as deepening both. Also a more efficient basin reduces dredging in the main channel and berths therefore reducing agitation dredging frequency.



Mr. William Bailey
 December 19, 1994
 Page Two

4. Page 97; Table 6.

- a) Should the 233,000 for 2A* be 244,000?
- b) The total of the volumes (accounting for use of one area in each pair or group) is 8,666,000. This exceeds the 7.2 million referenced in section 4.14 as the volume to be used throughout the 20 year period of analysis.
- c) Area 2A may not be available for the annual 233,000 cubic yards due to the inability to separate the sand shoals from the silt shoals during dredging.

5. Page 98; Section 5.72. There needs to be a continued effort of partnership between the sponsor and the Corps. The harbor is dynamic and can be unpredictable at times; emergencies can happen. Some flexibility needs to be incorporated so neither the Corps nor the Sponsor has to suffer needlessly.

There should be an annual meeting where the Corps and sponsor discuss the upcoming needs and discuss the dredging plans, dike raising plans and bird use plans.

- 6. Page 187; Section 7.95 A. The sponsor may choose to reclear the 26 acre site as opposed to pay incremental dredging costs, depending on which is cheapest to maintain the site.
- 7. Page 193; Table 14. It appears there may be some minor arithmetical errors. Are these due to rounding?
- 8. Page 206; Section 7.127. The sponsor will need adequate time to obtain funds for maintenance of the island.
- 9. Appendix A; page 9; Section A.5.11. We support speed limits of ships to reduce the erosive effects of their wakes on the dikes.
- 10. Appendix A; page 13; Section A.5.24 and page 15; Section A.5.35. DOT does not allow any persons on DOT property unless they are government employees or contractors, on official business associated with harbor dredging/disposal activities. Since DOT owns most of Area 12A and the general public is not allowed to cross DOT property, the fishermen and birdwatchers do not have land access to the disposal areas on the S. C. side.
- 11. Appendix C; page 6; Section C.2.19; and page 14; Section C.2.59. Both sections indicate there will be dike ramp construction. This does not agree with Section 7.102, page 196 of the main report.

Mr. William Bailey
December 19, 1994
Page Three

12. Appendix F; Section F.3.08. The underdrains have been closed in 12"B", not 12"A".

Please accept these comments in the spirit of partnering as they are offered to strengthen the document. If you have any questions please call John Phillips at (404)-651-9213.

Sincerely,



Duke Cousins, Administrator
Office of Intermodal Programs

LC:JP:jsd

cc: George Lyons
David Studstill

S&ME, INC-SAVANNAH

ID:1-912-353-8878

DEC 27'94

9:37 No.002 P.03

GEORGIA STATE CLEARINGHOUSE MEMORANDUM

TO: State Clearinghouse
Office of Planning and Budget
254 Washington St., S.W.
Atlanta, Georgia 30334

FROM: MR. C. GRIFFIN
GEORGIA PORTS AUTHORITY

SUBJECT: RESULTS OF REVIEW

STATE APPLICATION IDENTIFIER: GA 94 12 05-004

DATE: 12/27/94

This notice is considered to be consistent with those State (goals), (policies), (objectives), (plans), (programs), and (fiscal resources) with which this organization is concerned. (Line through inappropriate word or words).

This notice is recommended for further development with the following recommendations for strengthening the project (additional pages may be used for outlining the recommendations).

Charles F. Griffin
See Attached Pages.

This notice is not recommended for further development (accompanied by detail comments which explains the organization's rationale for this decision).

This notice does not impact upon the activities of this organization.

Form SC-3
March 1987

S.E.M.E., INC.-SAVANNAH

ID:1-912-353-8878

DEC 27'94

9:37 No.002 P.04

State Application Identifier: GA 94 12 05-004

- It appears to be unclear as to the applicability of the DEIS. The proposed action relative to this DEIS is, as we understand it, to address specific and defined dredging activities proposed for the Savannah River / Harbor area. However, the DEIS is titled and abstracted to address the LTMS which will be much broader in scope than the dredging program.
- The alternate management strategies (Chapter 5.0) appear to extend in scope beyond specific dredging alternatives into a broader range of management concerns.
- The DEIS is a large document; however, it is unclear as to how much of the appended environmental material is actually applicable to the proposed dredging. Likewise, the text of the DEIS presents a great deal of general environmental material, but is not focused on the environmental issues of the defined, proposed action.
- It appears the DEIS may not be completely accurate and current. For example, on page 111, the portion of the river system regulated by the state of South Carolina is discussed in terms of Class SA (saltwater) / Class B (fresh water) classification. The Class B designation for fresh waters was replaced by the FW (fresh water) designation in the last reauthorization of the State regulations 61-68 and 61-89 in 1993.
- Overall, the DEIS does not focus the environmental analysis of the proposed action of dredging. The DEIS does not appear to be applicable to the LTMS and, consequently, strays into areas and issues outside of its intended scope. While a great deal of material is presented, what would be more appropriate would be a cogent and focused analysis, per NEPA/DEIS protocol, of the proposed action. As such, much of the material may not be germane to the environmental aspects of the properly scoped, proposed action.
- Finally, given the general nature of uncertainty regarding the applicability of this DEIS to the actual proposed action, additional review time from the Agencies for all parties involved would be useful and judicious.

mm\ds\lunam\gpallms

RESPONSE -- GEORGIA STATE CLEARINGHOUSE MEMORANDUM;
December 8, 1994.

No comment necessary.

RESPONSE -- GEORGIA STATE CLEARINGHOUSE MEMORANDUM;
GA Department of Transportation,
Public Highways,
December 8, 1994.

No comment necessary.

RESPONSE -- GEORGIA STATE CLEARINGHOUSE MEMORANDUM;
GA Department of Natural Resources,
Environmental Protection Division,
Flood Plain Management,
December 16, 1994.

No comment necessary.

RESPONSE -- GEORGIA STATE CLEARINGHOUSE MEMORANDUM;
 GA Department of Transportation,
 Office of Intermodal Programs,
 December 1994.

No comment necessary on overall results of review. Specific
 comments are addressed after the letter provided directly to the
 District.

RESPONSE -- GEORGIA STATE CLEARINGHOUSE MEMORANDUM;
Georgia Ports Authority,
December 27, 1994.

SCOPE OF EIS. The EIS addresses activities considered in the LTMS Management Plan. This includes both dredging and disposal activities required to maintain the Federal Navigation Project. Also included are the activities required to manage the disposal sites required for deposition of sediments removed from the Project.

SCOPE OF ALTERNATIVES. The alternatives do indeed extend beyond dredging activities to also include disposal and disposal area operation and management actions.

ENVIRONMENTAL SETTING. The EIS does contain information which is not project specific, but provides information on the environmental setting of the project. This background information is intended to provide a framework for evaluations and decisions on an impact's importance in the project vicinity.

STATE WATER USE CLASSIFICATIONS. The EIS has been revised as suggested.

FOCUS OF ENVIRONMENTAL ANALYSIS. The EIS provides information necessary to perform an environmental analysis of the proposed action. That action includes dredging and disposal actions, and the activities required to manage the disposal sites required for deposition of sediments removed from the Project.

REVIEW TIME. An extension was granted to the Georgia Ports Authority, and everyone else who requested it, to provide comments on the draft EIS.

RESPONSE -- GEORGIA STATE CLEARINGHOUSE MEMORANDUM;
GA Department of Natural Resources,
Historic Preservation Division,
December 1994.

No comment necessary. The Historic Preservation Division commented directly to Savannah District in letters dated January 4 and 19, 1995. Responses to those comments are included after the letters.

Georgia Department of Natural Resources
 Historic Preservation Division

Joe D. Tanner, Commissioner

Mark R. Edwards, Director and State Historic Preservation Officer
 205 Butler Street, Suite 1462, Atlanta, Georgia 30334
 Telephone (404) 656-2840
 Fax (404) 651-8739

January 4, 1995

Mr. M.J. Yuschishin, Chief
 Planning Division
 Department of the Army
 Savannah District, Corps of Engineers
 P.O. Box 889
 Savannah, Georgia 31402-0889

RE: Memorandums of Agreement--Ft. Jackson, C.S.S. Georgia
 Savannah Harbor--Remove Tide Gate and New Cut Closure
 Chatham County, Georgia
 HP911114-001

Dear Mr. Yuschishin:

The Historic Preservation Division (HPD) has reviewed the draft Memorandums of Agreement (MOAs) outlining procedures for complying with Section 106 requirements concerning the removal of a tide gate and New Cut Closure in Savannah Harbor, Chatham County, Georgia. These MOAs seek to address the effects of this undertaking to Fort Jackson and the C.S.S. Georgia, historic resources located within the project's area of potential effects. Our comments for these draft MOAs are outlined as follows:

For the C.S.S. Georgia MOA:

1. Stipulation Two: A reasonable time frame should be included for the completion of these studies. HPD suggests two to three years; however, the Corps of Engineers may wish to allow for additional consultation time.
2. Stipulation Five: Any consideration of alternatives for minimizing the possible restrictions of the C.S.S. Georgia on harbor navigation should be specifically included in the overall mitigation plan.
3. Stipulation Six: If possible, a draft of the mitigation plan should be submitted to archaeologists with the National Park Service, university anthropology departments, and neighboring state Marine Archaeology programs for peer review. HPD has no in-house expertise for evaluating the specifics of the mitigation plan at this time, and peer review would be very valuable in selecting the most efficient and cost-effective mitigation for this complex resource.

Mr. M.J. Yuschishin, Chief
January 4, 1995
Page Two

4. Stipulation Eight: Some clarification is needed for this stipulation. If funds are not available within a given year, some contingency plans will be needed.
5. Stipulation Twelve: Our office requests a list of the curation facilities being considered to fulfill this stipulation.

For the Fort Jackson MOA:

1. Stipulation Seven: The review by the Coastal Heritage Society and interested local historic groups is especially important for this project. Additionally, review by managers in other historic sites which may have experienced this problem may be considered.
2. Stipulation Thirteen: A list of potential curation facilities considered for this stipulation is needed.

If we may be of further assistance, please contact Jeffrey L. Durbin, Environmental Review Coordinator, at (404) 656-2840.

Sincerely,



Richard Cloues
Deputy State Historic Preservation Officer

RC:drm

cc: Advisory Council on Historic Preservation
Kirk Schlemmer, Coastal Georgia RDC
Scott Smith, Coastal Heritage Society

RESPONSE -- GA Department of Natural Resources,
Historic Preservation Division,
January 4, 1995.

COMMENTS ON THE CSS GEORGIA MOA:

1. **TIME FRAME FOR COMPLETION OF STUDIES.** Stipulation #3 of the MOA has been revised to state that a draft report documenting the studies conducted under Stipulations #1 and #2, as well as the resulting findings and determinations would be complete within three years of the signature of the last party to the MOA.

2. **ALTERNATIVES.** Stipulation #5 has been revised to state that the mitigation plan will document the alternatives evaluated to eliminate or minimize restrictions which the CSS Georgia causes on the Savannah Harbor Navigation Project.

3. **REVIEW OF THE DRAFT MITIGATION PLAN:** Stipulation #7 has been revised to state that peer review of the draft mitigation plan will be pursued.

4. **AVAILABILITY OF FUNDS:** Stipulation #8 has been revised to state that should it appear that funds would not be available to implement all components of the recommended plan specified for a given year, the District would consult the parties to the MOA to determine what actions the District would need to perform to remain in compliance with Section 106 of the NHPA.

5. **POTENTIAL CURATION FACILITIES:** Stipulation #12 has been revised to include this information.

COMMENTS ON THE FORT JACKSON MOA:

1. **REVIEW BY OTHERS:** Stipulation #17 of the MOA has been revised to state that a review by managers of historic sites which have experienced similar problems would be pursued.

2. **POTENTIAL CURATION FACILITIES:** Stipulation #13 has been revised to include this information.

Georgia Department of Natural Resources

Historic Preservation Division

Joe D. Tanner, Commissioner

Mark R. Edwards, Director and State Historic Preservation Officer
205 Butler Street, Suite 1462, Atlanta, Georgia 30334
Telephone (404) 656-2840
Fax (404) 651-8739

January 19, 1995

Richard A. Hill
Acting Chief, Planning Division
Department of the Army
Savannah District, Corps of Engineers
P.O. Box 889
Savannah, Georgia 31402-0889

RE: Savannah Harbor Navigation Project
Long Term Management Strategy
Chatham County, Georgia
GA941205-004

Dear Mr. Hill:

The Historic Preservation Division (HPD) has reviewed the Environmental Impact Statement and Long Term Management Strategy for the Savannah Harbor Navigation Project, Chatham County, Georgia. HPD has been consulting with the Savannah District of the Corps of Engineers throughout the development of this project; therefore, we have no comments concerning the Environmental Impact Statement at this time.

However, we do offer the following minor technical comments regarding the final draft of the Long Term Management Strategy, as follows:

1. A few additions would make the management plan more useful to individuals who are not familiar with the overall project. These suggested additions are:
 - a. A map showing the location of the major components of the project, and
 - b. A bibliography of the major cultural resource surveys, testing, and data recovery reports generated as part of the consultation process.

If we may be of further assistance, please contact Jeffrey L. Durbin, Environmental Review Coordinator, at (404) 656-2840.

Sincerely,

Richard Cloues

Richard Cloues
Deputy State Historic Preservation Officer

RC:drm

cc: Tripp Reid, State Clearinghouse
Kirk Schlemmer, Coastal Georgia RDC

RESPONSE -- GA Department of Natural Resources,
Historic Preservation Division,
January 19, 1995.

SUGGESTED ADDITIONS TO MANAGEMENT PLAN:

1. MAP. An overall site map has been added.
2. BIBLIOGRAPHY. A bibliography has been added.

Georgia Department of Natural Resources

One Conservation Way, Brunswick, Georgia 31523-8600

Joa D. Tanner, Commissioner

Duane Harris, Director

Coastal Resources Division

912/264-7218

FAX 912/262-3143

January 31, 1995

William Bailey
 US Army Engineer District, Savannah
 P. O. Box 889, ATTN: CESAS-PD-EI
 Savannah, GA 31402-0889

Dear Mr. Bailey:

Coastal Resources Division has reviewed the Savannah Harbor Long Term Management Strategy Study (LTMS). In addition, I asked staff of the Wildlife Resources Division's Non-Game Program to review the LTMS.

We support the conclusion of the LTMS in that alternative 8 is the best solution to long range management of the harbor. This provides the flexibility needed to maximize the use of disposal areas while providing maximum protection of the natural resources. The Division stands ready to assist the Corps with projects to be implemented under this alternative.

Georgia is developing a Coastal Management Plan under authority of the Federal Coastal Zone Management Act. This plan is expected to be adopted by early 1997 and, as you state in the LTMS, will have similar policies to the South Carolina Coastal Management Plan. Any federal activity associated with the Savannah Harbor would be reviewed for consistency with the Georgia plan. Alternative 8 provides the flexibility to meet this consistency test.

If you require further information please contact me. Thank you for the opportunity to review this important study.

Sincerely,



Dr. Stuart A. Stevens, Chief
 Ecological Services and
 Research Coordinator SINERR

cc: Duane Harris
 Mike Harris, Non-Game Program
 Tiffany Lutterman, Coastal Zone Management Program

RESPONSE -- GA Department of Natural Resources,
Coastal Resources Division,
January 31, 1995.

No response necessary.

Savannah District hopes that the products of the Savannah Harbor LTMS Study -- the Management Plan and the EIS -- would be reviewed by the Coastal Resources Division and adopted as a Special Area Management Plan if/when the Georgia Coastal Management Program is implemented.

Georgia Department of Natural Resources

One Conservation Way, Brunswick, Georgia 31523-8600

Lorice C. Barrett, Commissioner

Duane Harris, Director

Coastal Resources Division

912/264-7218

FAX 912/262-3143

May 19, 1995

William Bailey
US Army Corps of Engineers
CESAS-PD-EI
P. O. Box 889
Savannah, GA 31402-0889

RE: Savannah Harbor LTMS Study.

Dear Mr. Bailey:

Please note my letter to you dated 31 January 1995 regarding the referenced project. After further evaluation of the LTMS Study and the potential impacts to the environment and the local socio-economic system, I recommend the Corps strongly consider placement of any suitable harbor dredged material onto adjacent beaches of Tybee Island. Tybee Island is suffering from beach erosion and suitable material must not be lost from the sand sharing system. Please consider the economic benefits of placement of dredged material onto Tybee's beaches similar to the recent Savannah Harbor deepening project.

If you have questions please contact me.

Sincerely,



Dr. Stuart A. Stevens, Chief
Ecological Services and
Research Coordinator SINERR

RESPONSE -- GA Department of Natural Resources,
Coastal Resources Division,
May 19, 1995.

ECONOMIC BENEFITS OF BEACH PLACEMENT.

During the 1993/1994 Savannah Harbor Deepening Project, beach placement was a lower cost disposal option than placement of excavated sediments at the ODMDS during the period when use of hopper dredges is excluded. To protect endangered sea turtles, maintenance dredging is performed by hopper dredges only during the winter months (December through March). If maintenance dredging is needed during other periods (April through November), some form of nearshore placement -- which includes direct beach placement -- would likely be the lowest cost disposal option for some of the Bar Channel sediments. The Draft EIS stated in Section 7.164 that "if the savings which would be experienced by the Shore Protection Project were included, the effective cost of placement directly on Tybee Island would be less than the normal cost for placing channel maintenance sediments at the Savannah ODMDS and such placement would, therefore, be a wise investment."

Under current procedures, if beach placement is more expensive than the original disposal location, the incremental cost of beach placement would be cost shared between the Corps and the local sponsor of the Shore Protection Project at the rate specified for the Shore Protection Project. The District could pursue such placement any time the maintenance material is determined to be of sufficient quality, the local sponsor for the Shore Protection Project requests such beneficial placement, and both the sponsor and the Corps can obtain funds to finance the incremental costs.

Georgia Department of Natural Resources

205 Butler Street, S.E., Suite 1152 East Floyd Tower, Atlanta, Georgia 30334

Lonice C. Barrett, Commissioner

Harold F. Reheis, Director

David Word, Assistant Director

Environmental Protection Division

404/656-4713

September 5, 1995

Colonel Grant W. Smith
Savannah District, Corps of Engineers
P. O. Box 889
Savannah, Georgia 31402-0889

RE: Water Quality Certification
Public Notice DRAFT EIS
Long Term Management Strategy
Savannah Harbor - Chatham County

Dear Colonel Smith:

Pursuant to Section 401 of the Federal Clean Water Act, the State of Georgia issues this certification to the Savannah District, Corps of Engineers, an applicant for a Federal permit or license to conduct an activity in, on or adjacent to the waters of the State of Georgia.

The State of Georgia certifies that there is no applicable provision of Section 301; no limitation under Section 302; no standard under Section 306; and no standard under Section 307, for the applicant's activity. The State of Georgia certifies that the applicant's activity will comply with all applicable provisions of Section 303.

This certification is contingent upon the following conditions:

1. All work performed during construction will be done in a manner so as not to violate applicable water quality standards.
2. No oils, grease, materials or other pollutants will be discharged from the construction activities which reach public waters.
3. No dredging will be conducted during the striped bass spawning period from March 16 to May 31.
4. Prior to initiation of dredging activity between July 1 and September 30, the applicant must establish the following procedures. Dissolved oxygen levels in the Savannah River will be obtained within 24 hours prior to the initiation of dredging. Three sampling locations will be established in the Savannah River to determine existing conditions. These sampling locations will be placed: 1) 1,000 feet upstream from the site of the dredging activity; 2) 1,000 feet downstream from the site of dredging activity; and 3) adjacent to the proposed dredging activity. All locations will be approximately at the mid-channel centerline. At each sample location, three depths will be sampled during low slack water or high slack water, when possible, as follows: 1) one meter below the surface; 2) one meter above a hard bottom or 2-3 meters above an indeterminate bottom; and, 3) at mid-depth. If dissolved oxygen levels are less than 4.0 mg/l at depths of one meter above a hard bottom or 2-3 meters above a soft or indeterminate bottom at any of the three established monitoring stations, dredging will not be permitted.

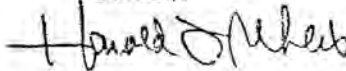
Colonel Grant W. Smith
 Page two
 September 5, 1995

Monitoring of the dredging activity will consist of the same sampling regime to be conducted daily within 4 hours of the commencement of dredging, but no earlier than 2 hours after the commencement of dredging. If dissolved oxygen levels fall below 3.0 mg/l at depths of one meter above a hard bottom or 2-3 meters above a soft or indeterminate bottom at any station, dredging will be suspended until dissolved oxygen levels are 4.0 mg/l or greater. Results of this monitoring must be submitted to the Georgia Environmental Protection Division, the Georgia Wildlife Resources Division, and the Georgia Coastal Resources Division within 30 days of the completion of each dredging operation. If the applicant does not maintain a satisfactory record of compliance with these conditions, the Georgia Environmental Protection Division may prohibit all dredging during the period of July 1 to September 30 upon written notice to the applicant.

5. Dredging should be conducted during December through March. These are the times when sea turtles are least abundant in the area of the Savannah Ship Channel. Dredging should not be conducted outside these months without implementation of a conservation plan approved by Georgia Department of Natural Resources. This plan should include trawling to remove turtles from the path of the dredge.
6. During December through March, dredge and support vessel speeds should be limited to less than 5 knots during nighttime operations. A trained whale observer should be on watch during daylight hours. If daily aerial surveys are conducted for right whales, the nighttime vessel speed limitation would only need to be enforced when a whale was spotted within 15 miles of the project area during the previous daily survey.

It is your responsibility to submit this certification to the appropriate Federal agency.

Sincerely,



Harold F. Reheis
 Director

HFR:kpr

cc: Mr. Nick Ogden
 Dr. Stuart Stevens
 Mr. Thomas Welborn
 Mr. Mike Gennings

RESPONSE -- GA Department of Natural Resources,
Environmental Protection Division,
September 5, 1995.

WATER QUALITY CERTIFICATION.

This letter provides Water Quality Certification from the State of Georgia for the Savannah Harbor LTMS. Savannah District has requested clarification on conditions 4, 5 and 6.

Georgia Department of Natural Resources

205 Butler Street, S.E., Suite 1152 East Floyd Tower, Atlanta, Georgia 30334

Lonice C. Barrett, Commissioner

Harold F. Reheis, Director

David Word, Assistant Director

Environmental Protection Division

404/656-4713

February 6, 1996

Colonel Grant W. Smith
Savannah District Corps of Engineers
P.O.Box 889
Savannah, Georgia 31402-0889
Attn: Mr. Bill Bailey

Re: Modification - Water Quality Certification
Public Notice DRAFT EIS
Long Term Management Strategy
Savannah Harbor - Chatham County

Dear Colonel Smith:

The Georgia Environmental Protection Division (EPD) issued Water Quality Certification under Section 401 of the Federal Clean Water to the above referenced project on September 5, 1995. The State intends to modify the certification to wit:

Condition 5 shall be struck and replaced to read:

5. Dredging should be conducted December through March. These are the times when sea turtles are least abundant in the area of the Savannah Ship Channel. Dredging outside these months should be coordinated with the Georgia Department of Natural Resources (DNR) Nongame Wildlife Program. Dredging in May will require the implementation of a conservation plan approved by the Georgia DNR. This plan should include trawling to remove turtles from the path of the dredge.

Condition 6 shall be struck and replaced with:

6. During December through March, dredge and support vessels should have a trained whale observer on watch during daylight hours. At night, or when visibility is reduced by fog or sea states greater than Beaufort 3, dredges must slow to 5 knots or less if whales have been spotted within 15 nm of the vessel's path within the previous 48 hours. Normal operational speeds can be resumed after 48 hours if visibility has not improved and no whales have been observed by dredge observers. These procedures are consistent with the "Recommended Safe Operating Procedures for Large Vessels Transiting the Right Whale Calving Area Critical Habitat Off Georgia and Florida During March-December" that have been developed by the Southeastern U.S. Implementation Team for the Recovery of the Northern Right Whale.

These changes update the Water Quality Certification conditions to reflect the best information available on turtles and right whales. It is your responsibility to submit these modifications to the appropriate Federal agencies.

Sincerely,



Keith A. Parsons
Environmental Specialist

KP/

cc: Mr. Thomas Welborn
Dr. Stuart Stevens
Mr. Mike Gennings

RESPONSE -- GA Department of Natural Resources,
Environmental Protection Division,
February 6, 1996.

MODIFICATIONS TO WATER QUALITY CERTIFICATION.

Savannah District agrees to abide by the modifications to conditions 5 and 6 contained in this letter. Subsequent discussions with GA DNR staff reveal that the dredging to which these conditions apply is hopper dredging.

Georgia Department of Natural Resources

205 Butler Street, S.E., Suite 1152 East Floyd Tower, Atlanta, Georgia 30334

Lonice C. Barrett, Commissioner

Harold F. Reheis, Director

David Word, Assistant Director

Environmental Protection Division

404/656-4713

February 28, 1996

Colonel Grant W. Smith
Savannah District Corps of Engineers
P.O. Box 889
Savannah, Georgia 31402-0889

Attn: Mr. Bill Bailey

Re: Modification - Water Quality Certification
Public Notice-DRAFT EIS
Long Term Management Strategy
Savannah Harbor - Chatham County

Dear Colonel Smith:

The Georgia Environmental Protection Division (EPD) issued Water Quality Certification under Section 401 of the Federal Clean Water Act for the above referenced project on September 5, 1995. The EPD intends to modify the certification to wit:

Condition 4 will be struck and replaced to read:

4. Prior to the initiation of dredging activity between July 1 and September 30 the dredge operator must establish the following procedures. Dissolved oxygen levels in the Savannah River contiguous with the immediate dredging activity will be determined at a depth of one meter above a hard bottom or 2-3 meters above an indeterminate bottom. This determination must be made within 24 hours prior to the commencement of dredging activity. If dissolved oxygen levels are less than 3.0 mg/l dredging activity will not be permitted.

Monitoring of the dredging activity will be conducted within 4 hours of the commencement of dredging, but no earlier than 2 hours after the commencement of dredging. In the event of 24 hour operation (around the clock) of the dredge, dissolved oxygen will be determined daily. The monitoring station will be located at mid-channel, 500 ft. downstream of the ongoing dredging activity. Dissolved oxygen levels will be determined at a depth of one meter above a hard bottom or 2-3 meters above an indeterminate bottom. If dissolved oxygen level fall below 3.0 mg/l dredging will be suspended until dissolved oxygen levels are 3.0 mg/l or greater.

Results of the monitoring must be submitted to the Georgia Environmental Protection Division, the Georgia Wildlife Resource Division, and the Georgia Coastal Resources Division within 30 days of the completion of each dredging operation. Failure to maintain satisfactory compliance with these conditions may result in the prohibition of dredging operations in the Savannah River Harbor during the period of July 1 through September 30 upon written notice to the applicant.

These changes update the Water Quality Certification conditions to reflect the best information available on dissolved oxygen dynamics in the Savannah River Harbor. It is your responsibility to submit these modification to the appropriate Federal agencies.

Sincerely,

A handwritten signature in black ink, appearing to read "Keith A. Parsons", written over a horizontal line.

Keith A. Parsons
Environmental Specialist

KP/

cc: Mr. Thomas Welborn
Mr. Mike Gennings
Dr. Stuart Stevens

RESPONSE -- GA Department of Natural Resources,
Environmental Protection Division,
February 28, 1996.

MODIFICATIONS TO WATER QUALITY CERTIFICATION.

Savannah District agrees to abide by the modifications to conditions 4 contained in this letter. The District wrote GA DNR requesting further refinement of this condition. The Corps believes that since previous monitoring data revealed that on average, hydraulic cutterhead dredges working in the channel had no discernible adverse impact on dissolved oxygen in the river, weekly monitoring until dissolved oxygen levels reach 3.5 mg/l -- rather than daily -- would be sufficient to protect aquatic resources. The District proposed weekly monitoring as long as river bottom dissolved oxygen levels exceeded 3.5 mg/l. Daily monitoring would be performed when river bottom dissolved oxygen levels dropped below 3.5 mg/l. GA DNR responded by stating that although the historic data does appear to support the Corps' position on minimal impact to riverine dissolved oxygen, that data is based on dredging which occurred in only a single calendar year. Therefore, the GA DNR would continue to require daily monitoring until a more comprehensive historic database was developed.



Department of Transportation

State of Georgia

#2 Capitol Square, S.W.

Atlanta, Georgia 30334-1002

December 19, 1994

WAYNE SHACKELFORD
COMMISSIONER

FRANK DANCHETZ
CHIEF ENGINEER

G. CHARLES LEWIS
DEPUTY COMMISSIONER

ARTHUR A. VAUGHN
TREASURER

Mr. William Bailey
U.S. Army Corps of Engineers
P. O. Box 889
Savannah, GA 31402

Dear Mr. Bailey:

My office has reviewed the Draft Environmental Impact Statement for the Savannah Harbor Long Term Management Strategy Study. The document appears to follow the outline the Corps initiated 2 years ago which we were allowed to participate in.

The management strategy recommended in the report should improve the long term environmental impact of harbor activities due to the potentially extended useful life of the disposal areas and reduced frequency of maintenance dredging. We support this strategy and the projects associated with it.

Our review of the document resulted in the following comments:

1. Page 16; Section 2.22. Ga. DOT owns approximately 60% of the acres in the disposal areas. DOT is not the sole "owner/operator of confined ...".
2. Page 29; Section 3.20. A berthing area is defined as "the area between a dock and the navigation channel". This can be a large area if the docks are distant from the navigation channel. Is the definition accurate?
3. Page 79; Section 5.49. It is stated that the throat to the sediment basin would not be modified. It is our understanding that a clean deep throat is a main criteria to an efficient sediment trap. To deepen the basin and not the throat would not be as beneficial as deepening both. Also a more efficient basin reduces dredging in the main channel and berths therefore reducing agitation dredging frequency.



Mr. William Bailey
 December 19, 1994
 Page Two

4. Page 97; Table 6.
 - a) Should the 233,000 for 2A* be 244,000?
 - b) The total of the volumes (accounting for use of one area in each pair or group) is 8,666,000. This exceeds the 7.2 million referenced in section 4.14 as the volume to be used throughout the 20 year period of analysis.
 - c) Area 2A may not be available for the annual 233,000 cubic yards due to the inability to separate the sand shoals from the silt shoals during dredging.
5. Page 98; Section 5.72. There needs to be a continued effort of partnership between the sponsor and the Corps. The harbor is dynamic and can be unpredictable at times; emergencies can happen. Some flexibility needs to be incorporated so neither the Corps nor the Sponsor has to suffer needlessly.

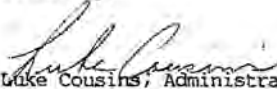
There should be an annual meeting where the Corps and sponsor discuss the upcoming needs and discuss the dredging plans, dike raising plans and bird use plans.
6. Page 187; Section 7.95 A. The sponsor may choose to reclear the 26 acre site as opposed to pay incremental dredging costs, depending on which is cheapest to maintain the site.
7. Page 193; Table 14. It appears there may be some minor arithmetical errors. Are these due to rounding?
8. Page 206; Section 7.127. The sponsor will need adequate time to obtain funds for maintenance of the island.
9. Appendix A; page 9; Section A.5.11. We support speed limits of ships to reduce the erosive effects of their wakes on the dikes.
10. Appendix A; page 13; Section A.5.24 and page 15; Section A.5.35. DOT does not allow any persons on DOT property unless they are government employees or contractors, on official business associated with harbor dredging/disposal activities. Since DOT owns most of Area 12A and the general public is not allowed to cross DOT property, the fishermen and birdwatchers do not have land access to the disposal areas on the S. C. side.
11. Appendix C; page 6; Section C.2.19; and page 14; Section C.2.59. Both sections indicate there will be dike ramp construction. This does not agree with Section 7.102, page 196 of the main report.

Mr. William Bailey
December 19, 1994
Page Three

12. Appendix F; Section F.3.08. The underdrains have been closed in 12"B", not 12"A".

Please accept these comments in the spirit of partnering as they are offered to strengthen the document. If you have any questions please call John Phillips at (404) 651-9213.

Sincerely,


Luke Cousins, Administrator
Office of Intermodal Programs

LC:JP:jsd

cc: George Lyons
David Studstill

**RESPONSE -- GA Department of Transportation,
Office of Intermodal Programs,
December 19, 1994.**

1. Page 16; Section 2.22. Concur.
2. Page 29; Section 3.20. A berthing area is defined as "the area between a dock and the navigation channel" since the total area is needed to safely berth and moor a vessel at the dock.
3. Page 79; Section 5.49 - Sediment Basin Throat. The proposed design, with the throat shallower than the basin, is not intended to trap additional heavy sediments which are transported along the floor of the channel. The increase in sediment trapping efficiency would result from the basin's improved retention and additional storage of finer-grained particles which are suspended higher in the water column.
4. Page 97; Table 6.
 - a) The 233,000 cubic yards is correct. This volume reflects the bulking which would occur during an excavation process.
 - b) This volume represents deposition volumes, rather than dredging or in-place volumes. The larger quantity reflects the bulking which would occur during an excavation process.
 - c) The engineering calculations are approximate and assume that Disposal Area 2A would receive 233,000 cubic yards on an average annual basis.
5. Page 98; Section 5.72. Continued coordination between the sponsor and the Corps is encouraged as it should increase the effectiveness and efficiency of harbor decision-making and management operations. An annual meeting between these two parties may be appropriate. However, specification of the form or times of coordination are not necessary in an EIS as they would not guarantee any level of environmental impact.
6. Page 187; Section 7.95 A. Maintenance of the upland nesting area may be accomplished by either placement of additional dredged material or removing existing vegetation.
7. Page 193; Table 14. This table has been revised,

8. Page 206; Section 7.127. The sponsor will be periodically made aware of the size of the island so that it can schedule funding for maintenance of the island.
9. Appendix A; page 9; Section A.5.11. Limits on vessel speeds are beyond the authority of the Corps of Engineers to implement.
10. Appendix A; page 13; Section A.5.24 and page 15; Section A.5.35. The actions included in Appendix A are not necessarily proposed for implementation, but were included only for information and background purposes.
11. Appendix C; page 6; Section C.2.19; and page 14; Section C.2.59, Concur. Revisions have been made to include dike ramp construction.
12. Appendix F; Section F.3.08. Concur. Revisions have been made.

Mr. William Bailey
Page 2
February 27, 1995

Adding the dredging of berths to the annual maintenance dredging of the harbor is proposed. Even with the proposed 4' over depth of the berths, annual dredging may be insufficient to maintain adequate depths. The changes in the river associated with the closing of new cut, opening of the tide gates, widening and deepening of the channel have not yet been fully realized. Dragging between annual dredging by the Corps may be inadequate to maintain the depths. However, agitation dredging must continue to be protected. Users of the channel should be assured that non-federal hydraulic dredging is protected. We also question if maintenance of the harbor and private berths can be accomplished within the limited time span now imposed by environmental restrictions and issues. Hydraulic dredging of the berths could be impractical, if not impossible, to accomplish on an annual basis given a limited number of suitable dredges, or a single dredge.

The Draft EIS states that the dredging of the berths would be bid as a separate cost item. This could result in higher costs for the dredging of the berths relative to the per yard cost for channel dredging. You would select a contractor which provided the overall lowest cost for the project, not necessarily the lowest berth dredging cost to the private owners. Some method of allowing private owners to participate in the final contract award decision should be made.

The Draft EIS states that testing will be accomplished by the Corps for berths which are deepened. It is not clear what responsibility for testing private owners have if deepening does not take place at their berth. Further, depths of berths are proposed to be increased to 4' below the adjacent channel depth. This will have to be coordinated with the Corps to maintain the structural stability of the dock. A definitive plan from the Corps should be established and reviewed.

The project sponsor or private dock owners are responsible for dredging between the Corps annual maintenance dredging. Separate permits would be required for this operation. Permitting of hydraulic dredging could become almost impossible due to the rotation of dredge disposal areas and the increased emphasis on maintaining the capacity of the existing disposal areas. A partial solution would be that the Corps dispose of all material practical in off-shore disposals, such as the berms proposed off Tybee and the off-shore disposal area. This would maintain more volume within the upland dredge disposal areas. It is noted that there are no proposals contained in the draft EIS to locate and establish new dredge disposal sites. However a more complete analysis of long term capacity requirements should be accomplished.

Mr. William Bailey
Page 3
February 27, 1995

Actions are presently in effect to minimize the environmental impact of maintaining the harbor. These actions have proven most effective. However, the draft EIS gives further alternatives such as, further restrictions when dredging can be performed, disallowing the use of hopper dredges, further restrictions on dredge operating speeds, disallowing dredging completely during summer months, reducing speed of vessels, etc. These alternatives need to more comprehensively analyzed before being addressed in an EIS

Regarding the right whale, the Georgia Ports Authority is a member of the implementation team for the recovery of this species. Successful actions as to sightings, avoidance, etc. are in effect. We do wish to point out that Savannah's harbor is not located within the critical habitat of this mammal

To conclude, it is recommended that the LTMS be more completely developed and a final EIS reflect factual information and define strategies for maintaining the Savannah Harbor Project. Further, the LTMS should document environmental resource agency approval of the management strategy with agreements in place to ensure the appropriate dredging permits can be secured by the Corps, Public and Private Terminals.

We would be very happy to discuss these issues further and look forward to hearing from you.

Sincerely,



Charles F. Griffen, P.E.
Director of Port Planning &
Harbor Development

MH/cv

cc: Mr. Doug Marchand
Mr. B. Richard Field
Mr. Jim Bradshaw

RESPONSE -- Georgia Ports Authority,
February 27, 1995.

TIMING AND CONTENTS OF DRAFT EIS. The Draft EIS was prepared in consort with the LTMS Management Plan. No items were included in the Draft EIS that were not in the Management Plan. The Management Plan includes environmental considerations as an integral component of harbor operations. A delay in releasing the Draft EIS for public and agency comment until after completion of the Management Plan could have seriously compromised the integration of environmental considerations into the other engineering and economic considerations.

REWRITING THE EIS. The LTMS was designed to be a comprehensive review of harbor operations. Separating the diking and use of Disposal Area 14A would have undermined the broad and comprehensive view of harbor operations which the LTMS was intended to provide.

ALTERNATING USE OF CDFS. Although alternating use of confined disposal areas would increase the cost of some individual disposal operations, the total long term cost of disposal operations and disposal area management would be reduced.

SEDIMENT QUALITY. Precise actions cannot be specified at this time for materials which may not comply with sediment criteria. The nature and extent of non-compliance will determine what actions are appropriate for that particular material.

BERTH DREDGING. Excavation of berth sediments by dock owners using hydraulic cutterhead dredges with subsequent placement of excavated sediments in confined disposal facilities is included in the Base Plan (Federal Standard) for the harbor. This means that the environmental aspects of such excavation and deposition has been evaluated, received public review and comment, and obtained the acceptance of regulatory agencies. When dock owners desire to implement that feature, Savannah District would be able to conduct an expedited permit application review process as long as the proposal follows the procedures described in the EIS. Since the total annual volume of harbor sediment is relatively constant, placement of berth sediments directly into confined disposal facilities should improve the Corps' ability to maintain authorized depths in the navigation channel. The multiple bidders which have typically responded to proposed maintenance dredging contracts indicates that there is currently no shortage of equipment available to perform this work. The District does not believe that the availability of hydraulic dredges will be a constraint to effective maintenance of the harbor.

COST OF BERTH DREDGING. The Corps cannot allow private dock owners to influence the final contract award decision. The award decision must follow procedures established prior to advertisement to ensure fairness to all parties who bid on the work. Discussions can continue on the evaluation criteria until work is advertised.

TESTING OF BERTH SEDIMENTS. If the berths are not used for off-channel storage for the Federal Navigation Project, the berth owners would have to complete a sediment testing program designed by the Corps prior to excavation and deposition of those sediments in a confined disposal facility under the auspices of this EIS.

DEEPENING OF BERTHS. Individual dock owners who desire to deepen their berths would receive an expedited permit application review if they propose to follow the procedures described in this EIS. That procedure includes the use of hydraulic cutterhead dredges to excavate the sediments, direct deposition of the new work and maintenance sediments in confined disposal areas, and fulfillment of the environmental criteria operative upon the Corps as a result of this EIS. Dock owners which choose to implement that alternative would be responsible for all costs associated from such implementation.

DISPOSAL SITE CAPACITY. With implementation of rotational use of the disposal areas, including the use of Disposal Area 14A, placement of berth sediments into a CDF is expected to become much easier. The District would follow an expedited permit application review procedure on proposals for hydraulic dredging of berths when the sediments are placed in CDFs. The engineering analyses performed during the LTMS determined that sufficient capacity is present at the existing CDFs, when Disposal Area 14A and dike raising are included, to contain all sediments from the inner harbor for the 20-year project life.

ADDITIONAL ALTERNATIVES. Appendix A - RESOURCE MANAGEMENT MEASURES AVAILABLE lists actions which could be taken if certain goals were established for the harbor. Many agencies and individuals have interests in the operation of Savannah Harbor. The goals of those groups are not the same, and in some cases conflict with the goals of others. The actions were included in that Appendix to describe the range of actions available to accomplish different goals and were listed without analysis of impacts which their implementation may have on other goals. The listing of an action was not intended to indicate support for that action by the Corps.

RIGHT WHALE. Appendix B, BIOLOGICAL ASSESSMENT OF THREATENED AND ENDANGERED SPECIES, has been revised to state that Savannah Harbor is not located within the critical habitat for this species.

FINAL EIS. The Final EIS does document environmental resource agency approval of the EIS and its various components.



COASTAL OFFICE: 711 Sandtown Road, Savannah, Georgia 31402 • 912/897-6462 • Fax 912/897-6470

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**PRESIDENT AND CHIEF
EXECUTIVE OFFICER**
Carolyn Bowditch

March 3, 1995

Col. Wayne W. Boy
District Commander
U.S. Army Corps of Engineers
P.O. Box 889
Savannah, GA 31402-0889

Dear Col. Boy:

Reference: Draft Environmental Impact Statement (EIS)
for the Savannah Harbor Long Term Management Strategy
(LTMS) Study

As determined in the above referenced Draft EIS and announced in the Joint Public Notice the Savannah District, U.S. Army Corps of Engineers proposes to discharge fill into navigable waters of the U.S. for diking Disposal Area 14A, construction of an access road, replacing weirs and pipe ramps. The Corps also proposes to continue discharging weir effluent from confined disposal areas into waters of the U.S., and transport dredged material from the bar channel for placement in the ocean during maintenance operations of the Savannah Harbor Navigation Project, located in Chatham County, Georgia, and Jasper County, South Carolina.

The Georgia Conservancy is a nonprofit organization of almost 10,000 people dedicated to the responsible stewardship of Georgia's vital natural resources. We strive to balance the demands of social and economic progress with our commitment to protect the environment. We appreciate the opportunity to provide the following comments.

1. Generally, The Conservancy supports the preferred alternative (Alternative 8). The Draft EIS is thorough and seems to address all pertinent issues that impact the environment. In addition, we believe that the EIS goes beyond the usual scope of work to suggest solutions to some long-standing issues.

2. The Conservancy supports the proposal to annually excavate and deepen berthing areas for off-channel storage of sediments. While the proposed alternative does not completely eliminate the practice of agitation dredging, it will have the beneficial effect of reducing that practice, thus, minimizing the negative impacts on the estuarine environment.

Col. Wayne W. Boy
February 15, 1995
page two

3. The Savannah District is funding a three-year study of striped bass in the Savannah Harbor. Deepening of the Sediment Basin should be delayed until the results of the striped bass study can be evaluated in terms of the role the Back River plays in restoration of that population.

4. We understand the proposed mitigation plan for loss of wetlands in Area 14A to be replacement of wildlife habitat function through manipulation of water levels within the disposal areas for maximum wildlife benefits, construction of a bird nesting island and construction of bird nesting mounds. The Georgia Conservancy supports the mitigation plan. However, alternative plans, such as acquisition and protection of Mulberry Grove Plantation by purchase and transfer to the U.S. Fish & Wildlife Service, should be considered. Protected as part of the Savannah National Wildlife Refuge Mulberry Grove would provide significant value as wildlife habitat to offset the losses in disposal area 14A. We request that this alternative be included in the EIS.

5. If the proposed mitigation plan for wetlands loss in Area 14A proceeds in the direction of managed and created nesting areas, a management strategy must be developed with the U.S. Fish & Wildlife Service in order to provide perpetual protection for the nesting areas.

6. Due to the rapid decline in nesting habitat for shorebirds, priority should be given to the use of dredged material for the creation of nesting areas prior to the use of materials for beach renourishment. This should be clarified in Alternative 8.

7. All sediment materials from the channel, berthing areas or other sediment basins should be tested for contaminants. Particularly those materials that will be utilized in areas where bird nesting will or does occur. This should be clarified in Alternative 8.

8. The Georgia Conservancy also believes that there is still a need to test the existing sediments in the disposal areas for contaminants. The fact that levels of arsenic were detected in underdrain discharges from two disposal sites suggests the potential for other contaminants in those sediments and potential leaching.

Thank you for your consideration of these comments.

Sincerely,



Rebecca R. Shortland
Vice President for Coastal Programs

RESPONSE -- The Georgia Conservancy,
March 3, 1995.

AGITATION DREDGING. Concur. Some of the proposed sediment control features, particularly hydraulic dredging of berths with direct deposition of excavated sediments in confined disposal areas, and deepening of berthing areas should reduce the need for agitation dredging, thereby minimizing negative impacts on the estuarine environment.

DEEPENING OF THE SEDIMENT BASIN. Deepening of the Sediment Basin was deferred until the foundational 3-years of the Corps striped bass studies were completed. Based on physical restrictions at the site, the proposed advance maintenance deepening of the Sediment Basin is not expected to adversely affect striped bass using Back River. Therefore, the District believes that an evaluation of potential environmental impacts of the proposed Sediment Basin deepening would not be substantively altered by waiting for the results of the extended striped bass study and that delaying until ongoing or yet-to-be-initiated studies concerning the disposition of the Tidegate structure are completed is not warranted.

MITIGATION PLAN. The District agrees that Mulberry Grove provides significant value as wildlife habitat. However, when the District initiated efforts to design a mitigation plan based on habitat values, state and Federal resource agencies agreed that there was a critical need for migratory and shorebird habitat in this region and that efforts should center around developing habitats for those species. The Mulberry Grove site does not provide a sufficient amount of such habitat. In addition, the present owner of the Mulberry Grove has long-term development plans for the site and would not voluntarily provide the site for use as a mitigation site.

MANAGEMENT STRATEGY. The Draft EIS contained a management strategy which includes management of water levels within the confined disposal areas and providing certain habitat features. That management strategy remains essentially the same in the Final EIS. The District does not believe that an additional management strategy developed with the FWS is needed.

BENEFICIAL USE OF DREDGED MATERIAL. An evaluation is made prior to each dredging contract to determine the best location for disposal of the sediments. Three steps are generally followed in this evaluation:

- (1) Identify a need for dredged sediments,
- (2) Evaluate the suitability of the specific sediments to be dredged for that need,
- (3) Identify sources and obtain funding for incremental costs.

The District does not anticipate conflicts to commonly occur when multiple uses for sediments obtained during a particular contract would successfully complete each of the steps listed above.

TESTING OF SEDIMENTS. A review of the quality of river sediments was documented in Appendix F SEDIMENT QUALITY EVALUATION. That evaluation concluded that the harbor sediments reflect soils of the region, as no chemical parameters within the average harbor sediments exceed values recorded in naturally-occurring soils in Georgia and the southeastern US. The District agrees that before disposal into the Project's confined disposal facilities occurs from a site that has not undergone a previous sediment evaluation by the District, both new work and maintenance sediments from that site would be evaluated.

TESTING OF DISPOSAL AREA SEDIMENTS. The District has agreed to test sediments in the confined disposal areas which will be used in the rotational program to ensure that increased use of the sites by migratory birds would not result in adverse impacts to those species.



*Ogeechee
Audubon
Society*

Ogeechee Audubon Society
4405 Paulsen Street
Savannah, GA 31405

October 25, 1995

Richard A. Hill,
Acting Chief, Planning Division,
Savannah District, Corps of Engineers,
P. O. Box 889,
Savannah, Ga 31402-0889.

Dear Mr. Hill:

Thank you for your letter dated December 2, 1994 enclosing a copy of the Draft Environmental Impact Statement for the LTMS Study for the Savannah Harbor Navigation Project.

Due to this document being mislaid in the Science Museum mail area (despite its size), we did not receive it until October 17 last. Although we appear to have passed the deadline for comments we would appreciate your keeping us informed of future developments which may have environmental impact.

Sincerely,

John R. H. Stafford,
President, Ogeechee Audubon Society

PS. I understand that the Sierra Club had the same experience with their copy.

RESPONSE -- Ogeechee Audubon Society.
October 25, 1995.

No comment necessary.

SAFE BERTH MAINTENANCE, INC.

ENVIRONMENTALLY SOUND SEDIMENT RECOVERY SYSTEMS

January 17, 1995

Mr. M. J. Yuschishin
Chief, Planning Division
Department of the Army
Savannah District, COE
P.O. Box 889
Savannah, Georgia 31402-0889

Dear Mr. Yuschishin:

I appreciated the opportunity to review the draft LTMS for the Savannah Harbor Navigation Project. It contains a great deal of information that is well developed. I commend the preparers for a job well done. This step towards achieving a management plan to secure the long term operational needs for the Savannah Harbor is important for the City of Savannah, the State of Georgia, as well as the Nation as a whole.

I support your conclusion to use Alternate 8 as the best suited plan for achieving both the NED, EQ and LED. However, the proposal to maintain the adequate depths in the berthing areas through annual channel maintenance may not be realistic. First, the current data supplied by the O&M Division clearly illustrates our collective ignorance as to where the shoaling is occurring. Secondly, we do not know what the shoaling rates are. Therefore, the spirit of maintaining the berthing areas through the use of the annual maintenance cycles may mislead both the environmental and terminal operator communities.

Your draft LTMS failed to point out the Terminal Management Corporation Agitation Study was the "preferred" method for agitation dredging (3.22 of Summary Section). This statement was made in review of the two agitation studies by both the State of Georgia DOT and DNR. I suggest this method be preferred as an alternate to perform maintenance dredging in the event the annual upland system fails to maintain the required deep drafts in the berthing areas. This method was proven to be more efficient and less environmentally damaging than the I-beam method in moving sediment away from berths. This will be necessary since not all docks in the Savannah Harbor are capable of allowing the water at the face of their docks to be deepened to the projected over-dredge or project depths. This is due to lack of engineering data to confirm existing dock piling depths. We must also look at the coordination requirements that will be necessary to review the existing soil sediment analysis and berth utilization.

P.O. BOX 2253 * SAVANNAH, GEORGIA 31402 * (912)236-1865 * FAX: (912)238-5524

Mr. M. J. Yuschishin

Page 2

January 17, 1994

I would like to focus on Section 3.04 of the Summary and clarify that non-GPA docks also can and do serve any individual or company which has an agreement with the vessel to transport its goods in the Savannah Harbor. The non-GPA docks are responsible for 45 to 50% of the annual income for services for the Savannah Harbor. The non-GPA docks are a significant portion of the active berthing facilities in the Savannah Harbor.

Southern Bulk Industries located at Mile 18 on the Savannah Harbor is one of the few dock owners mentioned in Section 3.23 of the LTMS Summary (page 31) who does have a permitted upland disposal site for dredged material. This site is small (less than 30 acres) and has a finite life as well as restricted availability for other users.

The summary in Section 4 is correct that ocean carriers and railroads compete aggressively and seek the most efficient ports to conduct their business. However, it is not just port authorities but all port users (including port authority, private and public operators) goal to provide better harbor services to accommodate and attract customers.

Sincerely,

A handwritten signature in black ink, appearing to read "Fred N. Beason, Jr.", with a stylized, cursive script.

Fred N. Beason, Jr.
Vice President

FNBjr:efa

RESPONSE -- Safe Berth Maintenance, Inc.,
January 17, 1995.

DREDGING OF BERTHING AREAS. The use of a hydraulic cutterhead dredge with direct deposition of the excavated sediments in a confined disposal area is an efficient and effective method of removing sediments which have deposited in berths. Use of the Corps' contracted hydraulic dredge would be efficient from a dock owner's perspective. However, temporary release of the Corps-contracted would only be feasible when the berth dredging would not impact the scheduled completion of the Corps' previously contracted work. The District concurs that annual dredging of berths would be insufficient to maintain depths in most berths for the entire year. The Draft EIS stated this position. Coordination with resource agencies reveals they are aware of that situation.

PREFERRED METHOD OF BERTH DREDGING. The EIS states that removal of sediments from berths through the use of a hydraulic dredge, with placement of the dredged sediments in confined disposal facilities, is the preferred method since it would minimize adverse environmental impacts.

SEDIMENT ANALYSIS. There are no specific coordination requirements for either the sediment analysis or berth utilization review which the District would perform.

USE OF PRIVATE DOCKS. Concur. Section 3.04 has been revised.

PORT COMPETITION. Concur. Section 4.03 has been revised.

COLONIAL TERMINALS, INC.

NORTH LATHROP AVENUE
POST OFFICE BOX 576
SAVANNAH, GEORGIA 31402-0576

TELEX 80-4729
FAX 912-235-3873

PHONE 912-236-1331

January 23, 1995

Myron J. Yuschishin, Chief
Planning Division
U.S. Army Corps of Engineers
Savannah District
P. O. Box 889
Savannah, GA 31402-0889

Re: Long-term Management Strategy Study

Dear Mr. Yuschishin:

Thank you for including Colonial Terminals, Inc. in the Long-Term Management Strategy review process. Colonial's three deep water berths have become key contributors to the total intermodal operation of the Port of Savannah. Modifying present harbor management practices will help reduce the maintenance expense of the various terminal operators and improve the economic benefits they provide to the community, the state and the nation.

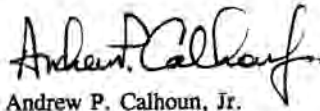
We agree that the "base plan," alternative 8, offers the best overall possibility for effective, efficient harbor operations. Any implemented plan, however, should afford terminal operators the ability to dredge their berths concurrently with dredging the navigational channel. Material dredged from berth areas would be placed in the disposal areas provided for channel dredging. Terminal operators must also retain the option of "agitation dredging." Documented siltation rates in the harbor are such that annual hydraulic dredging alone may not be sufficient to maintain authorized depths at the various berths. Further attention should be given to the system of fee assessment for dredging based on the redistribution of material that has been moved by agitation dredging.

The origin and ownership of silt material which is deposited at the various berths has been "cussed" and discussed for quite some time. Terminal operators have participated in several testing programs in the past and found that berth sediment is similar in composition to that found in the navigational channel. Test requirements for the various terminal berths mentioned in alternative 6 should, therefore, be no different than the test requirements for sediments of the contiguous navigation channel bottom. The listing of materials handled at the various terminals has traditionally remained proprietary and the reporting of any dredging events is required by 404 permits. Because of the closeness of the various terminals within the harbor, any sediment quality review required should consequently be performed on the harbor as a whole.

Myron J. Yuschishin, Chief
January 23, 1995
Page 2

Colonial appreciates the effort of the Corps of Engineers team and their recognition of the need for a comprehensive harbor management plan. This strategy allows both the private and the public terminals equal access to the benefits of a well-managed harbor operation. Thank you again for the opportunity to comment.

Sincerely,

A handwritten signature in black ink, reading "Andrew P. Calhoun, Jr." in a cursive style.

Andrew P. Calhoun, Jr.

APC,Jr/rbf

RESPONSE -- Colonial Terminals, Inc.,
January 23, 1995.

BASE PLAN. The Base Plan does include hydraulic dredging of berths with direct deposition of excavated sediments in confined disposal areas. This could include use of the Corps' contracted hydraulic cutterhead dredge with placement of the sediments in the Federal Project's confined disposal facilities. Use of the Corps' contracted dredge would be efficient from a dock owner's perspective. However, temporary release of the Corps-contracted would only be feasible when the berth dredging would not impact the scheduled completion of the Corps' previously contracted work. Approval from the disposal site's fee owner would have to be obtained by the dock owner prior to the deposition occurring. The District would follow an expedited permit application review procedure when dock owners desire to maintain their berths as proposed in the EIS, as long as the conditions described in the EIS are met. Terminal operators retain the option of seeking individual permits to perform agitation dredging.

BERTH SEDIMENTS. Berth sediments are generally finer-grained than that which settles in the navigation channel. Once new work and maintenance sediments from a berth are tested and found to be uncontaminated, subsequent testing would be performed in the same manner and timeframes as that for channel sediments. The Corps disagrees that the close spacing of terminals within the harbor demonstrate that any sediment quality review should be performed on the harbor as a whole. The quality of sediment in one berth is not necessarily indicative of the quality of sediments in other portions of the harbor. Variations in grain size exist between berth and channel sediments. The existence of the salinity wedge also introduces variation in sediment quality along the length of the harbor.

D.A. MISSROON
10 SOUTH LANCASTER ROAD
SAVANNAH, GA 31410

January 16, 1995

Colonel Wayne W. Boy
District Engineer
U.S. Army Engineer District, Savannah
P. O. Box 889
Savannah, GA 31402-0889

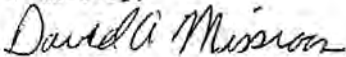
Dear Colonel Boy:

I am requesting a public hearing on the "Savannah Long Term Management Strategy (LTMS)", EIS for the following reasons.

Private properties will be contaminated, eroded, and made available for use of private birth owners.

Private industries will be given free use of property owned and maintained by the government without compensation to tax payers.

Sincerely,

A handwritten signature in cursive script that reads "David A. Missroon".

David A. Missroon

RESPONSE -- David A. Missroon,
January 16, 1995,

Savannah District does not believe that additional information, of which it is not already aware, would be gained through the conduct of a public hearing.

Box 372666
Satellite Beach, FL 32937
18 January 1995

Colonel Wayne W. Boy
District Engineer
U.S. Army Corps of Engineers
Savannah District
P.O. Box 889
Savannah, Georgia 31402-0889

Subj: COMMENTS ON ENVIRONMENTAL IMPACT STATEMENT
SAVANNAH HARBOR LONG TERM MANAGEMENT STRATEGY
(LTMS) STUDY

This is to oppose implementation of the referenced management strategy because it violates private property rights in several respects and fails to properly mitigate destruction of wetlands.

Allowing private companies to use the spoil areas without compensation to the underlying property owners is a clearcut violation of private property rights guaranteed by state and federal constitutions. No claims of overall economic benefit to the Port justifies giving to a private entity the use of property that was confiscated from other private individuals.

Moreover, the stated plan to dredge the private berths is a thinly disguised equivalent of the old-time practice of using public road-building equipment to maintain local big-wigs' driveways. The so-called dredging fees don't correct the situation.

The plan provides no protection to the underlying property owners from the arsenic and other pollutants known to be pumped onto their property in the spoil. In fact measures are taken to be sure that the pollutants pumped there stay there and therefore get concentrated year after year. Paragraph C.2.51 CDF Overflow Effluent states: "The normal harbor CDFs retain a very high percentage of heavy metals and other contaminants." The plan prescribes measures calculated to protect fish and birds in the marshes and rivers, but makes a toxic dump of citizens' property on which the Government has only an easement.

The plan proposes to mitigate destruction of wetlands by saying that dry land birds can use the dry disposal areas and water birds can use whatever disposal area happens to be under water from having been recently pumped on. These are the same disposal areas known to "retain a high percentage of heavy metals and other contaminants." What kind of nesting and feeding area is that? And how can the Government mitigate a new destruction with existing areas? Isn't the requirement to CREATE new mitigation areas to compensate for new destructions? Could a citizen meet his mitigation requirements by saying that mitigation land was hard to find and too expensive and the destroyed wetlands were not very good wetlands anyway? And, doesn't the Corps need whatever mitigation there is within the existing dikes to compensate for wetlands and creeks that lie under the spoil they have put there in the last 50 years?

I request that the strategy not be implemented until these deficiencies are corrected or a public hearing is held to discuss them.

Yours very truly,

Carolyn Allmon

RESPONSE -- Carolyn Allmon,
January 18, 1995.

VIOLATION OF PRIVATE PROPERTY RIGHTS. The EIS has been revised to clarify that private individuals or corporations are required to obtain the permission of a confined disposal area's fee owner, Chatham County, and the Corps before depositing sediments excavated from berths.

FEDERAL DREDGING OF BERTHING AREAS. Alternative 6 has been revised in the Final EIS and is now composed of privately contracted and funded dredging of those areas.

SEDIMENT QUALITY. The review of the quality of river sediments was documented in Appendix F SEDIMENT QUALITY EVALUATION. That evaluation concluded that the harbor sediments reflect soils of the region, as no chemical parameters within the average harbor sediments exceed values recorded in naturally-occurring soils in Georgia and the southeastern US.

MITIGATION PLAN. Savannah District will perform sediment testing on materials within the confined disposal areas to ensure that the habitat created in those areas is beneficial to wildlife. Creation of new areas is not a requirement for a beneficial or acceptable mitigation plan. All applicable Federal and state resource agencies have approved the Mitigation Plan contained in the Final EIS. Prior to this EIS, there were no requirements or commitments to operate existing confined disposal areas in a certain manner to compensate for creation of those sites.

PUBLIC HEARING. Savannah District does not believe that the proposed strategy is deficient or that additional information of which it is not already aware would be gained through the conduct of a public hearing.


W.C. SIMPSON, INC.
REAL ESTATE

 EIGHTEEN BROAD STREET
 CHARLESTON, SOUTH CAROLINA

TELEPHONE (803) 577-5449

 MAILING ADDRESS
 POST OFFICE BOX 909
 CHARLESTON, SOUTH CAROLINA 29402

January 18, 1995

Mr. William G. Bailey
 Environmental Resource Branch, Planning Division
 Savannah District, Corps of Engineers
 PO Box 889
 Savannah, GA 31402-0889

Reference: Properties in Jasper County owned by William C. S. Simpson, ETAL numbered TMS 036-00-02-010 and TMS 074-00-00-001

Dear Mr. Bailey:

The owners of reference properties which are partially in disposal area 14B and disposal area 12B, respectively, submit comments as follows on the draft environmental impact statement for the Savannah Harbor Long Term Management Strategy dated November 1994.

CONTAMINATION: Should liability for the quality of deposited material rest with the owner of the site where the material is deposited (par. 5.46), then the site should be:

- a) Diked along the owner's property line.
- b) Tested for contaminated disposal material within the site periodically as well as prior to and during dredging of material for disposal in the site.

EASEMENTS: The purpose for which easements were obtained from private property owners, dredged material disposal (H.2.12), is exceeded by such usage of private sites as: removal of dredged materials (A.6.02); disposal of materials dredged from privately owned berths (5.46); creation of wildlife nesting areas and resting ponds (G.4.01); establishment of production plants for construction of bricks (A.6.04) - to name a few. Further consideration or implementation of such excesses should be terminated without delay.

DISPOSAL AREA 14B (N.2.03): South Carolina lands placed under easement to provide for deposit of spoil excavated from the Savannah River did not include 480 acres along Fields Cut. This acreage, included in reference tract TMS 036-00-02-010 and partially included in Disposal Area 14B, was placed under easement as a spoil disposal area for the Intracoastal Waterway only. Hence, there is no authority for deposit of dredged material from Savannah Harbor Navigation Project on this 480 acre tract and the

practice should be terminated without delay.

DIKING OF DISPOSAL AREA 14A (M.4.19): Specifications for design of the new Disposal Area 14A dike as well all dikes in Jasper County should include the maximum height desired to assure compliance with county zoning code's now and in the future. Any raising of dike elevations should be subject to Jasper County review.

CULTURAL RESOURCES (APPD. J): Consideration has not been given to safeguarding or preserving the ferry wharf site on South Carolina's banks of the Savannah River. Nor has the old Union/Screven Ferry Road been considered. These historic landmarks were the pillars of transportation between Georgia and South Carolina from late 18th Century through the early 20th Century.

In review of the above, it is respectfully requested that the District Engineer schedule a public hearing on this project.

Sincerely,


William C.S. Simpson

cc: Mr. Henry Moss, Administrator Jasper County
Mr. Rob Mikell, OCRM, SCDHEC
Ms. Nancy Brock, SCSHPO

RESPONSE -- William C.S. Simpson,
January 18, 1995.

CONTAMINATION (PARA. 5.46): This paragraph has been revised to clarify that the liability for the quality of sediments at a berth is with the owner of the berth. That paragraph and the next one address the evaluations that must be performed to demonstrate that the material is safe for dredging and placement in the Project's confined disposal areas.

EASEMENTS: The District is reviewing its existing easements to ensure it has sufficient interests in the disposal area properties to conduct the proposed activities. Removal of deposited sediments as part of an operation to produce bricks or aggregate may require additional real estate interests to be acquired, depending on the wording of existing easements. Should additional interests be determined to be necessary, the local sponsor will be responsible for obtaining those interests. Consideration of new beneficial uses of harbor sediments will continue, as both the District and the local sponsor seek to maximize the useful life of the existing disposal areas.

DISPOSAL AREA 14B (N.2.03): Savannah District is reviewing its existing easements to ensure it has sufficient interests in the disposal area properties to conduct the proposed activities. Should additional interests be determined to be necessary, the local sponsor will be responsible for obtaining those interests.

DIKING OF DISPOSAL AREA 14A (M.4.19): Dikes would be constructed in compliance with all applicable laws and ordinances. Jasper County was provided a copy of the Draft EIS for review.

CULTURAL RESOURCES (APPD. J): The historic ferry wharf on South Carolina's banks of the Savannah River no longer exists. The upland portion of the site has been cleared and is now used as an access ramp to Back River for construction equipment. Dikes have been constructed over the location of the Union/Screven Ferry Road. The elevation of the dikes have been raised several times since the 1960's, effectively burying the old road bed under many feet of dredged material. The Final EIS has been revised to include these historic landmarks.

REQUEST FOR PUBLIC HEARING. Savannah District does not believe that additional information, of which it is not already aware, would be gained through the conduct of a public hearing.



W.C. SIMPSON, INC.

REAL ESTATE

EIGHTEEN BROAD STREET
CHARLESTON, SOUTH CAROLINA

TELEPHONE (803) 577-5449

MAILING ADDRESS
POST OFFICE BOX 802
CHARLESTON, SOUTH CAROLINA 29402

April 3, 1995

Colonel Wayne W. Boy
Savannah District Engineer
U.S. Army Corps of Engineers
P.O. Box 889
Savannah, Georgia 31402-0889

Re: Draft Environmental Impact Statement (EIS), for the
Savannah Harbor Long Term Management Strategy (LTMS)
Study dated November 1994.

Dear Colonel Boy:

Pursuant to Public Notice dated 30 November 1994 concerning reference study, I submitted comments to your office by letter dated 18 January 1995 (copy enclosed). As of this date, I have received no information from your office pertaining to my comments, scheduling of a public hearing or the status of the study.

Hence, I would appreciate hearing from you regarding the above at your earliest convenience.

With every best wish.

Sincerely,


William C.S. Simpson
Colonel, U.S. Army, Retired

Encl. a/s

RESPONSE -- William C.S. Simpson,
April 3, 1995.

Responses to all comments received on the Draft EIS, including Mr. Simpson's letters, are included in this Final EIS. Savannah District did respond directly to Mr. Simpson on May 12, 1995 to inform him that we did not plan to conduct a public hearing on this proposal.

JAMES F. MISSROON
2861 PLAYERS DRIVE
LAKE SPIVEY COUNTRY CLUB
JONESBORO, GEORGIA 30236

Subject: Request for a public hearing on Savannah Harbor Long Range Management Strategy (LTMS) and Draft Environmental Impact Study (EIS)

THIS LETTER WILL PROVE:

- (1) DISTRICT ENGINEER COLONEL WAYNE W. BOY LIED IN ANSWER TO INQUIRES CONCERNING FOIA VIOLATIONS. (5c, Page 9)
- (2) ALTERNATIVES 6, 7, & 8 OF THE EIS ARE NOT ACHIEVABLE AS PROPOSED. (1d, page 6)
- (3) THE DISTRICT HAS A LONG HISTORY OF PUBLISHING AND THEN BREAKING GLOWING ENVIRONMENTAL PROMISES. (Sect 5, pgs. 8-10)

January 19, 1995

Colonel Wayne W. Boy, District Engineer
U.S. Army Corps of Engineers
P.O. Box 889
Savannah, Georgia 30236

Dear Colonel Boy:

This is in request of a public hearing on the Savannah Harbor LTMS. My objections to the LTMS include the following list:

1. CONSIDERATIONS OF PROPERTY OWNERSHIP

Although listed in the Public Notice as an "evaluation factor", the EIS presents no analysis of property ownership considerations in regard to the confined disposal areas (CDFs).

Large tracts of the CDFs are privately owned property under perpetual easements imposed by the Corps. The owners hold fee simple title and continue to pay property taxes, already in excess of any compensation received for the imposed perpetual easements. All use of the CDF property has been completely taken by the Corps for the benefit and direct use of the Savannah shipping industry.

The CDFs are being contaminated, eroded and robbed of sand, which is then replaced by silt. The LTMS implies only two general alternatives for the owners: (1) Continue to pay property taxes while the Corps and the shipping industry maintain total and perpetual use of the land, or (2) continue to pay property taxes

until some time after the 20 year life of the LTMS, at which time the Corps may walk away from any responsibility for the contaminated and eroded CDFs. (EIS 5.46: "...liability for the quality of deposited material rests with the owner of the site where the material is deposited,...")

The EIS is not in compliance with the Federal Register unless considerations of property ownership are analyzed with specific regard to (1a) contamination, (1b) erosion, (1c) sand ownership and (1d) unauthorized disposal of spoil from non-federal berths.

1(a). Contamination of private CDF tracts.

The CDFs are diked settling ponds, carefully designed to contain any contaminants in the dredge spoil. Adjustable flood gates allow only the upper water level to overflow as the sediments settle out. This method of containment would tend to accumulate and concentrate any contaminants into the silt which is continuously being dredged from the upper surface of the river bottom. There is ample evidence of the likelihood of contamination of the soil and shallow groundwater of the CDFs.

The LTMS should insure against the almost certain contamination of the CDFs for property ownership considerations and for long term environmental reasons. The Corps has a responsibility to look beyond the useful spoil containment life of the CDFs. The only sure protection is to test the sediments within the dikes. There has never been any testing within the dikes.

- The 1994 Wright River Weir Effluent Study found elevated levels of arsenic and manganese and high marine life mortality in runoff waters from the CDFs. South Carolina banned further discharges of the runoff water into the Wright River. Again, Contaminants are generally trapped within the dikes and would not appear in runoff water.
- Sediments from the private berths in the Harbor have not been tested (EIS 5.47). For years, the corps has allowed the untested private berths to be dredged by agitation into the channel for re-dredging into the CDFs.
- The last Harbor-wide testing of sediments was in 1982. Those tests showed arsenic, cadmium, lead, mercury and silver well above the levels listed as toxic in the Federal Code of Regulations.
- The EIS relies heavily on two recent environmental studies paid for by agitation dredgers: "The Skidaway Study" and "The EMC Engineering Services, Inc. Study". U.S. Fish and Wildlife Services (FWS) and National Marine Fisheries Service (NMFS) interpreted the studies as verifying harbor contaminants at levels detrimental to marine life and as generally inadequate and inconclusive. Both agencies and USEPA have notified the Corps of the need for further testing, site specific testing, and testing in particular for dioxins and furans.

From EIS 6.05: "Introduction of water into the upper Floridian Aquifer would require contact with a fissure, fault, or ancient stream channel which would lead to this strata. This is possible, but not likely." Tests should be conducted within the dikes to preclude all possibility of metals, dioxins or other contaminants leaking into the aquifer.

EIS 6.06 further outlines the likelihood of water migration through soil layers above the aquifer and the resulting contamination of shallow ground water. Contamination of even shallow groundwater would be a violation of property rights of CDF landowners. Again, environmental concerns and considerations of property rights mandate testing within the dikes.

1(b) Erosion of Private CDFs

Shoreline erosion is listed in the Public Notice as an Evaluation Factor. The Corps recently demolished erosion protection in the form of a training wall, increased the lateral slope of the channel, and moved the channel 200 feet closer to CDF 13A. Shoreline erosion from ship wakes is now uprooting trees, washing out old dikes, and washing sediment and contaminated ooze back into the river. (See photos, next two pages, #s 4 & 5).

The CDF owners pay taxes while the Corps claims total perpetual use of the property. District Engineer Colonel Boy has arrogantly suggested that the owners also put up protection against the erosion of Corps projects. His letter to Senator Strom Thurmond, August 16, 1993: "The Government's easement does not prevent Mr. Missroon from protecting his property from erosion using methods such as rip-rap." The CDF river banks are littered with remains of the Corps' old failed rip-rap plans. The EIS should set up corrective steps.

1(c) Ownership of Sand in the Privately-owned CDFs

The LTMS proposes moving sand from one CDF tract to another for dike construction (EIS Appendix H.2.12). Sand deposited onto a private CDF, either as dredge spoil or for road or dike construction, becomes part of the property or a mineral component of the property. The easement grants to the Corps only the right to use the property for dredge spoil disposal and for other harbor maintenance activities (dike and road construction) on the property. The easement does not grant a mineral lease or the right to remove part of the property for use on another property.

The Georgia Department of Transportation (GDOT) has become a dealer in sediment sand for various local construction projects. Ownership of the sand is conferred through mineral leases from GDOT. GDOT has no mineral lease or other claim to sand on privately-owned CDFs for any type of construction, dikes or otherwise.

EROSION OF S.C. SHORELINE

The Corps removed the "training wall" erosion protection, increased the lateral slope and moved the channel 200 feet closer to this shoreline of CDF 13A.

The erosion seen here is clearly from ship wake surges with forces perpendicular to the channel. Natural erosion forces are generally parallel to the stream and do not create washouts deep into the creeks and low soft areas of the bank.

Erosion is now washing into the old contaminated dikes from the 50's and 60's. A few years ago, the marsh in the upper part of the bottom photo extended downward in a straight, marshy bank across what is now shallow water in the photo.

This not the same area where a dump truck fell into the erosion, as described in EIS Appendix H.3.25.





CONTAMINATED EROSION

These photos from the S.C. shoreline near CDF 12B/13A show deep orange liquid seeping into the river from old eroded dikes from the 50's and 60's.



GDOT determined in the 1989 "Waterways Dredged Material Containment Areas Study", page 40, that sand could not be moved across property line of the private CDFs: "Obtaining ownership in these lands will insure absolute dedication of them for disposal areas and eliminate access rights to them for hunting and other recreational activities. Additionally, GDOT ownership would improve security for the county's and contractor's equipment and remove doubt as to ownership of dredged material placed on these lands, which would, as an example, make material in 13A available for use in Area 14B."

1(d) Unauthorized Use of CDFs By Private Berth Owners.

The LTMS proposes dredging private berths into the CDFs along with scheduled channel dredging. This proposal is achievable only upon negotiations with the CDF landowners. The CDFs were condemned to easements for disposal of spoil from the Federal channel only, exclusive of any use by non-federal parties without the consent of the landowner. Constitutional law prohibits condemnation of private property for private use. The Corps has repeatedly cited the exclusion of private dredge spoil from CDFs without the owner's permission:

- EIS 3.23: "Dock owners do obtain separate approvals from both the owner of the disposal site and the Corps prior to the disposal operation."
- District Engineer Colonel D.R. Holzwarth's letter to me, June 23, 1993: "The Corps of Engineers does not have the authority to authorize the dredging of private berths onto private tracts in a disposal area without proof that the private applicant has obtained the right to do so from the disposal area landowner." ; "If a private berth owner wishes to dispose into one of these disposal areas, the private berth owner must first obtain the right to do so from the landowner." ; and "The Corps of Engineers cannot grant third party use of a Federal easement area, as this could only be given by the fee simple owner with the concurrence of the local assurer."
- District Engineer Colonel Wayne W. Boy's letter to Senator Strom Thurmond, August 16, 1993: "When a permittee proposes to undertake dredge disposal activities onto privately owned lands, the permittee is legally required to acquire rights or permission from the underlying fee owner."
- Mr. Thomas W. Yourk, Chief, Permits Section, letter to South Carolina Coastal Council, May 4, 1993: "Our Real Estate Division, from which our lease transactions have been formulated, advised us that unless Mr. Missroon grants approval to Chevron, or any other private user, this disposal area cannot be used for private use."

The Corps clearly recognizes a legal requirement for the landowner's approval prior to any private use of a CDF. The EIS should address the use of CDFs for both, (1) hydraulic dredging

and (ii) agitation dredging, in order to comply with the Federal Register requirement to evaluate considerations of property ownership.

(i) Hydraulic Dredging of Private Berths into the CDFs.
 Alternatives 6, 7, & 8 (EIS 5.00) for dredging private berths into the CDFs are clearly illegal and unattainable without the consent of the landowners. A major portion of the LTMS is not achievable as proposed.

(ii) Agitation Dredging of Private Berths. Re-dredging into CDFs.

Agitation dredging is a two-step dredging process (EIS 3.21) designed to illegally move sediment from private berths into the CDFs without the landowner's approval. The private berth owners agitate sediment from their berths into the channel and then pay private hydraulic dredgers, through the Corps, to re-dredge the sediment into the CDFs. Agitation dredging in the Savannah Harbor moves about 1/4 of the volume of material that is removed from the harbor by hydraulic dredging (EIS 7.16). Agitation dredging violates the requirement for landowner approval prior to private use of the CDFs. The EIS should address agitation dredging in consideration of the property ownership of the CDFs.

2. ILLEGAL FREE USE OF PUBLIC FACILITIES BY PRIVATE INDUSTRY

The LTMS proposes dredging the private berths into the CDFs. The only proposed fee would go to the private dredge operators. No fee is proposed for use of the CDFs. The Corps cannot legally give selected private industries the use of CDFs without reimbursement of the public cost of owning, leasing, and maintaining the CDFs.

3. SITE SPECIFIC TESTING OF PRIVATE BERTHS

EIS 5.46: "...some of the material deposited in the berths has never been tested for chemical contamination...". Site specific sediment testing of any ship berth should be required prior to any dredging regardless of disposal site (public or private) and regardless of dredging method (hydraulic, agitation or otherwise).

4. ENVIRONMENTAL OBJECTIONS TO AGITATION DREDGING

Agitation dredging is performed by towing an underwater device through private ship berths to mix thousands of cubic yards of untested sediment into the outgoing tide. The process is environmentally and operationally inefficient.

Environmentally, the process puts silt and known contaminants into tidal suspension. The resulting turbidity and reduced

dissolved oxygen levels are a major obstacle to recovery of the striped bass population.

Operationally, the same sediments must be successively re-agitated from each upstream berth to the next downstream berth before final hydraulic re-dredging into the CDFs. Agitation dredging goes on as a disgrace to Savannah and the Corps long after being banned in other U.S. ports for environmental reasons.

5. PRIOR MANAGEMENT STRATEGIES - A HISTORY OF DECEIT

The Savannah District has a history of formulating unsound management strategies in sole response to shipping industry needs and in total disregard to input from environmental organizations and the general public. The policies are then published with glowing environmental assurances and protective regulations. The published regulations are soon ignored and the District then lies to conceal the violations. I will give examples of disastrous policies, violations of published environmental regulations and lies to conceal the violations. The current LTMS promises more of the same.

(5a) The tidegate. When the District errs in favor of the shipping industry the costs to the tax payers and to the environment are usually severe. In 1977 the District installed a tidegate in Back River, dug a canal, and put in an extensive freshwater control system, primarily to alleviate natural sedimentation in shipping berths (EIS 3.10). Thirteen years later, the predictably unacceptable system had to be dismantled.

The taxpayers suffered the construction and removal of the Tidegate, digging and filling of the canal, cost of the freshwater control system, and continuing studies in hopes of reversing the damages. The environment suffered a 95 percent reduction in striped bass, a loss of 4,000 acres of freshwater tidal wetlands (EIS 7.184) and salinity increases in the Savannah National Wildlife Refuge.

(5b) Agitation dredging. Agitation dredging is another example of an environmentally damaging concession to the shipping industry. When federal environmental agencies opposed renewal of expiring agitation dredging permits several years ago, the District simply extended the old permits for three years in direct violation of a Federal Register regulation that maintenance dredging permits cannot be extended.

During the illegal three year extension, the agitation dredgers paid for two studies of agitation dredging. Three federal environmental agencies (USEPA, FWS and NMFS) rejected the studies and recommended denial of new permits. The District granted the permits, at the same time denying numerous requests for a public hearing, in violation of Federal Register guidelines for public

hearings. The District Engineer also failed to send out his written reasons for ignoring the request of each requester as required by the Federal Register.

The District announced the renewal of agitation dredging in late 1993, again, with glowing environmental assurances and protective regulations. Many of those same regulations are repeated in the current EIS-LTMS. I will show below that the District is aware of gross violations of the published regulations and is actively at work as a cover up agency for the shipping industry.

(5c) Sediment Testing in General

The EIS is vague concerning planned sediment testing during the 20-year LTMS. The EIS also fails to respond to recent criticism by three federal environmental agencies in regard to sediment testing by the Corps. USEPA, U. S. Fish and Wildlife (FWS), and National Marine Fisheries Service (NMFS) have all found sediment testing to be unsatisfactory.

The District has violated the Freedom of Information Act (FOIA) as a means of concealing from the public the inadequacy of Harbor sediment testing. I will show positively that District Engineer Colonel Wayne W. Boy lied in response to inquiries concerning FOIA violations by his staff.

Both FWS and USEPA have notified the District as recently as April 28, 1994 of the need to test Harbor sediments for dioxins and furans. On October 13, 1993 I asked Mr. William Bailey, prepare of the EIS-LTMS, whether there had ever been any dioxin tests of the river bottom or the CDFs. In early November, Mr. Bailey told me that he had written a response to my request. When his answer had not been received by late November, I submitted a FOIA for Mr. Bailey's response. I then received a response letter from Colonel Boy and a FOIA notification that Colonel Boy had destroyed Mr. Bailey's "draft" letter. Colonel Boy did not address dioxin testing.

I then sent the dioxin question to Washington. Later, the Office of Counsel in Atlanta advised that I must first agree to pay for a 3-day file search for the District to determine whether there had ever been a dioxin test in the Harbor. Soon afterward, Mr. Charles Samz of the Sierra Club of Georgia submitted a FOIA for results of all Savannah Harbor dioxin tests. His FOIA response was free, with search and production costs below the \$15.00 minimum.

The following paragraph is copied directly from Colonel Boy's letter to me December 9, 1994:

- You asked why it would take three days to give a yes or no answer concerning dioxin tests for the Savannah Harbor. A search would have to be conducted of every test to determine if a test was run for dioxins. You stated that Mr. Samz received the information for less than \$15.00 while you were informed that it

Colonel Boy's letter continued:

-2-

would take approximately three days to answer a yes or no question. In Mr. Samz' request letter of September 7, 1994, he asked for any and all studies or tests the Corps may have on record in regard to dioxin or furan levels in the Savannah Harbor as related to agitation dredging. Operations Division provided Mr. Samz with a copy of the test for agitation dredging. In your letter of May 4, 1994, to Colonel Boy, you asked "DOES THE CORPS HAVE ANY RECORD OF THE SAVANNAH HARBOR BOTTOM SEDIMENTS EVER BEING TESTED FOR DIOXINS?" Your request did not limit the search to agitation dredging; therefore, in order to provide you with the information that you were seeking, a search would have to be conducted of every project (past and present).

Colonel Boy lied to cover up FOIA violations. Mr. Samz's request was not limited to agitation dredging. The following is copied directly from his FOIA request:

Please send the following information on any and all studies or tests the Corps may have on record in regard to dioxin or furan levels in the Savannah Harbor.

1. A title page showing date, area tested, client, and testing facility.
2. A summary of the measured levels of contaminants listed by contaminant and test locations.
3. A list of conclusions, not to exceed 2 pages per report, if included in the test report.

The FOIA response to Mr. Samz reported only three soil samples taken July 28, 1992 by EMC Engineering under contract to agitation dredging permittees. All three of the reviewing agencies have found the EMC studies to be unsatisfactory. The following two sample pages (#s 11 & 12) are from seventeen pages rejecting the studies, opposing agitation dredging, and urging valid sediment testing.

(5d) Sediment Tests of Private Berths Prior to Dredging into CDFs
EIS 5.46 promises chemical testing of the private berths. That is an old promise from the Regulatory Branch (see "Guidelines", page 13). The Guidelines were only a public relations ploy to mislead the public. No private berths have ever been tested under the guidelines.

Page 2 of USEPA letter, April 28, 1994 to
District Engineer, Colonel Wayne W. Boy

The 404 (b)(1) Guidelines, Part 230.11 state that "The permitting authority shall determine in writing the potential short-term or long-term effects of a proposed discharge of dredged or fill material on the physical, chemical, and biological components of the aquatic environment ..." . The Agency requests that the agitation dredging proposal submit site specific analytical data including sediment analysis and bioassay/bioaccumulation studies as required in Part 230.11 (a) through (h). Dioxins and furans should be included in the analytical studies. >

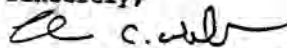
In summary, we continue to be opposed to the agitation dredging projects. We approve of the provisions of the Georgia Water Quality Certification which limits the time of year when the dredging operations can occur. However, we feel that although these provisions should lessen the impacts on aquatic life, there will still be significant adverse impacts. The Agency is also concerned with the cumulative impacts from the numerous ongoing agitation dredging projects. We recommend that the Corps coordinate these operations so that they are not proceeding concurrently.

We ask that the Corps fully consider the points raised above when evaluating this application and that the permit not be granted until these conditions are addressed. We also request that the applicant be required to comprehensively investigate innovative dredging alternatives so that we will not be facing these same issues in five years.

Previous discussions and correspondence with the Corps have not resolved the agitation dredging issue. We are not exercising our authority under Section 404(q) of the Clean Water Act, Memorandum of Agreement between EPA and the Department of the Army (8-11-92), Part III.2 to elevate this as a policy issue at this time. However, the Agency is planning to further research this issue and we are seriously considering initiating a policy elevation regarding the permitting of agitation dredging at a later date.

If there are questions regarding these comments, please contact Becky Fox of my Wetlands Regulatory North Unit staff at (404) 347-4015.

Sincerely,



Thomas C. Welborn, Chief
Wetlands Protection Section

cc: List enclosed

Page 3 of U.S. Fish and Wildlife letter, October 29, 1993 to District Engineer, Colonel Wayne W. Boy

Dredging during the spawning season would likely disrupt spawning and destroy eggs and larvae carried downstream to the project area by tidal action. The adverse impact on striped bass reproduction would reduce population levels and affect recreational fishing.

In addition, dredging may impact other fishery resources as well as striped bass by reducing dissolved oxygen to concentrations that cause stress or mortality (≤ 3.0 mg/l), particularly during July, August, and September when dissolved oxygen levels are naturally low.

In addition to high turbidity and low dissolved oxygen, data from the Skidaway Institute of Oceanography study (1993)¹ (Skidaway) indicates that contaminants are also a problem in the Savannah Harbor. Even though the berths in the Skidaway study (East Coast Terminals and Southern Bulk Industries) are not likely to receive significant contaminant inputs from onsite activities which involve only the onloading and offloading of cargo, the reported levels for metals were at a concentration known to cause adverse effects on aquatic organisms. The Skidaway study also found DDT and its metabolites in the slips at East Coast Terminals and Southern Bulk Industries at levels known to exhibit deleterious biological effects on aquatic organisms. Polyaromatic hydrocarbons were found in levels above "Effects-Range Low" in the slips which are not likely to receive significant input of this contaminant from onsite activities. It is therefore likely that the petroleum based companies in this public notice, which produce and/or transport these chemicals, will have significantly higher levels of polyaromatic hydrocarbons in their slips.

Skidaway did not test for all organics known to occur in the general vicinity (eg. dioxins and furans); therefore we don't know at what levels these contaminants, which are included on EPA's list of priority pollutants, occur in the Harbor.

The EMC Engineering Services, Inc. study (1993)² (EMC) also reported levels of metals known to have adverse effects on aquatic organisms. Their data on organics, however, are unusable because the detection limits cited for their laboratory procedures are several magnitudes above levels known to cause adverse effects to organisms.

In conclusion, at a minimum, both the Skidaway and EMC studies have indicated that contaminant levels in Savannah Harbor sediments are high enough to cause detrimental effects to organisms if resuspended by agitation dredging. Data on some contaminants is insufficient to allow us to fully understand potential impacts to aquatic resources. Neither study addressed the cumulative effects on aquatic organisms downstream.

Note: The Regulatory Branch mailed these Guidelines with an announced renewal of an agitation and hydraulic dredging permit. No testing has been done under the Guidelines.

GUIDELINES FOR PRIVATE DREDGING WITH DREDGED
MATERIAL PLACEMENT IN GOVERNMENT CONTAINMENT AREAS

The special conditions to be added to special conditions of all future applicable permits are:

a. At least 30 calendar days before private dredging is to begin, the following information should be furnished to the U.S. Army Corps of Engineers, Project Operations Branch, with a request to conduct the dredging:

(1) A copy of the Local Assurer-Private Concern agreement allowing use of specified containment area(s). The Private Concern should be required to comply with all applicable Federal, State, County, and Municipal laws, regulations, and any special conditions in the Department of the Army Permit.

(2) Results of priority pollutant sediment tests - EPA 301 including petroleum hydrocarbons. Sampling and testing should be required to be conducted by an independent laboratory. Sampling should be done within 90 days prior to scheduled dredging. The private concern should provide evidence that his actions have not caused pollution at the proposed dredging area during the time between sampling and dredging. Sample locations should be provided on a sketch. One test set per 500 feet of berth should be required. Results of all tests shall be provided to the Government and Local Assurer. The Savannah District Engineer will consider requests to modify the test scheme when presented with factual data indicating a modified test scheme would be more appropriate.

(3) A plan for placement of the pipeline outfall head section and monitoring of dredge, weirs, and dikes including repair of any dike or weir failures occurring during the time the dredge is released to dredge for private concerns. There should not be a required format for the plan. A simple statement of actions to be taken is adequate. Any property damaged or destroyed by the private concern, including dikes and weirs incident to the exercise of the privileges granted, should be required to be promptly repaired by the Private Concern to the satisfaction of the Local Assurer in concurrence with the Savannah District Engineer.

(4) A rough estimate of quantity of material to be dredged.

(5) A plan for conducting water quality tests (salinity, conductivity, turbidity, dissolved oxygen, pH, total suspended solids) at the containment area weirs if the dredging for the Private Concern is to take more than five calendar days. One set of water quality tests should be required for every five calendar days of dredging at a private concern.

The Corps issued Georgia Ports Authority (GPA) permits for dredging its berths into CDF 2a in 1994. GPA did so without testing. Colonel Boy responded that the EIS for the Deepening Project exempted GPA from the required testing. The EIS did not meet the sediment testing requirements of the Guidelines. The District simply wrote the test requirement out of the Deepening EIS in a continuing policy to excuse the shipping industry from all testing requirements.

The LTMS EIS states that the private berths have not been tested and should be tested prior to dredging into the CDFs. In contrast, the District has for years allowed agitation dredging of untested private berths with final disposal into the CDFs.

(5e) Dredging during the striped bass spawning period.

EIS 6.54 reads, in part: "Therefore, to remain in compliance with the Georgia Quality Certification and avoid possible impacts to the striped bass population of the Savannah River, dredging continues to be restricted to the lower harbor and the Bar Channel during the period from March 15 to May 31 of each year." There is no reference to exceptions.

That is another old broken promise from the Regulatory Branch. The Branch will grant any dredge permittee an exception for "urgent" dredging. The records for 1992 - 1994 show no denials. The only requirement is a little paperwork. The records show seven separate approvals, usually for one week each, during the 1992 spawning period. Five similar approvals were granted in 1994. Many more requests for exceptions can be expected with the deepened channel.

(5f) Dredging During Months of Low Dissolved Oxygen.

EIS 7.37 outlines procedures for the monitoring and restriction of agitation dredging during summer months when dissolved oxygen (DO) levels are reduced. That is another old broken promise from the Regulatory Branch.

The next page, #15, was distributed by the Regulatory Branch to assure the public that the Branch would monitor DO testing during summer months. The Branch also distributed the following "special condition" promising to "avoid" dredging during summer months.

7. That dredging will be avoided from June 1 through September 30. If justification for dredging during this period is adequate, the permittee will determine oxygen levels in the project area immediately before dredging. No dredging will be allowed if dissolved oxygen levels are 3.0 mg/l or less. If dissolved oxygen is less than 4.0 mg/l, the permittee will monitor dissolved oxygen during dredging and ceased when the dissolved oxygen drops to 3.0 mg/l or less. The permittee will provide the U. S. Army Corps of Engineers with all monitoring data.

July 11, 1989

DISSOLVED OXYGEN TESTING PROCEDURES
IN CONJUNCTION WITH SPECIAL CONDITIONS
FOR AGITATION DREDGING PERMITS

The following water quality procedures will be implemented as a procedural requirement of the special conditions as contained in all permits for agitation dredging as issued by the Savannah District.

The determination of existing DO levels prior to dredging is the first decision point to allow dredging during the time period 1 July - 30 September. Dissolved Oxygen levels in the Savannah River will be obtained no later than 3 days prior to initiation of dredging. Three sample locations will be established in the Savannah River to determine existing conditions. These three sample locations will be placed: 1) 1,000 ft. upstream from permittee's slip, 2) 1,000 ft. downstream from permittee's slip and 3) adjacent to permittee's slip, all approximately at or on a mid river center line. At each sample location, three depths will be sampled during low water slack or high water slack, when possible, as follows: 1) one meter below the surface, 2) one meter above a hard bottom or 2-3 meters above a soft or indeterminate bottom, and 3) at mid depth. If greater than 50% (5 of 9) of the readings are below the 3mgO /liter standard, dredging will not be permitted. A retest can be repeated in two weeks.

If 5 of 9 samples are above the standard, dredging will be permitted to commence within three days of existing condition sampling. Monitoring will consist of the same sampling regime to be conducted every second day of consecutive dredging. Should any 5 of 9 readings fall below the 3mgO /liter standards, dredging will be suspended for two weeks at which time existing condition sampling can be repeated. All test results for all locations and depths will be reported to the Chief, Regulatory Branch of the Savannah District within one week after the completion of dredging. The Savannah District reserves the right to conduct additional sampling for DO in the Savannah River and on the basis of this information may require the suspension of dredging activities. A Dissolved Oxygen meter or other methods as approved by EPA for the measurement of Dissolved Oxygen in Estuarine or fresh waters is required. A location map, date of sampling, tide condition (flood or ebb) depth in meters and DO will be reported. Instruments (manufacturer's make and model) and/or methods used for DO measurement along with calibration technique and results should be reported as well.

To the contrary, DO testing by the permittees is not monitored and agitation dredging is not avoided during summer. The level of agitation dredging is highest during summer months.

Open Records requests and FOIA requests confirm that none of the permittees sent DO test results to the Corps or to any state environmental agency for 1993 or 1994. No inquiries were made for 1992. The Corps is aware that DO testing is not being monitored and has taken no action.

A summary of agitation dredging activity for FY '91 to FY '93:

Quarter	Average per quarter	
	hrs.	cubic yds. (@ 2,100 CY/hr., EIS 7.18)
Jan, Feb, Mar	205	430,530 (spawning Mar 15 - Mar 31)
Apr, May, Jun	183	384,300 (spawning Apr 1 - May 31)
Jul, Aug, Sep	260	546,000 (Low dissolved oxygen)
Oct, Nov, Dec	156	327,600

Once again, the regulations in regard to the spawning season, DO test monitoring, and dredging restrictions during low DO months were all published to mislead the public without restricting the environmentally damaging activities of the shipping industry.

(5g) Violations of Corps' Policy for Disposal onto Private CDFs
Consider the published policy on third party use of the CDFs. EIS 3.23 reads: "Dock owners do obtain separate approvals from both the owner of the disposal site and the Corps prior to the disposal operation." District Engineer Colonel D.R. Holzwarth's letter to me, June 23, 1993: "The Corps of Engineers cannot grant third party use of a Federal easement area, as this could only be given by the fee simple owner with the concurrence of the local assurer."

To the contrary, the next page (#17) is from a Corps permit granting GPA permission to dredge onto CDF 2a. Under this permit, GPA dredged untested sediment onto property owned by Fish and Wildlife in CDF 2a without FWS approval and without concurrence of the local assurer. The GPA berths were also dredged without the tests as required by the "Guidelines" on page 13.

DEPARTMENT OF THE ARMY PERMIT

Permittee: Georgia Ports Authority
 Permit Number: 199200090

ISSUING OFFICE:

Savannah District
 U. S. Army Corps of Engineers
 Post Office Box 889
 Savannah, GA 31402-0889

NOTE: The term "you" and its derivatives, as used in this permit, means the permittee or any future transferee. The term "this office" refers to the appropriate district or division office of the U. S. Army Corps of Engineers having jurisdiction over the permitted activity or the appropriate official of that office acting under the authority of the commanding officer.

You are authorized to perform work in accordance with the terms and conditions specified below.

PROJECT DESCRIPTION: To excavate by dredging at two areas.

a. Berth - An area approximately 5,075' long, 100' wide from the face of the fenders to the channel line to a depth of -42' mean low water (mlw). Excavation at this site will require initial removal of approximately 35,000 cubic yards of accumulated sand, silt, clay and debris material and periodic maintenance dredging of approximately 80,000 cubic yards annually.

b. Slip - An area approximately 1,100' long, 300' wide, between the face of the fenders to a depth of -40' mean low water (mlw). Excavation at this site will require initial removal of approximately 80,000 cubic yards of accumulated sand, silt, clay and debris material and periodic maintenance dredging of approximately 80,000 cubic yards of material annually.

The permittee, in conjunction with the proposed hydraulic dredging, will place a temporary submerged pipeline from the sites across the river to dispose of the dredged material in the diked area of Disposal Area 2 A on Hutchinson Island. Dredging is necessary to provide adequate depth for deeper draft vessels using the facilities.

The site is currently authorized by Department of the Army Permit to perform agitation maintenance dredging. The Savannah River is a Federal Project maintained by the Savannah District, U. S. Army Corps of Engineers.

PROJECT LOCATION: The site is located in Savannah River, at the Ocean Terminal berths, Savannah Harbor River Mile 14.7 to 15.6 (Sta. 77+500 to 82+500), Lat. 32°07'00"N, Long. 81°07'00"W, Savannah, Chatham County, Georgia.

6. PLEASE PROCESS THIS LETTER IN ACCORDANCE TO EIS 8.05 AND THE FEDERAL REGISTER.

(6a) EIS 8.05

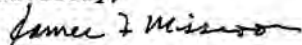
Please address each of my comments, listed below, in the comment/response section of the final EIS as specified in the Draft EIS 8.05

- considerations of property ownership (privately owned CDFs)
 - contamination
 - erosion
 - ownership of sand, in terms of laws and regulations, rather than vague rationalizations (EIS H.2.12)
 - unauthorized disposal for private hydraulic dredging
 - unauthorized disposal for agitation dredging
- Free private access to publicly owned and maintained CDFs.
 - for proposed hydraulic dredging
 - for agitation dredging.
- Site specific testing of private berths prior to dredging
 - for hydraulic and agitation dredging
 - with disposal onto government and privately owned areas

(6b) Please schedule a public hearing in accordance to the Federal Register, Part 327.4(b)

(6b) If no public hearing is scheduled please communicate to me the reasons why you have determined the issues I have raised are insubstantial, as required in Part 327.4(b).

Sincerely,



James F. Missroon

cc: Senator Sam Nunn
 Senator Paul Coverdale
 Lieutenant General Arthur E. Williams, Chief of Engineers
 Mr. John Hankinson, USEPA
 Dr. Gregory Madison, U.S. Fish and Wildlife Service
 Mr. Andreas Mager, Jr., National Marine Fisheries Service
 Mr. Charles Samz, Sierra Club of Georgia
 Mr. Harold F. Reheis, Ga. DNR
 Mr. Thomas E. McCutchen, Columbia, S.C.
 Mr. William C. Simpson, Charleston S.C.
 Ms. Becky Shortland, Georgia Conservancy
 Mr. L. J. Thomas, Hardeeville, S.C.
 Students for Environmental Awareness, University of Georgia
 Mr. Rich Whitt, Atlanta Journal- Constitution
 Mr. Brad Swope, Savannah News Press

RESPONSE -- James F. Missroon,
January 19, 1995.

REQUEST FOR PUBLIC HEARING. Savannah District does not believe that additional information, of which it is not already aware, would be gained through the conduct of a public hearing.

CONSIDERATIONS OF PROPERTY OWNERSHIP.

A. Contamination.

A review of the quality of river sediments was documented in Appendix F SEDIMENT QUALITY EVALUATION. That evaluation concluded that the harbor sediments reflect soils of the region, as no chemical parameters within the average harbor sediments exceed values recorded in naturally-occurring soils in Georgia and the southeastern US.

Paragraph 5.46 in the Draft EIS has been revised to clarify that the liability for the quality of sediments while deposited at a berth rests with the owner of the berth. That paragraph and the next one address the evaluations that must be performed to demonstrate that the material is safe for dredging and placement in the Project's confined disposal areas.

The District has agreed to test sediments in the confined disposal areas which will be used in the rotation program to ensure that increased use of the sites by migratory birds would not result in adverse impacts to those species.

If/when the Federal government decides that it no longer needs an easement for the Navigation Project, it would release its easement ownership. Under current procedures a Preliminary Assessment Screening would be performed to determine the condition of the property, including an evaluation of the potential for chemical contamination, prior to release of the easement. If the Preliminary Assessment Screening determines the site contains unacceptable levels of some chemicals, liability for that condition would be determined in accordance with the laws and regulations in effect at the time of the release. Under present laws, the landowner -- because of his ownership status -- would be considered a potentially responsible party. However, a party or combination of parties involved in the Navigation Project may choose to assume responsibility if they had maintained sole restrictive use of the site since the project easement was obtained. If contamination was discovered and a party or combination of parties involved in the Navigation Project chose to assume responsibility, under present clean-up standards the site would be cleaned prior to release of the

easement to the point where the chemicals would no longer be present at levels which constitute a health or safety hazard. It should be noted that this current site clean-up standard may not represent the standard or laws in effect at the time of the easement release.

B. Erosion.

Training walls placed in a river are intended to shift underwater river currents, not protect a shoreline from eroding. The training walls placed in Savannah Harbor were not intended to reduce erosion, but to concentrate the river flow so that (1) the channel alignment would be more stable and (2) a deeper channel depth would be maintained by river currents.

As mentioned in Section H.3.25 of the Draft EIS, erosion of the outside slope of the front dikes along the Savannah River is a problem. The apparent major cause of the erosion is the wakes and propwash produced by the large container ships. Erosion from such sources is not the responsibility of the Corps, but the vessel owner/operator.

Chatham County, acting as the local sponsor, or the GA Department of Transportation (GA DOT), acting in behalf of the County, have received approvals to place shore protection measures along portions of the Savannah River shoreline of the dikes. A portion of the approved project, approximately 800 to 1,000 feet, would be placed to protect Mr. Missroon's property. GA DOT intends to place the shore protection measures along highly eroded portions of the riverbank to protect the dikes which extend along the shore. GA DOT will place the majority of the shore protection on property which it owns in fee, an action which any landowner has the option of pursuing. The Final EIS includes an evaluation of placing additional shore protection measures along portions of the Jones/Oysterbed Island shoreline. That shoreline is also eroding severely and GA DOT intends to protect both its property and the adjacent dike through that action.

C. Ownership of Deposited Sediments. The State of Georgia claims ownership of all lands within the state up to the Mean High Water elevation. Materials resting on the river bottoms are included. Excavation of sediments from Georgia river bottoms require approval from the state for the disposition of those state properties. Sometimes the state charges a fee for excavation and private use of those state resources. The state has given the Corps approval to excavate river sediments and place them in the confined disposal facilities. State approval has been provided contingent upon use of the sediments for the purposes of the Federal Navigation Project. The Georgia GA DOT currently administers the use of the state bottoms in Savannah Harbor. Should GA DOT decide that it needs some of the deposited

sediments for uses other than harbor purposes, such use is within its authority for materials deposited on land it owns. If/when the Federal government decides that it no longer needs to use a disposal area for the Navigation Project, the Government would release its interest in the property.

D. Disposal for Private Hydraulic Dredging.

When private individuals or firms perform dredging in the harbor, that individual or firm is responsible for obtaining a site to deposit the excavated sediments. If those individuals are dredging under authority obtained through a Section 404 permit administered by the Corps, a condition of the permit is typically that they must obtain permission from the underlying fee owner of the CDF.

Such a condition would also be in effect if/when a dock owner wishes to use a hydraulic dredge to excavate berth sediments and place them directly in a Project CDF. In that case, approval from the site's underlying fee owner, Chatham County, and the Corps would be required.

The EIS for the LTMS Study evaluated the excavation of berth sediments and their deposition in the CDFs used for the Navigation Project. Environmental clearance for the specific dredging and disposal techniques approved in the EIS would be obtained through this EIS for such actions, whether Savannah District or its designee implemented the action. When a dock owner desires to implement the berth dredging features proposed in the EIS, the District would follow an expedited review of the permit application since the environmental impacts of that action have already been evaluated in this EIS, received public review and comment, and received approval from other regulatory agencies. Approval would be required from the disposal sites's underlying fee owner before the deposition could occur.

E. Disposal for Private Agitation Dredging.

When berth owners perform agitation dredging, the sediments are distributed by river currents to other portions of the harbor. Savannah District believes that a majority of those sediments resettle in the Federal Navigation Project. Some redeposit just downstream of the berth being dredged, while finer-grained materials are likely to move further from the dredging area. A precise identification cannot be made of the locations where all the berth sediments redeposit. The Corps presently removes all sediments which settled in the Navigation Project and deposits those materials in its approved dredged material disposal areas. Removal of harbor sediments which had once been located in a berth, but have since been relocated into the Navigation Project as a result of either agitation dredging or normal tidal or river currents, becomes a responsibility of Corps under the terms of the cost sharing agreement for the Savannah Harbor Navigation Project.

FREE PRIVATE ACCESS TO FEDERAL PROJECT CDFS.

A. Hydraulic Dredging.

Berthing areas are important to the Federal Navigation Project as they provide areas for vessels to dock outside the navigation channel while loading/unloading cargo. Adequate depths are required in the berths, as well as the navigation channel, before ships can move their goods through the port. Before sediments excavated from berths by private interests could be placed in an upland confined disposal site, the dock owner must obtain approval from the disposal site's underlying fee owner.

The provision and maintenance of suitable CDFs for the Federal Navigation Project is the responsibility of the local sponsor, Chatham County. The County is responsible for developing and providing to the Corps sufficient storage capacity at the CDFs for use by the Federal Navigation Project. The sponsor can allow use of the CDFs which it owns in fee simple for placement of materials from sources other than the Navigation Project. A decision to charge private individuals for using storage capacity of the site is a decision of the County.

B. Agitation Dredging. In agitation dredging, sediments are lifted from the floor of the berth by physical agitation and subsequently moved off-site by river currents. The District estimates that eighty percent of the sediments removed from the berths redeposits in the Navigation Project. The Corps presently removes all sediments which have settled in the Navigation Project and deposits those materials in its approved dredged material disposal areas. Removal of harbor sediments which had once been located in a berth but have since been relocated through agitation dredging into the Navigation Project becomes a responsibility of Corps under the terms of the cost sharing agreement for the Savannah Harbor Navigation Project.

TESTING OF SEDIMENTS AT BERTHS.

A. For Hydraulic and Agitation Dredging.

A sediment evaluation is required to complete the Section 404(b)(1) Evaluation for any dredging and disposal activity. Appendix F SEDIMENT QUALITY EVALUATION contained a review of the quality of river sediments. That evaluation concluded that the harbor sediments reflect soils of the region, as no chemical parameters within the average harbor sediments exceed values recorded in naturally-occurring soils in Georgia and the southeastern US.

CHRONOLOGY OF DELAYED FOIA RESPONSE

December 28, 1994: I submitted a FOIA request for any easements which would allow disposal of Harbor spoil onto CDF 14B. I related the request to EIS-LTMS public response.

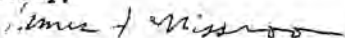
January 6, 1995: The Corps responded: "Please be advised that our project Management Division does not have any records that fulfill your request because the Corps does not have the environmental clearance to use CDF 14B." I called back and asked specifically for any easement allowing disposal of Harbor spoil onto the Simpson tract in 14B.

January 13, 1995 The Corps mailed a cancellation of the earlier response and two easements for disposal onto two tracts owned by GDOT, one in 13B and one in 14B. I called back and again specified the Simpson tract, CDF 14B and Savannah Harbor dredge disposal.

January 25, 1995: The Corps Fedex'ed an easement allowing only for disposal of dredge spoil from the Inland Waterway onto the Simpson tract. I called again and was informed by Mr. Warren G. Svartz that the Corps has no other easement on the Simpson tract, i.e. no easement for disposal of Harbor dredge spoil.

Please advise me as to whether these comments will be considered with my earlier comments..

Sincerely,



James F. Missroon

cc: Senator Sam Nunn
 Senator Paul Coverdell
 Lieutenant General Arthur E. Williams, Chief of Engineers
 Mr. John Hankinson, USEPA
 Dr. Gregory Madison, U.S. Fish and Wildlife Service
 Mr. Andreas Mager, Jr., National Marine Fisheries Service
 Mr. Mark Musaus, U.S. Fish and Wildlife Service
 Mr. Charles Samz, Sierra Club of Georgia
 Mr. Harold F. Reheis, Ga. DNR
 Mr. Thomas E. McCutchen, Columbia, S.C.
 Mr. William C. Simpson, Charleston S.C.
 Ms. Carolyn Boyd Hatcher, CEO, Georgia Conservancy
 Ms. Becky Shortland, Georgia Conservancy
 Mr. L. J. Thomas, Hardeeville, S.C.
 Students for Environmental Awareness, University of Georgia
 Ms. Debra Hasan, Citizens for Environmental Justice
 Mr. Rob Mikell, OCRM, SCDHEC
 Mr. Henry Moss, Administrator, Jasper County
 Mr. Rich Whitt, Atlanta Journal- Constitution
 Mr. Brad Svope, Savannah News Press

RESPONSE -- James F. Missroon,
January 27, 1995.

REQUEST FOR PUBLIC HEARING. Savannah District does not believe that additional information, of which it is not already aware, would be gained through the conduct of a public hearing.

DEPOSITION OF DREDGED MATERIAL ONTO DISPOSAL AREA 14B. Savannah District is reviewing its existing easements to ensure it has sufficient interests in the disposal area properties to conduct the proposed activities. Should additional interests be determined to be necessary, the local sponsor will be responsible for obtaining those interests.

DEPOSITION OF BERTHING AREA SEDIMENTS ONTO PRIVATELY-OWNED LANDS. Berthing areas are important to the Federal Navigation Project as they provide areas for vessels to dock outside the navigation channel while loading/unloading cargo. Adequate depths are required in the berths, as well as the navigation channel, before ships can move their goods through the port. As stated in the EIS, before sediments excavated from berths by private interests could be placed in an upland confined disposal site, the dock owner must obtain approval from the disposal site's underlying fee owner.

MITIGATION PLAN. The additional wildlife habitat described in the Mitigation Plan is based on a 2-year rotational use of the disposal areas. Disposal Areas 12A, 12B, 13A, 13B, 14A, 14B, and Jones/Oysterbed Island are included in the rotation plan.

Rt. 2, Box 324
Hardeeville, SC 29927

February 21, 1995

Colonel Wayne W. Boy
District Engineer
U.S. Army Corps of Engineers
P.O. Box 889
Savannah, GA 31402-0889

Dear Colonel Boy:

I am a long time resident of Jasper County, South Carolina, and own land in the Savannah River spoilage site area.

In the mid 50's, the Corps of Engineers (COE) imposed, much to our dissatisfaction, a perpetual easement on our land for the purpose of dredging silt from the Savannah River harbor. The government paid my husband (who passed away in 1964) approximately \$22,000 for the easement. The COE has pumped spoilage on my land since that date. At the time of the condemnation we were verbally led to believe that we should expect to have our land returned in less than 30 years. In the 40 years that the COE has now been pumping on my land, it has cost me more than \$25,000 in annual property taxes.

During these 40 years I have never complained about the above actions, nor objected when me or my family were not allowed access to this property. It could be said that I have been the model landowner as far as your purposes were concerned. However, it has come to my attention on February 13 of this year the COE held a public hearing in January concerning pumping on my land for another 20 years. I have since received a document concerning this public hearing and an environmental study that accompanied it.

I notice several things in this document entitled the Savannah Harbor Long Term Management Strategy (SHLTMS) published by the COE. First, it appears that your agency went to a lot of trouble to notify many people and agencies about this study. I am disturbed that you could not place my name and a 29 cent stamp on one of the notices since it is my land you are studying and using.

Second, and of more importance is that the document reflects a study by the S.C. Coastal Council, S.C. Department of Health, and S.C. Marine Resources noting high/elevated levels of arsenic coming from the runoff of the spoilage area into the adjacent S.C. rivers. Furthermore, the arsenic and other chemicals, which are killing marine life in those rivers, were of such concern to those S.C. agencies that they ordered your agency to reroute the runoff where it cannot enter S.C. waters. It is my understanding you you have agreed to route this contaminated runoff into the Savannah River at the city of Savannah by January of 1995.

FEB 23 1995

Colonel Wayne W. Boy

Page Two

February 20, 1995

Since I have been inquiring into this problem, I have also been advised of other studies that have been conducted regarding my land by other agencies. I have requested and received copies of studies from the COE, and the NOAA-Marine Fisheries Laboratory at Charleston, S.C. I have been informed of and requested other studies that have been completed by the U.S. Fish & Wildlife Service the University of Georgia. I have further been advised of other studies of which I have requested. Of all the studies conducted, each seem to reveal a high level of dangerous chemicals which have been and are currently being pumped onto my land.

To add insult to injury, I have been advised that your agency holds the opinion that I am liable for any chemicals which exist on my property. Since that is your opinion, I am demanding that you stop dredging on my property as I am not able to accept that liability.

I realize that the government had the authority in the 1950's to condemn this land for an spoilage easement, but I do not think the government can place toxic chemicals on this or any other personal property. The pristine quality of my property has been destroyed and you expect me to assume the liability.

I am disgusted that your agency has destroyed my property as well as that of adjacent landowners, but am grateful that the state of South Carolina responded and stopped your agency from contaminating our rivers. However, I am concerned that you continue pumping this poisonous waste into the Savannah River.

Many people in the low country of Jasper and Beaufort counties as well as those of the city of Savannah and Chatham County enjoy boating and fishing in the Savannah River, you should not be allowed to expose them to increased levels of dangerous chemicals caused by dredging operations. Additionally, numerous fish and wildlife have suffered detrimental effects from this contamination.

What effects will these chemical findings now have on the Olympics that are scheduled to come to Savannah for water sports in and around the Savannah harbor? The people of the Olympics certainly need to be made aware of all the chemicals now being stirred up and pumped into the Savannah River due to the dredging operation.

I understand that the Georgia Ports Authority needs deep channels to run ships. However, other ports have faced this problem and have chosen to take their spoilage out to sea. Since we have this option, it should be exercised to reduce the pollution in this area.

Colonel Wayne W. Boy

Page Three

February 20, 1995

I guess I should not place all the responsibility for this problem on your agency as your study reflects that Chatham County, Georgia is responsible for maintaining the spoilage area facilities in Jasper County, South Carolina. Additionally, the Georgia Department of Transportation (GA DOT) serves as the owner/operator of the spoilage area. Just because they have been using this land improperly for 40 years, gives them no right to call themselves the owner.

Approximately 5 years ago the GA DOT offered me \$300 per acre for my land in the spoilage area on the Savannah River, which I refused. At the same time, they did purchase several hundred acres adjacent to me for approximately \$900 per acre. At the time I did not understand the difference in the price, but now I firmly believe they knew they had already contaminated my land through the COE dredging operation.

The environmental impact on Jasper County and the city of Savannah is criminal. Many residents of Jasper, Beaufort and Chatham Counties either work in the fishing industry or simply enjoy the waterways. With the documented findings of the above mentioned studies, we now know that marine life cannot survive in the contaminated waters adjacent to the spoilage area; and we also know by these studies that the contamination will get worse before it gets better.

We host the largest waterfowl area (at the spoilage site) of any location near this area. We have ducks by the thousands on my property. It is sad to know the quality of water in which they feed and swim. I would like to go out and put up a sign stating POLLUTED WATER, DO NOT NEST, DRINK OR FEED IN THIS AREA, but it will not be that easy to save our dying duck populations. I wonder how long they can live after being exposed to high levels of ARSENIC, CADMIUM, COPPER, LEAD, MERCURY, NICKEL, SILVER, ZINC and MANGANESE as well as POLYCYCLIC AROMATIC HYDROCARBONS. Additionally, what is the effect on humans who consume fish, shellfish and wildlife from these contaminated areas.

A study should now be done on the amount of pollutants in the air in the city of Savannah less than a mile south of the spoilage area when a north wind blows across the dry, loose polluted sand. There is very little vegetation in the spoilage area and this could cause a threat to the entire city of Savannah. My belief is based on the findings in the strategy study of the COE and the study conducted by NOAA at the Charleston, S.C. laboratory.

Three years ago I leased an old abandoned service station site to the U.S. Postal Service in Hardeeville, S.C. During the excavation of the land, the S.C. Health Department discovered an old underground gas tank. I had to pay \$20,000 to have the old tank and nearby dirt removed and burned in Charleston, S.C., in order to comply with EPA regulations.

Colonel Wayne W. Boy

Page Four

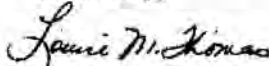
February 20, 1995

I must question if your agency would be responsible for removing the contaminated dirt from the spoilage area to have it properly disposed. I welcome EPA involvement to enforce their regulations in having your agency return this land to the pristine condition that existed prior to dredging.

I have several reports from federal and state studies that document the contamination you have pumped on my property. I demand you stop the pumping of contaminated spoilage onto my property in Jasper County, South Carolina.

Please reply to me within 10 days, as I believe that would be sufficient time. I request all replies be sent to my daughter and son-in-law, Bonnie and Duane Swygert who live next door on our farm. Their home number is 803-784-2699 and work is 803-784-2844. The mailing address is P.O. Box 486, Hardeeville, SC 29927.

Sincerely,


Louise M. Thomas

RESPONSE -- Louise M. Thomas,
February 21, 1995.

Savannah District provided a response to Ms. Thomas in a letter dated March 19, 1995. The environmental issues raised in her letter are addressed individually in the following paragraphs:

PUBLIC HEARING. No public hearing was held in January for the Savannah Harbor LTMS Study.

WEIR EFFLUENT STUDY/UNDERDRAINS. As a result of information which became available through the weir effluent study conducted by Savannah District, the District volunteered to close underdrains which discharge to the small tidal creeks in South Carolina. Those small creeks had insufficient flow capacity to accept those discharges without impacts which the District determined to be unacceptable to the aquatic resources in those creeks. One component of the LTMS was an evaluation of the installation and operation of new underdrains which would drain the other direction from that previously in use so that they would discharge to the Savannah River or Back River.

SEDIMENT QUALITY. The review of the quality of river sediments was documented in Appendix F **SEDIMENT QUALITY EVALUATION.** That evaluation concluded that the harbor sediments reflect soils of the region, as no chemical parameters within the average harbor sediments exceed values recorded in naturally-occurring soils in Georgia and the southeastern US. The concentration of chemicals found in the sediments were below levels which would cause adverse impacts to humans who consume fish, shellfish or wildlife that may use the disposal areas or the receiving waters. The District is aware of no information which supports Ms. Thomas's statement concerning the quality of materials being deposited on her property. Therefore, the District disagrees with Ms. Thomas's statement concerning the quality of the deposited sediments.

LIABILITY. The paragraph in the EIS mentioning this issue (Section 5.46 in the Draft EIS) has been revised to clarify that the liability for the quality of sediments while at a berth rests with the owner of the berth. That paragraph and the next one address the evaluations that must be performed to demonstrate that the material is safe for dredging and placement in the Project's confined disposal areas. If/when the Federal government decides that it no longer needs to use an easement for the Navigation Project, it would release the disposal easement. Under current procedures a Preliminary Assessment Screening would be performed to determine the condition of the property, including an evaluation of the potential for chemical

contamination, prior to release of the easement. If the Preliminary Assessment Screening determines the site contains unacceptable levels of some chemicals, liability for that condition would be determined in accordance with the laws and regulations in effect at that time of the release. Although under present laws the landowner, because of his ownership status, is considered a potentially responsible party, a party or combination of parties involved in the Navigation Project may choose to assume responsibility if they had maintained sole restrictive use of the site since the easement was obtained. If contamination were discovered and a party or parties involved in the Navigation Project chose to assume responsibility, under present clean-up standards, prior to release of the easement the site would be cleaned to the point where the chemicals would no longer be present at levels which constitute a health or safety hazard. It should be noted that this is the site clean-up standard at the present time and does not represent the standard or laws, if any, in effect at the time of a future easement release.

CONTAMINATION OF OFF-SITE RESOURCES. The District disagrees that weir discharges from the confined disposal facilities are contaminating off-site aquatic resources. Impacts of weir discharges on the receiving waters were evaluated in the EIS and found to be acceptable. Appendix E of the EIS, titled WRIGHT RIVER WEIR EFFLUENT STUDY RESULTS, contained a summary of the study performed of weir effluent and sediments near the South Carolina discharges. The study found that discharges from the overflow weirs did not result in acute effects to aquatic life. Based on the study findings, the District determined that relocation of the overflow weirs was not warranted. The South Carolina Department of Health and Environmental Control (DHEC) Office of Oceans and Coastal Resource Management (OCRM) concurred.

OCEAN DISPOSAL. Sediments deposited in the Bar Channel (entrance channel) are presently deposited at the Savannah Ocean Dredged Material Disposal Site (ODMDS). Such disposal is the lowest cost, environmentally acceptable procedure for sediments excavated from that portion of the navigation channel. Due to the large distance from the inner harbor to the ODMDS, a high transportation cost would be incurred should inner harbor sediments be placed at that site. However, should upland sites become unavailable for inner harbor sediments, placement at the ODMDS would be evaluated.

IMPACTS TO ON-SITE WILDLIFE RESOURCES. The review of the quality of materials placed in the confined disposal facilities was documented in Appendix F SEDIMENT QUALITY EVALUATION. That evaluation concluded that the harbor sediments reflect soils of the region, as no chemical parameters within the average harbor sediments exceed values recorded in naturally-occurring soils in Georgia and the southeastern US. No chemicals are found in the river sediments at levels which would be harmful to ducks using the disposal areas.

AIR-BORNE POLLUTION. Although air is a potential pathway for the movement of materials off the confined disposal facilities (CDFs), the District does not believe there is a reasonable likelihood of adverse impacts to adjacent areas from dust leaving the CDFs.

APPENDIX Q

COMMENTS RECEIVED FROM REVIEW OF THE DRAFT EIS
AND DISTRICT RESPONSES TO THOSE COMMENTS

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APPENDIX R

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ENVIRONMENTAL IMPACT STATEMENT

APPENDIX M: Sediment Quality Evaluation

SAVANNAH HARBOR EXPANSION PROJECT
Chatham County, Georgia and Jasper County, South Carolina

January 2012



**US Army Corps
of Engineers**
*Savannah District
South Atlantic Division*

Sediment Quality Evaluation

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Savannah Harbor Expansion Project

Sediment Quality Evaluation

Executive Summary

Savannah District has prepared a sediment quality evaluation assessing potential contaminant impacts associated with the proposed Savannah Harbor Expansion Project (SHEP). The evaluation also establishes whether management actions need to be taken to ensure the proposed placement of project sediments within the dredged material containment areas (DMCAs) would occur in a manner protective of human health and the environment. The evaluation followed tiered approach guidance prepared jointly by the US Army Corps of Engineers and the US Environmental Protection Agency.

The evaluation reviewed and summarized the findings of a number of sediment quality investigations/assessments performed for the SHEP. The effort began with a broad look at potential contaminants and used the tiered approach to identify potential contaminants of concern for the project sediments.

In 1997, sediment core samples were collected and examined for sediment physical and chemical properties. The sampling area covered the entire area proposed for harbor deepening, extending from deep water in the ocean to the Kings Island Turning Basin (Station 103+000). Parameters investigated included metals, PCBs, PAHs, petroleum hydrocarbons, phenols, pesticides, dioxin congeners, cyanide, organotin, and nutrients.

The evaluation found that most of the sediments provided no reason for concern over potential contaminant-related impacts associated with the proposed dredging and dredged sediment placement. However, three potential issues were identified.

One issue involved sediments near the old RACON Tower site. Subsequent sampling conducted in 2005 revealed that sediments at that location do not pose potential for contaminant-related environmental impacts.

The second issue pertained mostly to whether the sediment chemistry data for pesticides, PAHs and phenols, especially achieved detection limits, were adequate for comparison to screening criteria. This issue was addressed during the 2005 sampling. The confirmatory sampling within the channel revealed there was no potential sediment contaminant concerns related to pesticides, PAHs, phenols, or metals other than cadmium.

The final issue involved the concentration and distribution of cadmium within the new work sediments. Sampling was conducted in 2005 to address this issue. Cadmium was found to occur naturally in unusually high levels within Miocene clays that would be

excavated during the SHEP dredging. Evaluation of the laboratory results could not rule out the potential for adverse impacts from sediments with elevated cadmium levels in some reaches of the channel.

Therefore, additional sampling and detailed analyses were conducted in 2007. The potential pathways by which cadmium might enter the environment were evaluated. Pathways of particular concern were identified to be exposure of cadmium-containing clays within the channel with subsequent movement of cadmium into the river ecosystem, and potential environmental impacts associated with placement of cadmium-containing sediments within the DMCAs.

The detailed Tier III studies in 2007 included the following:

- Sediment Profile Imaging to locate/verify exposed Miocene clays and assess the potential existence of benthic communities in the clay;
- Side scan sonar survey to identify and map bottom characteristics in the channel;
- Benthic community assessment;
- Sediment sample collection (vibracoring 6 ft into Miocene clay at four locations in the navigation channel, reference sediment sampling, and upland reference soil sampling);
- Collecting dredging water from one location in the Federal navigation channel and one receiving water location in Fields Cut;
- Compositing and processing sediment cores to create "high cadmium" and "low cadmium" composite samples for further testing;
- Analytical testing of bulk sediment, standard elutriates, effluent elutriates, dredging water, and receiving water samples;
- Analytical testing of porewater and SLRP samples at the high cadmium locations only;
- Aquatic bioaccumulation studies and plant uptake studies using high and low cadmium composites; and
- Risk evaluation and report preparation.

These studies found that sediments with a minimum cadmium concentration of about 29.8 ppm could potentially produce environmental impacts to birds feeding 100 percent of the time in these sediments. These studies also found when these wet sediments are dried, cadmium becomes much more mobile, with cadmium concentrations as low as 14 ppm potentially causing environmental impacts.

The evaluations concluded that SHEP project sediments from Stations +90+000 to +80+125, +57+000 to 51+000, and +45+000 to +6+375 (found to contain layers averaging 14 ppm cadmium or greater) should be isolated within the DMCAs and covered with other new work sediment to ensure they are not exposed to the environment. This procedure would ensure the sediments stay moist and are not relocated for use as dike raising materials, since that action would cause the sediments to dry and the cadmium to become mobile. Sediments from other reaches, including the bar channel, averaged from <1 to <5 ppm cadmium and were found to present minimal risk to the environment and therefore not require special management when placed in a

DMCA. The results of these assessments show there should be no contaminant-related concerns associated with placement of bar channel sediments in the nearshore. However, placement of dredged material into the nearshore sites has been removed from the project.

Sediment Quality Evaluation

Savannah Harbor Expansion Project (SHEP)

1.0 Introduction

This sediment quality evaluation was conducted to assess potential contaminant-related impacts associated with the proposed Savannah Harbor Expansion Project (SHEP). This evaluation considers sediments to be removed throughout the entire extent of the project and proposed sediment placement alternatives, and determines whether management actions need to be taken to place those sediments within the dredged material containment areas (DMCAs)/dredged material confined disposal facilities (CDFs) under the jurisdiction of the Savannah District of the US Army Corps of Engineers to ensure protection of human health and the environment. This report follows tiered approach guidance contained in the *Evaluation of Dredged Material Proposed for Disposal at Island, Nearshore, or Upland Confined Disposal Facilities – Testing Manual* (UTM) prepared jointly by the US Army Corps of Engineers and the US Environmental Protection Agency (USACE 2003).

This evaluation reviews and summarizes the findings of a number of sediment quality investigations/assessments performed for the SHEP. These investigations/assessments include:

1. Sediment sampling in 1997 by ATM (Applied Technology and Management). Dredged Material Environmental Effects Evaluation, Savannah Harbor Deepening. Prepared by Applied Technology and Management, Inc., for the Georgia Ports Authority, Final Draft, April 22, 1998 (ATM, 1998).
2. 2005 sampling by CESAS, including grab samples at the RACON tower site, and channel cores divided into 2-ft lifts.
3. TCLP procedures conducted on archived 2005 samples (contracted out by CESAS-EN in 2006).
4. Savannah Harbor Expansion Dredged Material Evaluation, Phase 1, Draft. CESAM-PD-EC, February 2006, PD-EC 2006a.
5. Savannah Harbor Expansion Dredged Material Evaluation Screening Analysis to Evaluate Potential Environmental Impacts of Cadmium. ERDC, July 06

6. Conceptual Model developed by CESAM-PD-EC in 2006, PD-EC, 2006b.
7. Ecological Risk Assessment by CENWO-HX-S, June 2006.
8. Human Health Risk Assessment by CENWO-HX-S, 2006.
9. Assessment of Wet Sediment Leachate and Potential Groundwater Interactions within Confined Disposal Facilities, Potential for Wet Sediments to Impact the Upper Floridan Aquifer, CESAS-EN-GG, 2 Aug 06.
10. Sediment Quality Evaluation Phase II – Cadmium, for Savannah Harbor Expansion Project, CESAM-PD-EC, 1 Sept 06, PD-EC 2006c, and 7 Sep 2006 Addendum, PD-EC 2006d.
11. Results of pore water analyses on two samples taken from the high cadmium stations (Stations +26+000 and +26+500) 2006 and analyzed by USGS, USGS Memorandum, 27 March 2007.
12. 2007 sampling by EA (EA Engineering, Science, and Technology). Savannah Harbor Expansion Project Phase II Sediment Evaluation, Savannah, GA. Prepared for the U.S. Army Corps of Engineers, Savannah District by EA Engineering, Science, and Technology, Sparks, MD, January 2008 (EA, 2008).

These studies began with a broad look at potential contaminants and used the tiered approach to identify contaminants of concern for the Savannah Harbor Expansion Project (SHEP). Cadmium was identified as the only contaminant of concern and was found to occur naturally in unusually high levels within Miocene clays that would be excavated during the SHEP dredging. All of the potential pathways by which cadmium might enter the environment were evaluated. Pathways of particular concern were identified to be exposure of cadmium containing clays within the channel with subsequent movement of cadmium into the river ecosystem, and potential environmental impacts associated with placement of cadmium containing sediments within the DMCAs/CDFs. Primary potential DMCA impacts were identified to be worker exposure, leachate and groundwater impacts, and movement of cadmium to wildlife that inhabit the confined disposal facilities.

The potential availability of cadmium and conditions under which cadmium might be released from the clay substrate were found to be determinate factors driving potential environmental impacts. When the Miocene clays are in a wet environment, release of cadmium was found to be minimal. Therefore, risks to the river aquatic ecosystem are expected to be minimal and risks to the aquatic environment within the DMCAs are expected to be minimal with the exception of birds feeding 100 percent of the time within a DMCA. Movement of cadmium to groundwater is also expected to be minimal. Cadmium was found to be much more available in dried and oxidized sediment, conditions expected to occur if the sediments are placed in a DMCA, allowed to dry, and later used to raise dikes in the manner of the District's normal maintenance operations.

Potential environmental risks associated with sediments containing about 4.6 ppm cadmium were found to be minimal, whereas potential impacts associated with dried sediments containing about 14 ppm cadmium could not be discounted.

Therefore, it is recommended that SHEP new work sediments from Stations +90+000 to +80+125, +57+000 to 51+000, and +45+000 to +6+375 (found to contain layers averaging 14 ppm cadmium or greater) be isolated within the DMCAs and covered with sediment in a manner that will ensure they are not exposed to the environment. This procedure would ensure the sediments stay isolated and are not relocated for subsequent use as dike raising materials. Such sediments placed on the dikes would be expected to dry and the cadmium become mobile. Sediments from other reaches (averaging from <1 to <5 ppm cadmium) are found to present minimal risk to the environment and do not require special management.

The remainder of this evaluation reviews data and evaluations from the above mentioned reports, describes the process by which contaminants of concern were narrowed to cadmium, and presents justification for the recommended management technique.

2.0 Background: Determination of Contaminants of Concern

2.1 Radiological Screening

The project area is located downstream from the Savannah River Site, where radioactive materials are processed. Releases of radioactive materials from the site have been documented over the years, raising concern as to whether such releases could cause accumulation of these materials within the sediments that are to be removed from the project area. The likelihood of this occurring has been considered improbable; nevertheless, a decision was made to screen selected sediment samples that were collected during the 2002 investigations for gross radioactivity.

All results were measured in milli-Rems per hour (mRem/hr). Background values varied between 0.01 and 0.03 mRem/hr. Values from the sediment samples ranged from 0.02 to 0.04 mRem/hr. These results are consistent with background values, with only a few samples exhibiting an increase of 0.01 mRem/hr over the background range. The slight increase in some samples was expected, as the soils encountered are known to contain phosphatic and glauconitic minerals, along with other clays, that exhibit naturally-occurring radiation levels above background. The results are two magnitudes below acceptable action levels approved by OSHA and the EPA that range between 1 mRem/hr and 5mRem/hr. Based on these results, it is believed that the levels of gross radioactivity measured in the samples is naturally occurring and poses no hazard to the environment. The complete report is included as part of the *Dredged Material Physical Analysis Report* included in the Engineering Investigations Supplemental Materials C.2.4.c.

2.2 Phase 1, Tier 1 EIS

In 1997, as part of the Tier 1 EIS process, approximately 31 sediment core samples for sediment physical and chemical evaluation were taken from the channel and bend widener new work material and most of the core samples contained sufficient sediment for analyses. The sampling area covered the entire area proposed for harbor deepening at that time. It extended from deep water in the ocean (Station -60+000B) to the Kings Island Turning Basin (Station 103+000). Parameters investigated included metals, PCBs, PAHs, petroleum hydrocarbons, phenols, pesticides, dioxin congeners, cyanide, organotins, and nutrients. Results of these investigations were reported as part of the 1998 Tier I EIS for the Expansion Project and the April 23, 1998 "Dredged Material Environmental Effects Evaluation, Savannah Harbor Deepening", prepared by ATM for the Georgia Ports Authority (ATM, 1998). That study also included a review of previous sediment testing in Savannah Harbor. The results for metals from that study are shown in Tables 1 to 4, below. Table 5 shows relevant marine sediment screening criteria.

Table 1. Metal Sediment Concentrations Kings Island (Station +103) to Talmadge Bridge (Station +79) Sampled 1997, dry wt.mg/kg (ATM, 1998)

Sample No.	103NW	T01NW	095NW	090NW	085NW	080NW	W01NW	W02NW
Stations *	103	99.5	95	90	85	80	102.5	88.2
Aluminum	16000	6410	6860	22500	6050	6070	1930	7750
Iron	25600	16000	14600	21200	12700	9530	6240	11300
Antimony	<4.8	<3.2	<2.7	<3.8	<2.9	<2.9	<3.8	<2.6
Arsenic	10	5	3	9.9	5.3	1.6	<1.9	2.7
Beryllium	<1.2	<0.79	<0.68	1.3	<0.72	<0.74	<0.94	<0.66
Cadmium	<0.7	0.7	<0.4	8.5	5.5	5.1	<0.6	<0.4
Chromium	39.6	22.7	19.9	162	33.7	36.3	4.8	13.4
Copper	14.7	12.2	8.3	16.6	6.3	3.8	<4.7	6.1
Lead	15.8	5.6	3.1	5.8	3	2.3	2.1	7.8
Manganese	808	223	148	189	413	361	233	160
Mercury(7471)	0.07	<0.016	<0.014	<0.019	<0.014	<0.015	0.02	0.1
Nickel	12	13.8	10.8	30.8	11.2	7.4	<2.8	4
Selenium	<2.4	<1.65	<1.4	<2.2	<1.4	<1.5	<1.9	<1.3
Silver	<0.48	<0.32	<0.27	<0.38	<0.29	<0.29	<0.38	<0.26
Thallium	<0.48	<0.32	<0.27	<0.38	<0.29	<0.29	<0.26	<0.26
Zinc	72.2	44.4	34.4	95.3	49.3	34.5	10.4	20.2

* Stations in 1000's feet above Station 0+000.

Table 2. Metal Sediment Concentrations Talmadge Bridge (Station +79) to Elba Island (Station +50) Sampled 1997, dry wt. mg/kg (ATM, 1998)

Sample No.	075NW	W03NW	W04NW	C07NW	W05NW	W06NW
Station*	75	77	71	65	54	50.8
Aluminum	4200	26700	21500	17200	10300	15100
Iron	8400	32200	30700	17100	14400	21500
Antimony	<3.2	<5.1	<5.9	<3.4	<4.2	<4.3
Arsenic	3.6	15.8	14.5	9.5	7.8	10.4
Beryllium	<0.81	<1.3	<1.5	<0.94	<1.00	<1.1
Cadmium	<0.5	<0.8	<0.9	4.7	2.5	<0.7
Chromium	12.3	51.1	15.6	63.6	24.2	33.8
Copper	4.5	17.5	14.6	11.9	6.3	11.5
Lead	7.2	24.5	20.1	12.5	8.1	16.6
Manganese	311	860	998	338	376	426
Mercury(7471)	0.02	<0.26	<0.029	<0.017	0.03	0.05
Nickel	4.1	15.9	13.2	15.9	6.9	9.1
Selenium	<1.6	<2.6	<2.9	<1.7	<2.1	<2.2
Silver	<0.32	<0.51	<0.59	<0.34	<0.42	<0.43
Thallium(7841)	<0.32	<0.51	<0.59	<0.34	<0.42	<0.43
Zinc	26.4	90.7	80.3	13.6	43.6	45.2

* Stations in 1000's feet above Station 0+000.

Table 3. Metal Concentrations Elba Island (Station +50) to Mouth of Harbor (Station 0+000) (ATM, 1998)

Sample No.	W07NW	045NW	W08NW	W09NW	015NW	W10NW	005NW
Stations*	46.2	45	35.2	29.2	15	10.6	5
Aluminum	5520	1100	13600	13100	8220	3390	2290
Iron	11500	8370	20500	17500	16600	6650	4030
Antimony	<3.2	<2.4	<4.5	<3.4	<3.4	<3.1	<2.6
Arsenic	5.7	3.7	11.4	9.9	7	4.1	2.9
Beryllium	<0.81	<0.59	<1.1	<1.0	1.1	<0.77	<0.65
Cadmium	<0.5	<0.4	<1.1	<0.9	<0.9	<0.5	0.48
Chromium	15.1	4.8	32.6	29.4	23.6	9.6	17.9
Copper	<4.0	<2.9	9.2	9	5.9	<3.8	<3.2
Lead	5.4	1.2	14.9	11.2	10	4.2	1.9
Manganese	275	38.4	488	252	297	140	58.9
Mercury(7471)	<0.016	0.01	0.13	<0.017	<0.017	<0.015	<0.013
Nickel	4.3	3.4	9	10.3	9	2.3	5
Selenium	<1.6	<1.2	<2.3	<1.7	<1.7	<1.5	<12.3
Silver	<0.32	<0.24	<0.45	<0.34	<0.34	<0.31	<0.26
Thallium(7841)	<0.32	<0.24	<0.45	<0.34	<0.34	<0.31	<0.26
Zinc	18.5	9.6	42.1	69.5	36.4	13.6	12.6

* Stations in 1000's feet above Station 0+000.

Table 4. Metal Concentrations in the Bar Channel (ATM, 1998)

Sample No.	005NW	015NW	W01NW	W02NW	035NW	075NW
Stations*	-5	-15	-19	-39.5	-35	-75
Aluminum	2510	2780	11300	1200	3020	3830
Iron	2600	2840	18100	2910	4600	3650
Antimony	<2.7	<2.7	<3.1	<2.5	<2.7	<2.6
Arsenic	3.3	3.4	8.7	3.6	6.4	12
Beryllium	<0.67	<0.68	<0.78	<0.62	<0.68	<0.64
Cadmium	0.68	1.5	<0.5	<0.4	<0.4	24.3
Chromium	20.2	39.4	20	7.1	9.2	35.9
Copper	3.9	5.6	8.1	<3.1	<3.4	5.5
Lead	1.3	1.7	11.3	1.8	2.9	2.3
Manganese	25.2	13.9	436	33.6	63	38.4
Mercury(7471)	<0.013	<0.014	0.04	<0.012	<0.014	0.04
Nickel	6.8	8.9	5.9	1.9	3.1	9
Selenium	<1.3	<1.4	<1.6	<1.2	<1.4	<1.3
Silver	<0.27	<0.27	<0.31	<0.25	<0.27	<0.26
Thallium(7841)	<0.27	<0.27	<0.31	<0.25	<0.27	<0.27
Zinc	12.2	16.3	26.3	8	10.1	51.4

* Stations in 1000's feet above Station 0+000.

Table 5. Sediment Screening Criteria (mg/kg), from Buchman, 1999

	TEL	ERL	ERM	AET
Aluminum				1800
Iron				220000
Antimony				9.3
Arsenic	7.2	8.2	70	35
Beryllium				
Cadmium	0.68	1.2	9.6	3
Chromium	52.3	81	370	62
Copper	18.7	34	270	390
Lead	30.2	46.7	218	400
Manganese				260000
Mercury(7471)	0.13	0.15	0.71	0.41
Nickel	15.9	20.9	51.6	110
Selenium				1
Silver	0.73	1	3.7	3.1
Thallium(7841)				
Zinc	124	150	410	410

The following paragraphs contain summaries of findings that were made based on the above 1997 data and data obtained more recently. Most metals were eliminated as potential contaminants of concern after comparing the observed sediment levels to sediment screening criteria (Table 5). The only metal found to be of concern at that time was potential cadmium contamination at the old RACON tower site. Therefore, cadmium was the only heavy metal that was included in the 2005 confirmatory testing. The following paragraphs describe the metals most likely to be considered potential

contaminants of concern and the findings and conclusions eliminating them from further consideration.

2.2.1 Arsenic

The 1997 sampling found some new work sediments would be expected to contain arsenic above possible effects sediment screening levels, but below probable effects levels. However, average concentrations in the new work sediments are expected to be below screening levels. Furthermore, the observed levels are similar to levels observed in maintenance sediments (1.7 to 17 ppm) and the harbor reference area (14 ppm)(ENSR, 2003). No additional environmental impacts are expected due to new work sediment arsenic levels and no additional evaluation is warranted.

2.2.2 Chromium

This metal was found above possible effect sediment screening levels, but below probable effects levels for only one 1997 sample. Therefore, the 1997 sampling results were considered to indicate the potential for environmental effects was minimal. However, some additional investigation of chromium was continued in later studies to confirm this. For example, consideration is warranted of how easily it might be released from the sediment to the environment. Such an assessment would guide one's expectation of environmental impacts. If the majority of the element is tightly bound within the sediment, the potential for environmental impact should be minimal. EA (2008) conducted sequential extraction procedures (SEP) to estimate how tightly chromium is bound to the new work sediments. The low cadmium composite found chromium at 134 and 139 ppm. SEP analyses found 92.1 and 91.9 percent existed in the sulfide and residual fractions. The chromium is considered to be tightly bound when it exists in these fractions. The high cadmium composite found chromium at 126 and 146 ppm. SEP analyses of the high cadmium sediments found 91.1 and 89.1 percent existed in the sulfide and residual fractions. These percentages are even higher in the dried soil. These data indicate chromium would not be available or expected to produce adverse environmental impacts. No further investigation of chromium is warranted.

2.2.3 Manganese

In the 1997 sampling, this metal was found below sediment screening levels (AET, Buchman, 1999). Because of its low potential for bioaccumulation, manganese is not expected to cause environmental impacts. However, additional study of the potential availability of manganese in new work sediments was performed by EA (2008). SEP procedures conducted by EA found 16 to 32 percent of manganese is either in the sulfide or residual fractions. These percentages are about the same for dried soil (27-28 percent). The low Cd sediment showed 10-12 percent of manganese in the exchangeable fraction. The high Cd sediment showed only 4-5 percent in the exchangeable fraction. The dried soils showed 10-20 percent in the exchangeable fraction. These data indicate that some manganese would be expected to be available in both aquatic and upland environments. However, because of its low potential for bioaccumulation, potential environmental

impacts are expected to be minimal, so no further consideration of manganese is warranted.

2.2.4 Nickel

This metal was found above no effect sediment screening levels, but below probable effects levels, in only one 1997 sample. As in the case of the other metals found above no effects screening criteria during the 1997 sampling, EA (2008) conducted SEP procedures for nickel. The SEP procedures conducted by EA (2008) found 48 to 54 percent of nickel in the wet sediment and dried soil is either in the sulfide or residual fractions. These data indicate at least half of the sediment/soil nickel would not be available to aquatic life or upland plants. However, because of its potential to bioaccumulate, nickel was included in the bioaccumulation and plant uptake studies.

The bioaccumulation study found both *Macoma* and *Nereis* accumulated nickel and produced wet weight tissue nickel concentrations of 0.48 to 0.69 ppm. These results were significantly higher than reference. These results are discussed in Sections 4.2.5 and 4.3.1.5. These results are below the lowest NOAEL in the ERED vertebrate database except for a frog (2.0 mg/kg wet wt. for the Rainbow Trout). The highest sediment nickel concentration was 30.8 mg/kg and the inner harbor sample average was 11.6 mg/kg. The Terrestrial Toxicity Database (USACHPPM, chppm-www.apgea.army.mil) shows a lowest tissue NOAEL of 63 mg/kg and 35 ppm soil concentration as a concentration below which adverse effects should not occur. These data are thought to show minimal environmental concern regarding potential environmental impacts associated with nickel concentrations in the proposed new work sediments.

2.2.5 Zinc

The 1997 study found zinc below no effect screening criteria. However, because zinc was found above no effect screening criteria in the high cadmium composite, EA (2008) also conducted SEP procedures for zinc on the new work composites. Exchangeable and carbonate fractions are the most available fractions in an aquatic state. As Tables 6 and 7, show, the amount of zinc in these fractions is small, indicating little environmental concern for zinc in an aquatic environment. When sediments oxidize, the hydroxide and organic fractions can become available. The washed and dried sediments showed a loss of zinc from the hydroxide fraction, and an increase in the exchangeable and carbonate fractions. These data indicate zinc is unlikely to become available to aquatic life but could become a little more available under some oxidizing conditions. The aquatic bioaccumulation study found that *Macoma* accumulated zinc at concentrations slightly above reference. *Macoma* in the low sediment composite showed zinc concentrations of 10.2 ppm, which was significantly higher than the 9.32 ppm found in organisms grown in the reference sediment (EA, 2008, Table 8-7). This minimal difference shows that new work sediments are unlikely to produce any additional environmental impacts related to zinc in an aquatic environment. The plant uptake study found zinc did bioaccumulate in plants under oxidizing conditions. The Terrestrial Toxicity Database (USACHPPM) lists for zinc 140 mg/kg as a soil concentration below which adverse effects should not occur

and a lowest NOAEL of 100 mg/kg. Table 6 shows zinc levels associated with the sediments containing elevated levels of cadmium. These results indicate a potential concern for possible effects of zinc associated with sediments containing elevated cadmium levels when placed in a dry environment. The results of potential plant uptake of zinc are discussed at Section 4.3.1.5.

2.2.6 Selenium

The 1997 sampling found no detection of selenium in the new work sediments, but showed MDLs for selenium above published possible effects criteria (Apparent Effects Threshold = 1 mg/kg). Previous O&M sampling has found selenium to be non-detectable with MDLs ranging from 0.83 to 1.0 mg/kg (ENSR, 2003). Because selenium has not been found in O&M sediments and the achieved MDLs for the new work sediments were not greatly above 1 mg/kg (in the range of 1.2 to 2.4 mg/kg), the potential for environmental effects was deemed minimal. Selenium was tested for in the river water and elutriate samples. Dissolved concentrations were similar to the river water concentrations, thus confirming the potential for selenium environmental impacts to be minimal.

Table 6. Zinc Sediment Concentrations from SEP Fractions (EA, 2008), mg/kg

	Exchange- able	Carbon- ate	Organi c	Hydrox- ide	Sulfid e	Residua l	Total*1	Total*2	Total*3
High Cd Comp	0.65	3.8	35.8	121	31.8	10.7	191	130	163.5
High Cd Comp Dup	0.7	3.3	33.8	119	29.2	11.1	210	164	159.3
High Cd Comp Wash/Dry	1.9	5.6	31.9	114	70.7	13.1	219	171	197.8
Low Cd Comp	0.75	3.8	22.7	71.7	31.4	15.4	146	100	117.9
Low Cd Comp Dup	0.75	3.8	23.7	71.2	33.6	13.1	146	92.1	117.9
Low Cd Comp Wash/Dry	1.4	5.7	22.9	59.5	37	8.5	132	93.1	105

*1 Microwave digestion

*2 Total standard digestion

*3 Total relatively unavailable (hydroxide, sulfide, residual) (microwave digestion)

Table 7. Zinc, Percentages from SEP Fractions (EA, 2008), mg/kg

	Exchange-able	Carbon-ate	Organic	Hydroxide	Sulfide	Residual	Total*
High Cd Comp	0.3	1.9	17.6	59.4	15.6	5.30	80.2
High Cd Comp Dup	0.4	1.7	17.1	60.4	14.8	5.6	80.8
High Cd Comp Wash/Dry	0.8	2.4	13.4	48.1	29.8	5.5	83.4
Low Cd Comp	0.5	2.6	15.6	49.0	21.6	10.6	81.2
Low Cd Comp Dup	0.5	2.6	16.2	48.7	23.0	9.0	80.7
Low Cd Comp Wash/Dry	1.0	4.2	17.0	44.1	27.4	6.3	77.8

* Total relatively unavailable (hydroxide, sulfide, and residual fractions)

2.2.7 Cadmium

During the 1997 sampling, cadmium was detected between ERLs and ERM_s at several inner harbor stations and above ERM_s at a station near the old RACON tower site (-75+000). It was determined that cadmium warranted additional investigation through the Phase 2 verification sampling. Additional investigations are covered at Sections 2.3.2.1 and 3.0.

2.2.8 Other Potential Contaminants of Concern

2.2.8.1 PCBs. The 1997 sampling (ATM 1998) found total PCBs were below available no effect sediment screening criteria and therefore of no environmental concern. No further investigation of PCBs was warranted.

2.2.8.2 Pesticides. In the 1997 sampling, observed pesticide levels were found to be below available screening criteria. However, questions existed about attained detection limits. Further analysis or documentation was needed, see Section 2.3.3.3.

2.2.8.3 Phenols. In the 1997 sampling, phenolic compounds were not detected, but some detection limits were above available sediment screening criteria. Further analysis or documentation was needed, see Section 2.3.3.1.

2.2.8.4 PAHs. In the 1997 sampling, one bend widener sample showed some PAHs above threshold effects screening criteria, but below probable effects levels. Unacceptable adverse effects were determined to be unlikely because only a few PAHs were observed above the effects thresholds and the observed concentrations were relatively low. Additional sampling (verification samples) was planned to more clearly

define the sediment levels of these parameters and their potential for environmental impact. PAHs and cadmium were detected in a sample taken at about Station 75+000 near the old RACON Tower where a spill of fuel, batteries, and paint lacquer occurred in November 1996. Additional sampling at the RACON tower site and sediment testing was planned to clearly determine whether concentrations of cadmium and PAHs in this area would impact the Expansion Project, see Section 2.3.3.2.

2.2.8.5 Dioxins. The 1997 sampling (ATM 1998) found 2378 PCDD/PCDF dioxin congeners in new work sediments. Since calculated TBPs (theoretical bioaccumulation potentials) were less than reference values, there was no reason for environmental concern. No further investigation of dioxins was warranted.

2.2.8.6 Organotins. The 1997 sampling (ATM 1998) detected low levels of butyltins throughout the harbor. Other studies (see ATM, 1998) showed conflicting results, so additional testing of these parameters was planned through the Phase 2 verification sampling. EA reviewed existing project data on butyltins and concluded "it is not expected that there are any risks associated with any exposure to the sediment, or to soil should the sediment be utilized for upland placement" (EA, 2007). No further investigation of butyltins was warranted.

2.2.8.7 Petroleum Hydrocarbons. The 1997 sampling (ATM 1998) detected total recoverable petroleum hydrocarbons at levels ranging from <10 ppm to 70 ppm. These levels were considered minor, but warranted additional investigation through the Phase 2 verification sampling, see Section 2.3.2.2.

2.2.8.8 Cyanide. The ATM sampling in 1997 found no detection of cyanide in any sediment samples or elutriates. Detection limits ranged from 1.2 to 2.9 mg/kg for the sediment samples and 0.01 mg/L for the elutriates. No further investigation of cyanide was warranted.

2.2.8.9 Nutrients. Nutrients were not considered to present an environmental hazard and additional evaluation was not performed.

2.3 SHEP Phase 2 Testing

2.3.1 Goals

Results of the first set of sediment sampling and analysis (1997) for the Expansion Project left open some questions concerning the potential for contaminant-related impacts associated with the proposed dredging and dredged material placement.

One set of questions involved the old RACON Tower site. Do the sediments around the old RACON Tower site pose a potential for environmental impacts due to the proposed Expansion dredging? The 2005 sampling included twenty grab samples taken in the RACON Tower area to answer that question. These samples were analyzed for cadmium and PAHs.

The second set of questions pertained mostly to whether the sediment chemistry data, especially achieved detection limits, were adequate for comparison to screening criteria. To address this set of questions, the 2005 sampling included six confirmatory samples spread along the length of the channel to be analyzed for pesticides, PAHs, and phenols.

As a result of sampling and testing unrelated to the SHEP but which occurred after the 1998 evaluation, additional questions arose concerning the concentration and distribution of cadmium within the new work sediments (these questions are addressed in Section 3.0). To address this issue, the 2005 sampling included collection of approximately 350 samples for cadmium analysis taken at 2-ft intervals from 45 cores distributed throughout the harbor, but concentrating in areas believed to contain Miocene clays. Sampling intervals (measured from MLW) were assigned letter designations as follows: -42 ft to -44 ft (a), -44 ft to -46 ft (b), -46 ft to -48 ft (c), -48 ft to -50 ft (d), -50 ft to -52 ft (e), -52 ft to -54 ft (f), -54 ft to -56 ft (g), -56 ft to -57 ft (h). A subset of these samples was subjected to both standard extraction and total digestion techniques to determine if the cadmium was tightly bound to the sediment. Should these analyses show cadmium exists in the new work sediments at levels of concern, additional testing would have to be performed at a later time to address specific environmental concerns associated with the specific dredged material placement options under consideration.

In addition, since the Tier 1 EIS was written, the depth of potential impact of a hydraulic cutterhead dredge was clarified. In general, a cutterhead dredge usually disturbs and mixes sediment below the level it is capable of removing. In the case of a large cutterhead dredge, this disturbance depth can be 3 to 4 feet below the final channel depth that is actually attained, depending on the size of the dredge. To account for this increased disturbance depth, the target depth for all core samples for the Phase 2 (2005) sediment sampling and analysis was 3 feet below the expected removal depth (see Table 8, below). For example, the core depth would be the authorized depth, plus 2 feet of overdepth, any additional amount of Advance Maintenance, and 3 feet of disturbance depth. Table 9 shows the difference between the core depths achieved by the 1997 sampling and the calculated disturbance depth. The failure to reach disturbance depth in 1997 would be corrected in the next round of testing.

Table 8. Channel Depths (in feet MLW)

STATION (1000 FT)	AUTH DEPTH	ADV MAINT	ALLOW OVER- DEPTH	SEDIMENT REMOVAL DEPTH	DISTURBANCE DEPTH*1	TOTAL O&M DREDGING DEPTH*2
112.5 to 105.5	30	2	2	34	3	37
105.5 to 103	36	2	2	40	3	43
103 to 102	42	0	2	44	3	47
102 to 70	42	2	2	46	3	49
70 to 37	42	4	2	48	3	51
37 to 35	42	6	2	50	3	53
35 to 26	42	4	2	48	3	51
26 to 0	42	2	2	46	3	49
0 to 14B	42	2	2	46	3	49
14B to 60B	44	0	2	46	3	49
24B to 32B south ½	44	2	2	48	3	51
29B to 41.5B ³	44	100-ft widener	2	46	3	49
Oysterbed Island Turning Basin	40	0	2	42	3	45
Fig I TB	34	4	2	40	3	43
Marsh I TB	34	0	2	36	3	39
Kings I TB	42	8	2	52	3	55
Argyle I TB	30	0	2	32	3	35
Port W TB	30	0	2	32	3	35
Sediment Basin: 0 to 2+000	38	0	2	40	3	43
Sediment Basin: 2+000 to 13.3	40	0	2	42	3	45

NOTES:

*1 Depth below the intake of a cutterhead hydraulic dredge but which the cutterhead disturbs during dredging.

*2 Total Dredging depth includes the depth that is disturbed by a cutterhead dredge. This is deeper than the depth to which sediment is actually removed, as it includes the disturbance depth.

*3 These advance maintenance sections are currently under environmental review and do not presently have environmental clearances. CESAD approved an additional advance maintenance feature in the entrance channel in June 2003 that would be located between Stations -24+000(B) to -41+500(B). It has not yet been implemented, but CESAS is seeking funds for the initial construction.

Table 9. 1997 Sampling Depths (ATM 1998)

Harbor Location	Sample	Station* (1000 feet)	Penetration	Core Depth	Disturbance Depth*
SHIH	103NW	103	4	-45.9	-53
SHIH	W01NW	102.5	9.5	-33	-53
SHIH	T01NW	99.5	2	-43	-55
SHIH	095NW	95	8	-52.7	-55
SHIH	090NW	90	3	-47.8	-55
SHIH	085NW	85	7	-52.4	-55
SHIH	080NW	80	4.5	-48.2	-55
SHIH	W02NW	88.2	11	-31.8	-55
SHIH	075NW	75	11	-51.1	-55
SHIH	W03NW	77	11	-42.1	-55
SHIH	W04NW	71	12	-47.1	-55
SHIH	C07NW	"25 to 65"	"2.5 to 5"	"-43 to -49"	"-57 to -59"
SHIH	W05NW	54	5	-42.2	-57
SHIH	W06NW	50.8	12	-38.3	-57
SHIH	W07NW	46.2	10	-19.4	-57
SHIH	045NW	45	3	-47.4	-57
SHIH	W08NW	35.2	12	-40.1	-59
SHIH	W09NW	29.2	11	-31.1	-57
SHIH	015NW	15	6	-49.3	-55
SHIH	005NW	5	12	-55.1	-55
SHIH	W10NW	10.6		-42.3	-55
SHBC	005NW	-5		-44.2	-55
SHBC	015NW	-15		-48.8	-55
SHBC	W01NW	-19		-40.2	-55
SHBC	W02NW	-39.5		-43.3	-57
SHBC	035NW	-35		-50.9	-55

* For a 6-foot deepening.

2.3.2 RACON Tower Testing Results

The Tier I Expansion sampling (1997) collected sediment near the RACON/light tower site at Station -75+000 in the bar channel. Cadmium and low molecular weight (LMW) PAH compounds were detected in that sediment, presumably from a fuel, battery, and paint lacquer spill that occurred in November 1996. While the PAH compounds that were encountered were not found at concentrations normally associated with benthic effects, the cadmium concentration was detected above probable effects levels (ATM, 2004, p. 5). To further investigate the potential for environmental impacts from dredging in this area during the proposed Expansion Project, additional grab samples were taken in the vicinity of the site and analyzed for PAHs and cadmium.

2.3.2.1 Cadmium. In the second round of testing, twenty sediment samples were taken in a circular area at distances of 300 to 1500 meters from the old RACON tower site and analyzed for cadmium to define the distribution of cadmium in the area. No cadmium was detected in any of the samples, with the MDL at 0.30 ppm or less. These samples were also analyzed for aluminum and iron. Aluminum values ranged from about 600 to 4500 ppm, with the lowest values found mostly to the south of the tower near the

channel. Iron values ranged from about 560 to 1850 ppm, with the highest values mostly to the NE and SW of the tower site. These data indicate no environmental concerns related to metal concentrations near the RACON tower site.

2.3.2.2 PAHs. PAH's were analyzed in four samples taken at 300 meters from the tower site along N, S, E, and W radii. Low molecular weight totals for detected PAHs ranged from 2.4 to 3.6 ppb. High molecular weight totals for detected PAHs ranged from 0.07 to 6.7 ppb, except for the sample taken 300m east of the tower site, which showed a high molecular weight PAH total of 23.6 ppb. These observed values are well below TELs (Threshold Effects Levels) for both low molecular weight PAHs (311.7 ppb) and high molecular weight PAHs (655.34 ppb).

These data show no contaminants in the area of the RACON tower site at levels of concern and no additional investigations at the site by the Savannah Harbor Expansion Project are warranted. Available evidence indicates that sediments in the vicinity of the RACON tower site do not pose any environmental concerns related to the proposed Expansion Project work.

2.3.3 Confirmatory Sampling

This section reviews the list of potential contaminants of concern remaining after the Phase 1 sampling in 1997 and the results of the six Phase 2 confirmatory samples taken in 2005, and presents findings which eliminated concern for all contaminants except cadmium. The discussion is presented by contaminant.

2.3.3.1 Phenols. The 1997 sampling (ATM 1998) detected no phenols, but some detection limits were above no effects sediment screening criteria. Therefore, analysis for phenols was included for the six confirmatory samples taken during the 2005 sampling. No phenols were detected. Five of the samples achieved very low MDLs (0.2 to 2.6 ug/kg). The other sample (bar channel sample at Station -63+000) showed higher MDLs (from 1 to 13 ug/kg). These MDL's were all below marine sediment screening criteria except for 2, 4, 5 trichlorophenol in the bar channel Station -63+000 sample, where the MDL of 7.23 ug/kg exceeded the AET of 3 ug/kg. The lowest and highest MDL's achieved for the six samples are listed in the table below. These results indicate minimal concern for potential environmental effects due to phenols and further investigation of phenols was judged to not be warranted.

Table 10. Confirmatory Sampling Phenol Results for All Samples (SH083+000 (A+B), SH065+000 (D), SH025+282(B), SHBC027+000(C), SHBC045+000 (B), SHBC063+000 (F))

ANALYTE	RESULT	LOWEST MDL	HIGHEST MDL	AET*	UNITS
4-Chloro-3-methylphenol	U	0.389	2.07		µg/kg
2,4,6-Trichlorophenol	U	1.07	5.68	6	µg/kg
2,6-Dichlorophenol	U	0.565	3.01		µg/kg
2,4-Dichlorophenol	U	0.565	3.01	5	µg/kg
2-Nitrophenol	U	0.560	2.98		µg/kg
3-Methylphenol (m-Cresol)	U	0.493	2.63		µg/kg
4-Methylphenol (p-Cresol)	U	0.493	2.63	100	µg/kg
2,4-Dimethylphenol	U	0.418	2.22	18	µg/kg
2-Methylphenol (o-Cresol)	U	0.237	1.26	8	µg/kg
Phenol	U	0.190	1.01	130	µg/kg
4-Nitrophenol	U	1.28	6.82		µg/kg
2,4,5-Trichlorophenol	U	1.36	7.23	3	µg/kg
2-Methyl-4,6-dinitrophenol	U	1.59	8.46		µg/kg
2-Chlorophenol	U	0.195	1.04	8	µg/kg
Pentachlorophenol	U	1.42	7.55	17	µg/kg
2,4-Dinitrophenol	U	2.65	13.4		µg/kg

* Buchman, 1999.

2.3.3.2 PAHs. The 1997 sampling (ATM 1998) found one bend widener sample above sediment threshold effects screening criteria. PAHs were also detected in one sample taken at about Station -75+000 near the old RACON Tower where a spill of fuel, batteries, and paint lacquer occurred in November 1996.

PAHs were analyzed during the 2005 "confirmatory" sampling (Tables 11 and 12). Neither the low molecular weight totals nor the high molecular weight totals approached threshold effects levels. These results indicate no concern for potential environmental effects due to PAHs and no further investigation of PAHs occurred related to the confirmatory sampling.

Table 11. PAHs Upper Harbor 2005 Testing (ppb (ug/kg))

Analyte	SH083+000 (A+B)			SH065+000 (D)			SH025+282 (B)			SH025+282 (Z)	
	Result	MDL		Result	MDL		Result	MDL		Result	MDL
1-Methylnaphthalene	0.81	0.55	J	1.10	0.58	J	0.39	0.32	J	0.72	0.31
2-Methylnaphthalene	1.20	0.75	J	1.60	0.78	J	0.66	0.43	J	1.10	0.42
Acenaphthene	1.30	0.36	J	7.80	0.37			0.20	U	0.30	0.20
Acenaphthylene	2.00	0.49	J	4.20	0.51	J		0.28	U	0.54	0.27
Anthracene	4.50	0.49	J	7.20	0.51			0.28	U	0.27	0.27
Benz(a)anthracene	12.00	0.36		21.00	0.37		0.28	0.20	J	0.24	0.20
Benzo(a)pyrene	13.00	0.49		19.00	0.51		0.59	0.28	J	0.27	0.27
Benzo(b)fluoranthene	17.00	1.10		20.00	1.20		0.60	0.60	J	0.87	0.59
Benzo(g,h,i)perylene	10.00	0.51		13.00	0.53		0.45	0.29	J	0.29	0.29
Benzo(k)fluoranthene	15.00	0.73		20.00	0.76		0.49	0.42	J	0.41	0.41
Chrysene	17.00	0.90		22.00	0.95			0.51	U	1.50	0.50
Dibenz(a,h)anthracene	2.30	0.58	J	3.10	0.60	J		0.33	U	0.32	0.32
Fluoranthene	40.00	0.75		54.00	0.78		1.20	0.43	J	5.00	0.42
Fluorene	1.50	0.42	J	4.70	0.44	J		0.24	U	0.66	0.24
Indeno(1,2,3-cd)pyrene	13.00	0.53		17.00	0.56		0.45	0.30	J	0.33	0.30
Naphthalene	5.60	0.75		6.10	0.78		4.40	0.43	J	3.70	0.42
Phenanthrene	8.80	0.73		12.00	0.76		0.44	0.42	J	5.40	0.41
Pyrene	38.00	0.79		45.00	0.83		1.20	0.45	J	2.20	0.44
LMW TOTAL, TEL=311	25.71			44.70			5.89			12.69	
HMW TOTAL, TEL=655	177.30			234.10			5.26			11.43	

Table 12. PAHs Bar Channel 2005 Testing (ppb (ug/kg))

		SHBC -27+ 000(C)		SHBC -45+ 000(B)		SHBC -63+ 000(F)		
Analyte		MDL	Flag	MDL	Flag	Result	MDL	Flag
1-Methylnaphthalene	L	0.340	U	0.310	U	0.340	0.320	J
2-Methylnaphthalene	L	0.460	U	0.420	U	0.470	0.440	J
Acenaphthene	L	0.220	U	0.200	U		0.210	U
Acenaphthylene	L	0.300	U	0.270	U		0.280	U
Anthracene	L	0.300	U	0.270	U		0.280	U
Benz(a)anthracene	H	0.220	U	0.200	U	1.000	0.210	J
Benzo(a)pyrene	H	0.300	U	0.270	U	0.780	0.280	J
Benzo(b)fluoranthene	H	0.640	U	0.590	U	1.100	0.610	J
Benzo(g,h,i)perylene	H	0.310	U	0.280	U	0.700	0.300	J
Benzo(k)fluoranthene	H	0.440	U	0.400	U	0.810	0.420	J
Chrysene	H	0.550	U	0.500	U	0.990	0.530	J
Dibenz(a,h)anthracene	H	0.350	U	0.320	U		0.330	U
Fluoranthene	H	0.460	U	0.420	U	2.000	0.440	J
Fluorene	L	0.260	U	0.230	U		0.250	U
Indeno(1,2,3-cd)pyrene	H	0.320	U	0.300	U	0.650	0.310	J
Naphthalene	L	0.460	U	0.420	U	1.000	0.440	J
Phenanthrene	L	0.440	U	0.400	U	0.580	0.420	J
Pyrene	H	0.480	U	0.440	U	1.500	0.460	J
LMW TOTAL, TEL=311						2.39		
HMW TOTAL, TEL=655						9.53		

2.3.3.3 Pesticides. The 1997 sampling (ATM 1998) found pesticides were below potential effects screening criteria and therefore of no environmental concern. However, pesticides results in the 1997 sampling often had somewhat elevated reporting limits. These results also showed scattered low concentrations of several pesticides (see Table 13, below). Therefore, analysis of pesticide concentrations was added to the confirmatory sampling.

The confirmatory sampling (Tables 14 and 15, below) shows detection of only two pesticides, beta-BHC (5.554 ug/kg) in the upper harbor sample at Station 83+000, and gamma-BHC (lindane) (2.109 ug/kg) in the upper harbor sample at Station 65+000. Buchman (1999) does not list screening criteria for beta-BHC. ATM (2004) lists a consensus Threshold Effects Level (TEC) for beta-BHC of 5.1 ug/kg. Since this level was observed in only one sample, this substance is not expected to be widespread and project sediments would be expected to average much less than this screening value. Therefore, no environmental impacts are expected due to beta-BHC.

Buchman lists lindane at a TEL of 0.32 ug/kg and a PEL of 0.99 ug/kg. ATM (2004) lists a consensus TEC for gamma-BHC (lindane) of 0.80 ug/kg. The observed level of lindane at Station 83+000 is above these screening levels. However, the observed level (2.109 ug/kg) is less than one of the reference values (3.989 ug/kg). Moreover, since this level was observed in only one sample, this substance is not expected to be widespread and the overall project sediments would be expected to average much less than the screening values. Therefore, no environmental impacts are expected due to gamma-BHC (lindane).

Table 13. Pesticides Detected in New Work Sediments during 1997 Sampling (all detections J flagged) ppb (ug/kg)

SAMPLE	SHIH W03NW	SHIH 075NW	SHIH W05NW	SHIH W06NW	SHBC 035NW	SHBC 075NW	SHIH R02
Station #	+77+100	+75+000	+54+000	+50+800	-35+000	-75+000	Reference
Aldrin	0.50	0.125	U	0.15	U	U	U
4,4' DDE	U	U	U	0.71	U	U	U
4,4' DDT	U	0.33	U	U	U	U	U
Dieldrin	U	0.16	U	U	0.12	0.10	0.13
Endrin	U	0.39	0.24	0.29	U	U	0.085
Endrin aldehyde	U	0.25	U	U	U	U	U
Heptachlor	U	0.13	U	U	U	U	U

Table 14. Pesticides Upper Harbor 2005 Testing

ANALYTE	UNITS	SH083 + 000 (A+B)		SH065 + 000 (D)		SH025 + 282 (B)	
		RESULT	MDL	RESULT	MDL	RESULT	MDL
2,4'-DDD	µg/kg	U	1.460	U	1.450	U	0.404
2,4'-DDE	µg/kg	U	1.460	U	1.450	U	0.404
2,4'-DDT	µg/kg	U	1.460	U	1.450	U	0.404
4,4'-DDD	µg/kg	U	4.850	U	4.830	U	1.340
4,4'-DDE	µg/kg	U	4.850	U	4.830	U	1.340
4,4'-DDT	µg/kg	U	4.850	U	4.830	U	1.340
Aldrin	µg/kg	U	0.485	U	0.483	U	0.067
alpha-BHC	µg/kg	U	0.097	U	0.097	U	0.067
alpha-Chlordane	µg/kg	U	0.097	U	0.097	U	0.067
Beta-BHC	µg/kg	5.554	0.485	U	0.483	U	0.067
Chlordane (Technical)	µg/kg	U	3.880	U	3.870	U	1.610
cis-Nonachlor	µg/kg	U	0.058	U	0.058	U	0.040
delta-BHC	µg/kg	U	0.485	U	0.483	U	0.067
Dieldrin	µg/kg	U	0.194	U	0.193	U	0.134
Endosulfan I	µg/kg	U	0.097	U	0.097	U	0.067
Endosulfan II	µg/kg	U	0.194	U	0.193	U	0.134
Endosulfan sulfate	µg/kg	U	0.194	U	0.193	U	0.134
Endrin	µg/kg	U	0.194	U	0.193	U	0.134
Endrin aldehyde	µg/kg	U	0.194	U	0.193	U	0.134
Endrin ketone	µg/kg	U	0.194	U	0.193	U	0.134
gamma-BHC (Lindane)	µg/kg	U	0.485	2.109	0.483	U	0.067
gamma-Chlordane	µg/kg	U	0.097	U	0.097	U	0.067
Heptachlor	µg/kg	U	0.485	U	0.483	U	0.067
Heptachlor epoxide	µg/kg	U	0.097	U	0.097	U	0.067
Hexachlorobenzene	µg/kg	U	0.058	U	0.058	U	0.040
Methoxychlor	µg/kg	U	0.970	U	0.967	U	6.710
Mirex	µg/kg	U	0.058	U	0.058	U	0.404
Oxychlordane	µg/kg	U	0.058	U	0.058	U	0.040
Toxaphene	µg/kg	U	3.880	U	3.870	U	1.610

Table 15. Pesticides Bar Channel 2005 Testing

ANALYTE	UNITS	SHBC027+000(C)		SHBC045+000 (B)		SHBC063+000 (F)	
		'RESULT	'MDL	'RESULT	'MDL	'RESULT	'MDL
2,4'-DDD	µg/kg	U	0.460	U	0.069	U	1.400
2,4'-DDE	µg/kg	U	0.460	U	0.069	U	1.400
2,4'-DDT	µg/kg	U	0.460	U	0.069	U	1.400
4,4'-DDD	µg/kg	U	1.530	U	0.139	U	2.810
4,4'-DDE	µg/kg	U	1.530	U	0.139	U	2.810
4,4'-DDT	µg/kg	U	1.530	U	0.139	U	2.810
Aldrin	µg/kg	U	0.077	U	0.069	U	0.070
Alpha-BHC	µg/kg	U	0.077	U	0.069	U	0.070
Alpha-Chlordane	µg/kg	U	0.077	U	0.069	U	0.070
beta-BHC	µg/kg	U	0.077	U	0.069	U	0.070
Chlordane (Technical)	µg/kg	U	1.840	U	1.660	U	1.400
cis-Nonachlor	µg/kg	U	0.046	U	0.069	U	0.070
Delta-BHC	µg/kg	U	0.077	U	0.069	U	0.070
Dieldrin	µg/kg	U	0.153	U	0.139	U	0.140
Endosulfan I	µg/kg	U	0.077	U	0.069	U	0.070
Endosulfan II	µg/kg	U	0.153	U	0.139	U	0.140
Endosulfan sulfate	µg/kg	U	0.153	U	0.139	U	0.140
Endrin	µg/kg	U	0.153	U	0.139	U	2.810
Endrin aldehyde	µg/kg	U	0.153	U	0.139	U	2.810
Endrin ketone	µg/kg	U	0.153	U	0.139	U	2.810
gamma-BHC (Lindane)	µg/kg	U	0.077	U	0.069	U	0.070
gamma-Chlordane	µg/kg	U	0.077	U	0.069	U	0.070
Heptachlor	µg/kg	U	0.766	U	0.069	U	0.070
Heptachlor epoxide	µg/kg	U	0.077	U	0.069	U	0.070
Hexachlorobenzene	µg/kg	U	0.046	U	0.069	U	0.070
Methoxychlor	µg/kg	U	7.660	U	0.693	U	0.702
Mirex	µg/kg	U	0.460	U	0.069	U	0.070
Oxychlordane	µg/kg	U	0.046	U	0.069	U	0.070
Toxaphene	µg/kg	U	1.840	U	1.660	U	1.400

Pesticide levels in the reference samples taken during confirmatory sampling were either non-detect or very low. The three outer reference samples showed no detection of pesticides. Each sample is listed below, along with the range of detection limits. All values are µg/kg dry wt.(ppb).

SHRF OU (0.153 to 6.14, 30.7 for methoxychlor)

SHRF MD (0.159 to 7.65)

SHRF IN (0.173 to 4.16)

The three inner reference samples showed mostly no detection of pesticides, except for two samples that showed small amounts of gamma-BHC (lindane). Each sample is listed

below, along with the range of detection limits, and values for lindane. All values are ug/kg dry wt.(ppb).

SHWRF 01 (0.1112 to 4.48), lindane = 3.989.

SHWRF 02 (0.099 to 1.980), lindane = 0.268J

SHWRF 03 (0.188 to 7.540, 37.7 for methoxychlor), lindane = <3.770(U)

In summary, very low levels of a number of pesticides have been detected in Savannah Harbor sediments in scattered parts of the harbor from time to time. This is also true for sediments from the Savannah Harbor reference areas. Environmental effects due to these low levels are expected to be minimal and no contaminant related impacts from pesticides would be expected due to the proposed Savannah Harbor dredging and dredged material placement.

2.3.3.4 Metals. The 1997 sampling (ATM 1998) found some metals (cadmium, chromium, manganese, nickel, zinc) occurred in new work sediments above no effect sediment screening levels, but below probable effects levels. The one exception was the discovery of cadmium at Station -75+000 near the RACON Tower spill (discussed above). These data overall indicate little potential for sediment contaminant-related environmental impacts due to proposed new work channel dredging or dredged material placement. Elimination of other metals as contaminants of concern is covered above in Section 2.2. However, subsequent unrelated testing indicated the potential for cadmium to occur in new work sediments above probable effects sediment screening criteria. These results led to the decision to identify cadmium as a contaminant of concern warranting additional investigation during the Phase 2 sampling. The identification of cadmium as a contaminant of concern is discussed in detail in Section 3.0.

3.0 Identification of Cadmium as a Contaminant of Concern

In February 2006, Savannah District completed an evaluation of sediments that may be excavated to deepen the Savannah Harbor Navigation Project as part of the Savannah Harbor Expansion Project. That evaluation reviewed the information obtained on the physical and chemical properties of the sediments that may be removed by the Expansion Project. That information included results of the 1997 and 2005 sampling. The evaluation concluded that: (1) there is sufficient reason to believe that cadmium is a contaminant of concern (COC) in the proposed SH Expansion Project since it occurs above concentrations of potential concern (available sediment screening criteria) in portions of the proposed dredge material, and (2) this warrants a more detailed evaluation of potential COC (cadmium) effects both inside and outside the DMCAs (Savannah Harbor Expansion Dredged Material Evaluation, Phase 1, PD-EC, 2006a). The process leading up to the decision to conduct further testing and risk evaluation is described below.

3.1 1997 Sediment Sampling

The first observation of cadmium in harbor sediments at levels of concern was in 1997. The following table (Table 16) contains a list of the ten sediment samples collected in 1997 during the Tier 1 studies in which cadmium was detected. The other approximately 18 new work samples showed no detection of cadmium. Using marine sediment screening levels (Buchman, 1999), some of these values were above the Threshold Effects Level (TEL) of 0.676 ppm (mg/kg), Effects Range Low (ERL) of 1.2 ppm (mg/kg), and Probable Effects Level (PEL) of 4.2 ppm (mg/kg). However, none were above the Effects Range Median (ERM) of 9.6 mg/kg, except for the sample taken near the RACON tower (SHBC075NW). These data indicated little overall concern for potential environmental impacts due to expected average cadmium concentrations in the Expansion sediments, but did warrant additional investigation of the RACON tower site.

Table 16. Cadmium Levels Detected during 1997 Sediment Testing for Savannah Harbor Expansion*

SAMPLE DESIGNATION	SAMPLE NUMBER	CADMIUM CONCENTRATION (mg/kg)
SHIHT01NW	76256-3	0.7
SHIH090NW	76256-6	8.5
SHIH085NW	76256-1	5.5
SHIH080NW	76256-2	5.1
SHIHC07NW Composite	76415-20	4.7
SHIHW05NW	76415-8	2.5
SHIH005NW	76415-5	0.48
SHBC005NW	76415-3	0.68
SHBC015NW	76415-10	1.5
SHBC075NW (Archive)	76415A-1	14
SHBC075NW	76415-1	24.3

* Samples taken in October and November, 1997

3.2 Savannah Harbor Advance Maintenance Widener

At approximately the same time in 1997, sediment testing and evaluation was conducted for an unrelated proposed action in the harbor. The testing was conducted in September 1997, as part of an environmental assessment of a proposed advance maintenance widener. Sediment samples were collected between Stations +35+000 and +37+000 (Area 1) and between Stations 0+000 and -14+000 (Area 2) (GEL, 1997).

Two cores, one to -45 feet MLW and one to -46.5 feet MLW were composited for the Area 1 NW (new work) sample. The two cores were taken from Stations 37+100 and 36+100. Four cores (to -45 to -47 feet MLW) were taken in the bar channel from Stations -5+300 to -12+500 for the Area 2 new work sample. The Area 1 new work sample showed a cadmium level of 6.96 mg/kg. The Area 2 new work sample showed cadmium at a level of 0.939 mg/kg. Since the observed cadmium level in the sediments in the Area 1 new work sample (Stations 37+100 to 36+000) was less than the ERM value of 9.6 mg/kg and the relatively small amount of new work sediment would be expected to mix with overlying O&M sediment during the dredging process, the potential for cadmium-related impacts from the dredging and disposal within a DMCA was considered minimal and no additional evaluation was performed.

3.3 Southern LNG Proposed Turning Basin, November 2000 (ATM, 2000)

As part of the dredged material evaluation for a turning basin to be constructed by Southern LNG in the Savannah River adjacent to the navigation channel, three berth cores and three turning basin cores were collected and analyzed for contaminants in November 2000. The berth cores returned cadmium values of 4.94 mg/kg, 3.79 mg/kg, and 13.1 mg/kg. The turning basin cores returned cadmium values of <0.17, <0.40, and 11.4 mg/kg. Since the observed level of cadmium in some of the cores was above the ERM value of 9.6, additional testing was conducted by Southern LNG to more clearly identify the location and extent of cadmium concentrations above the ERM value of 9.6 mg/kg.

3.4 Southern LNG Proposed Turning Basin, Sampling February 2001 (ATM, 2001), SLNG(2001)

In a second round of sediment sampling and evaluation for the proposed turning basin, ATM developed a sampling and analysis plan for Southern LNG in which five cores were collected in February 2001, divided into 2.5 foot sections and analyzed for cadmium. Observed cadmium concentrations by elevation are shown in the following Table 17 in mg/kg dry wt. This work showed that elevated cadmium levels existed in the deeper new work sediments. In subsequent negotiations between the District and Southern LNG, it was determined that sediment below -35 feet MLW on the South Carolina side of the Federal Project would be placed in the applicant's DMCA, as well as sediment below -45 ft MLW on the Georgia side of the Federal Project. Their data showed that sediments above -35 ft MLW that were destined for a Federal Project DMCA would be expected to contain <4.12 mg/kg cadmium and that sediment above -45 ft MLW on the Georgia side and also destined for a Federal Project DMCA would be expected to contain 6.7 mg/kg cadmium or less. The applicant further indicated that sediments deposited within their DMCA (on Elba Island) and containing 12.8 to 83 mg/kg cadmium would be maintained "in as dry as possible a state so as not to create an attractive nuisance for shorebirds".

Table 17. Southern LNG Turning Basin - Cadmium Sediment Core Concentrations by Elevation (ATM, 2001)(mg/kg dry wt)

APPROXIMATE						
TOP ELEVATION OF CORES -MLW (FT)	BOTTOM ELEVATION OF CORES -MLW (FT)	CORE VC-1	CORE VC-2	CORE VC-4	CORE VC-6	CORE VC-7
		STATIONS (feet)				
		40+000	38+000	38+750	39+000	37+000
31	34	0.7		1.2		4.1
33.5	36.5	0.9				13.7
36	39.5	1.2			1.57	17.1
38.5	42	1.7		29.6	1.1	17.3
41	44.5	1.8	1	30.9	2	14
43.5	47	5.4	1.6		6.7	14.1
46	49.5	24.1	1.6		24.2	83
48.5	52	24.5	23.7		27.9	

3.5 Implications of Southern LNG Sediment Findings for SHEP Sediment Testing and Evaluation

Results of the 2001 sediment sampling program by ATM at Southern LNG suggested that elevated cadmium levels might be associated with a clay layer described as Miocene Unit A. ATM analyzed geotechnical boring data from the harbor to predict where this layer might be encountered during the Expansion Project. The goal of the proposed sampling plan was to characterize the potential distribution and concentration of cadmium in the proposed Expansion new work sediments. Due to the unknown nature of the distribution and concentration of cadmium within the Federal Project and the lack of funds for a more comprehensive set of analyses, it was determined that the second round of sediment testing (Phase 2) would consist of only physical and chemical testing. The testing would include two different metals extraction procedures to assess whether the cadmium was tightly bound to the sediments and thus unavailable for potential environmental impacts. If cadmium were found to be tightly bound to the sediment matrix, that finding would be good evidence to expect cadmium would not be released to plants, animals, or water when the sediments were placed in a DMCA. It could then be concluded that sediment concentrations of cadmium above the ERM level would not pose significant potential for environmental impact when placed in a DMCA.

3.6 Phase 2 Sediment Sampling for Cadmium Concentrations by Depth

Sampling in 2005 collected approximately 350 sediment samples at 2-foot intervals from 45 cores distributed throughout the harbor, but concentrating in areas believed to contain Miocene clays. These samples were also analyzed for aluminum, iron, TOC (total organic carbon) and acid volatile sulfides.

Material existed above -46 feet MLW at only a few stations. Cores of that material represented O&M sediments that accumulate within the channel regularly and are the impetus for the annual maintenance dredging of the navigation channel. These O&M samples all showed cadmium levels of about 2 ppm or less.

The most down-river station in the harbor found with elevated cadmium is Station 10+000, where cadmium shows up at 19.2 ppm in the -46 to -48 foot layer. This layer also showed cadmium at concentrations of about 10 to 20 ppm between Stations 28+000 and 36+000. The next upriver sampling location is Station 24+000, where high levels of cadmium (58 – 62 ppm) were found only at depth (in the -54 to -57 foot interval). The next few upriver stations (to Station 26+000) show high cadmium concentrations (40 ppm) in the -48 to -50 foot layer, with deeper layers increasing in cadmium concentration up to 70 ppm in the -54 to -56 foot layer. The deepest interval (-56 to -57 foot) showed less cadmium (30 to 7 ppm) in a decreasing trend with depth while moving upstream to Station 28+000. This cyclical pattern of increasing then decreasing cadmium concentrations is repeated four or five times as one examines sampling Stations, moving upstream (see Figures 1-4, below).

Proceeding upstream, cadmium concentrations show a pattern of generally decreasing peaks and lows that is reflected in each of the 2-foot layers. This pattern shows decreasing peaks and wider intervals between peaks proceeding upstream. The pattern deteriorates somewhat in the deepest layer (either -56 to -57-foot, or -56 to -58-foot), although less data exist for these intervals. At some stations the peak concentrations tend to decrease with depth, while other stations show lower concentrations at the surface and higher concentrations at depth.

Station 32+000 shows very low cadmium concentrations (1 ppm or less) throughout the sediment column (down to -57 feet MLW). Proceeding upstream from Stations 32+000 to 40+000 there is another spike in cadmium concentrations between Stations 34+000 to 36+000, with the -48 to -50 foot layer showing a lower peak concentration (12 ppm) than the deeper layers (about 20 ppm).

The cyclical nature of the data suggest the layers containing cadmium may show a wave-like pattern, with the more inland sediments exhibiting decreasing cadmium concentrations. Data from four depth intervals presented in the following four figures show the cyclical nature of cadmium concentrations in the harbor sediments.

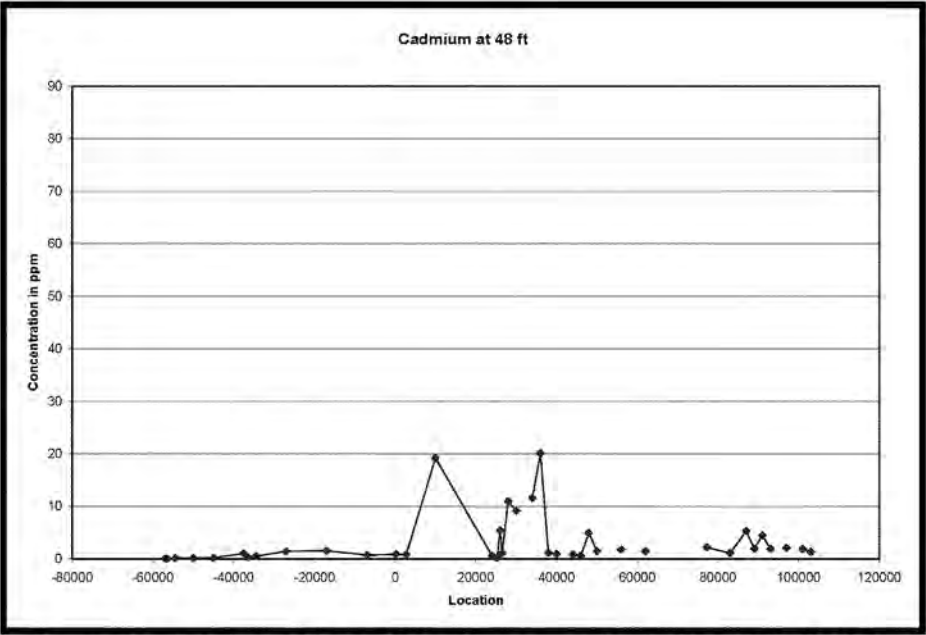


Figure 1. Cadmium distribution in the core segment from -46 to -48 feet MLW, 2005 sampling.

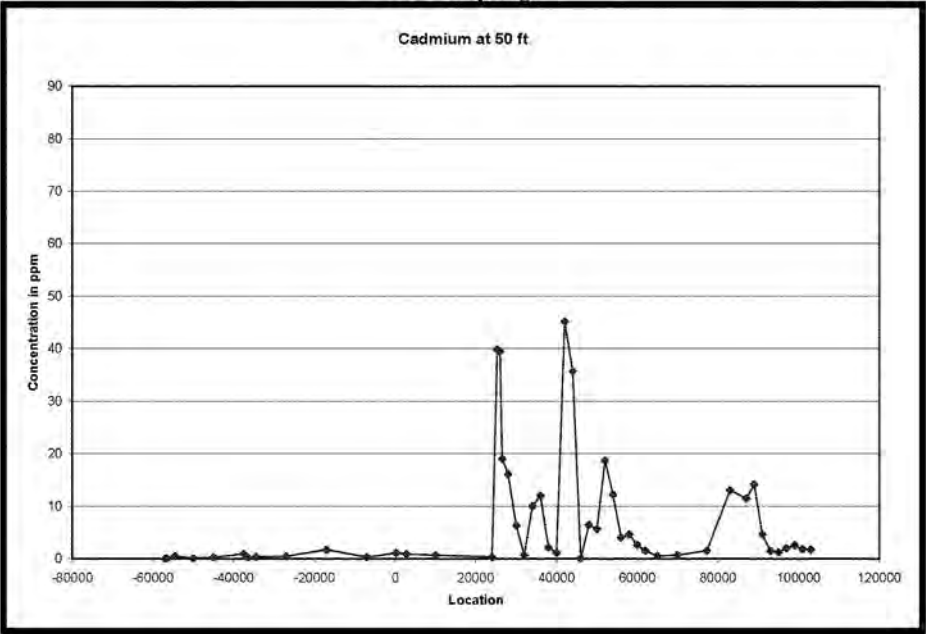


Figure 2. Cadmium distribution in the core segment from -48 to -50 feet MLW, 2005 sampling.

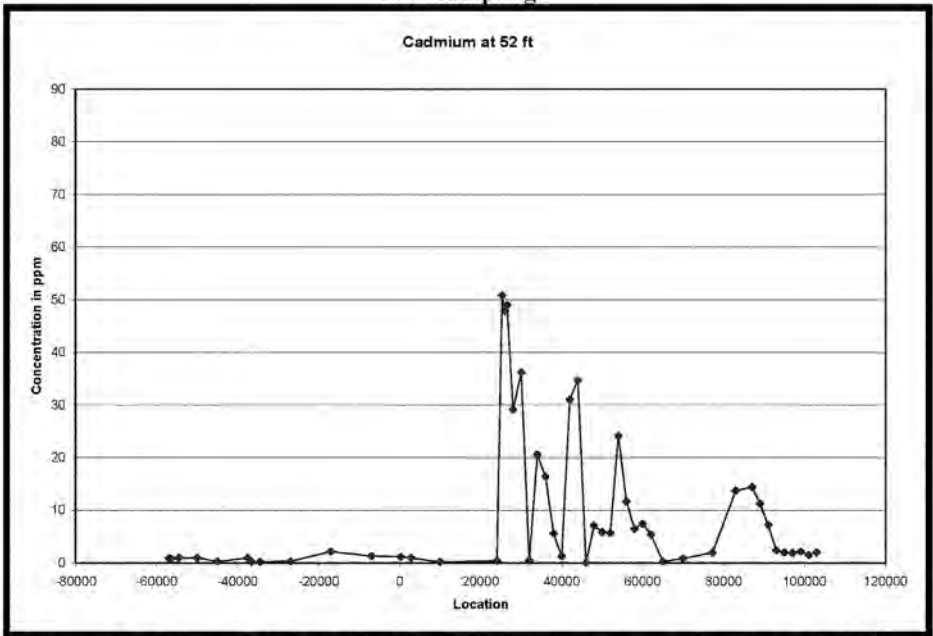


Figure 3. Cadmium distribution in the core segment from -50 to -52 feet MLW, 2005 sampling.

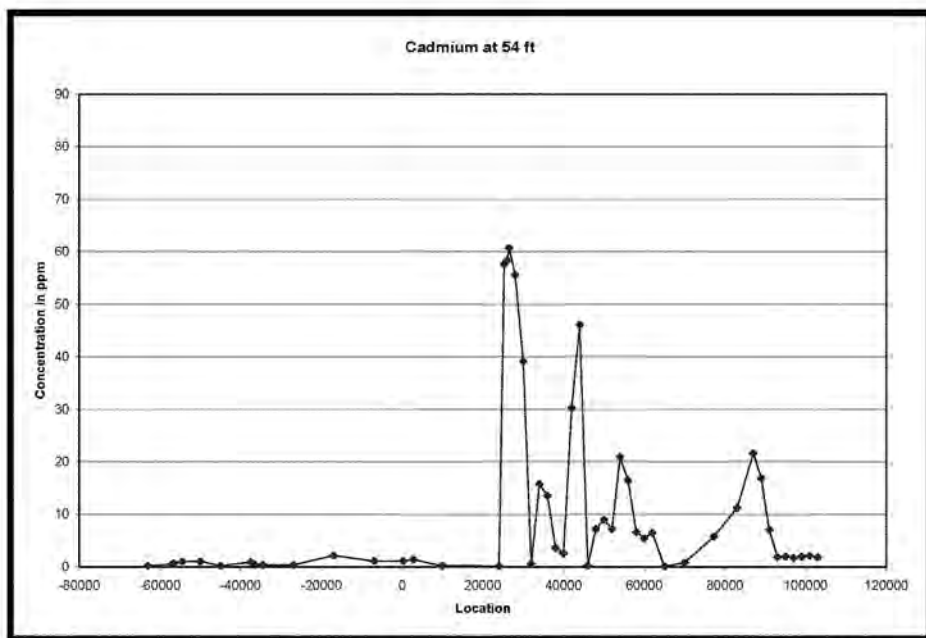


Figure 4. Cadmium distribution in the core segment from -52 to -54 feet MLW, 2005 sampling.

3.7 Expected Distribution of Miocene in the Channel Bottom Surface

Savannah District geologists examined several sources of information to determine where Miocene clays are currently exposed in the channel and where they are expected to be exposed after a 6-foot deepening (EN-G, 2006a). Within the inner harbor, most of the channel currently contains exposed Miocene, with gaps from Stations 0 to +25+000, and between Stations +65+000 and +85+000. Under Expansion, more of the channel would contain exposed Miocene, with a small gap at about Station +68+000, and another gap between Stations +5+000 and +15+000.

The 2005 core sampling was used to estimate the expected cadmium concentrations in surface Miocene clays forming the channel bottom sediments for both the existing condition and after SHEP (EN-G, 2006b). Expected changes in surface cadmium concentrations in the channel bottom sediments have also been identified. In general, cadmium concentrations in bottom sediments are expected to increase after Expansion, except in the reach from Stations +35+000 to +55+000, where some spots should increase and some decrease (EN-G, 2006b through e). Cadmium concentrations in the surface of river bottom sediments are discussed in the next section (3.8).

3.8 Expected Range in Cadmium Concentrations in the Surface Layer of Bottom Sediments by Reach

3.8.1 Use of Core Segment Data to Predict Ranges with Similar Channel Bottom Cadmium Concentrations

Table 18 shows the cadmium ranges expected in the parent material forming the bottom of the channel after SHEP. Ranges with the highest expected cadmium concentrations in bottom sediment are from Stations +94+000 to +80+000 and from Stations +45+000 to +16+000.

Table 18. Cadmium Concentrations of the Surface of Channel Bottom Sediments after SHEP Dredging, Station Ranges Selected According to Similarity of Sediment Cd Concentrations

BEGIN STATION	END STATION	AVERAGE CONC. (MG/KG)	MINIMUM-MAXIMUM CORE SEGMENT CONC. (MG/KG)
103 + 000	94 + 000	1.9	1.8 – 2.0
94 + 000	80 + 000	13.3	9.2 – 20.1
80 + 000	45+000	7.4	ND-11.0
45 + 000	16 + 000	23.4	1.0 – 77.1
16 + 000	6 + 375	0.4	0.4
6 + 375	-63 + 000	0.9	ND – 2.4

3.8.2 Estimate of Reaches where Bottom Sediments are Exposed vs. Areas where Bottom Sediments Are Covered by Extensive O&M Sediments.

Using survey data from 2003 to 2006, District geologists identified areas of the channel experiencing scour and those areas experiencing fill (EN-G 2006f). In general, the upper end of the harbor down to about Station +79+000 experiences continual fill from deposition of O&M sediments. Scouring is the predominant characteristic from about Station +79+000 downstream to Station +49+000. From about Stations +49+000 downstream to Station +27+000, there are areas of scour and areas of fill. The reach from Stations +27+000 to +18+000 experiences predominantly scour. The area from Stations +18+000 to 0+000 experiences predominantly fill. According to the 2005 core data, areas expected to contain exposed bottom sediments with elevated cadmium levels occur from Stations +79+000 to +18+000. The data indicate that the area of major concern would be from Station +18+000 to Station +43+000 (this range includes all of the individual sample readings above 17 ppm Cd except for one 20.1 ppm reading at Station +87+000). A summary of these data is shown in Table 19.

Table 19. Cadmium Concentrations of the Surface of Channel Bottom Sediments after Expansion Dredging, Station Ranges Selected According to Expected Exposure of Bottom Sediments

BEGIN STATION	END STATION	BOTTOM CHARACTER	AVERAGE CONC. (MG/KG)	MINIMUM-MAXIMUM CORE SEGMENT CONC. (MG/KG)
103 + 000	79 + 000	Covered with O&M Sediment	7.6	1.8 – 20.1
79 + 000	49 + 000	Scoured	7.9	4.1 – 11.0
49 + 000	27 + 000	mixed	17.9	ND- 77.1
027 + 000	18 + 000	scoured	29.4	12.9 – 57.9
18 + 000	0 + 000	Covered with O&M Sediment	1.1	0.4 – 1.6

3.9 Estimated Cadmium Concentrations of Sediments Proposed to be Dredged During SHEP

The 2005 core data show the distribution of cadmium within the proposed expansion sediments. These data are presented by elevation (2 foot lifts) in Figures 1-4, above. Average cadmium concentrations by station, based on data from each 1-2 foot lift within each core, are presented in Table 20. Table 21 shows the average cadmium concentration by reaches defined as containing similar levels of cadmium. There are no core data between Stations +10+000 and +24+000, hence the reach dividing point is listed as half-way between the two stations (Station +17+000). There are also no core data between Stations +2+750 and +10+000, hence the reach dividing point is again listed half-way between the two stations (Station SH00 +6+375). As discussed in the Phase 1 Evaluation (PD-E, 2006a), the 2005 sampling provided data by which reaches from Stations +103+000 to +94+000 and Stations +6+375 to -63+000B could be eliminated from further environmental concern due to low sediment cadmium concentrations within those reaches (PD-EC, 2006a).

Table 20. Average Sediment Cadmium Concentration (mg/kg) by Station

STATION	AVG CONC (mg/kg)	HIGHEST CONC (mg/kg)
+000 + 250	1.07	1.29
+002 + 750	1.03	1.65
+010 + 000	3.78	19.20
+24 + 000	16.85	63.48
+25 + 282	36.76	74.91
+26 + 000	39.37	72.94
+26 + 500	34.42	60.69
+28 + 000	27.15	55.61
+30 + 000	26.60	77.09
+32 + 000	0.58	1.02
+34 + 000	14.77	20.55
+36 + 000	15.69	20.07
+38 + 000	4.98	11.63
+40 + 000	7.10	26.16
+42 + 000	28.39	45.14
+44 + 000	23.57	40.06
+46 + 000	0.32	1.10
+48 + 000	6.76	9.66
+50 + 000	6.45	11.20
+52 + 000	9.25	18.71
+54 + 000	18.18	24.07
+56 + 000	8.42	16.43
+58 + 000	6.46	9.08
+60 + 000	6.44	9.02
+62 + 000	5.00	11.21
+65 + 000	2.94	10.09
+70 + 000	3.78	10.97
+77 + 250	2.99	5.46
+83 + 000	8.25	13.72
+87 + 000	11.91	21.58
+89 + 000	9.89	16.88
+91 + 000	5.02	10.64
+93 + 000	2.71	9.20
+95 + 000	1.77	2.00
+97 + 000	1.88	2.03
+99 + 000	2.16	2.55
+101 + 000	1.84	2.09
+103 + 000	1.57	1.98
-7+ 000	0.85	1.27
-17+ 000	1.95	2.36
-27+ 000	0.63	1.45
-34+ 500	0.38	0.53
-36+ 500	0.30	0.42
-37+ 500	0.84	1.04
-45+ 000	0.20	0.45
-50+ 000	0.63	1.07
-54+ 500	0.70	1.11
-56+ 500	0.40	1.31
-57+ 000	0.42	0.88
-63+ 000	0.21	<0.30

Table 21. Characterization of Cadmium Concentrations by Reaches as Initially Proposed*

BEGIN STATION	END STATION	AVERAGE CADMIUM CONC (MG/KG)	UCL 95% CHEBY-SHEV (MG/KG)	MINIMUM-MAXIMUM CORE SEGMENT CONC. (MG/KG)	APPROX 10 ⁶ CU YDS (TOTAL)	ENVIRONMENTAL CONCERN DUE TO CADMIUM?
+103 + 000	+94 + 000	1.83		1.12 – 2.52	2.4	No
+94 + 000	+45 + 000	6.67	10.5	0.04 – 24.07	8.9	No*
+45 + 000	+17 + 000	21.45	36.2	0.11 – 77.09	4.5	Yes*
+17 + 000	+6+ 375	3.78		0.15 – 19.20	1.0	No*
+6+ 375	-63+ 000	0.70		0.023 – 2.36	10.6	No

* Quantities include proposed advance maintenance from Stations +50+000 to +70+000 and passing lanes from Stations +55+000 to +58+000 and from +16+000 to +19+000. A bulking factor of 1.4 should be used to estimate required upland disposal area capacities.

These data indicate that 4.5 million cubic yards of SHEP sediments should average approximately 21.5 ppm cadmium and about 9 million cubic yards should average approximately 6.7 ppm cadmium.

An analysis of the latest sediment testing results indicates that a cadmium concentration of 14 mg/kg is the lowest concentration for which environmental impacts would be expected, see Sections 3.9 and 4.3.1.7. CESAS at first compared average cadmium concentrations by reach to this concentration of concern (Table 21). However, subsequent information became available on the deposition of clay-predominated sediments in DMCA's as clay balls. This information indicated that at least some of the clay sediments would not be expected to mix with other sediments but would tend to form clay balls. Therefore, determinations based on an assumption of sediments mixing to an average condition may not be appropriate where heavy clays are present. Because of the uncertainty surrounding how well clay balls will actually mix in the deposited materials, CESAS re-examined the individual lift data to determine if there are any areas not previously considered for management where the clay sediments could be expected to exhibit cadmium levels of 14 mg/kg or more. Sediments from the following stations (Table 21b) have certain depths where the cadmium occurs at a level of about 14 mg/kg or greater. Reaches with these stations (Stations 51+000 to 57+000 and 80+000 to 90+000) are now also proposed for management (covering) because of the potential for exposure of clay in an upland environment at levels of environmental concern.

Table 21b. Additional Stations Identified for Management

Station	Sample	Depth Interval (feet below MLW)	Cadmium (mg/kg)
10+000	A+B	42 to 46	0.3
	C	46 to 48	19.2
	D	48 to 50	0.7
	E	50 to 52	0.3
	F	52 to 54	0.3
	G	54 to 56	0.4
52+000	D	48 to 50	18.7
	E	50 to 52	5.7
	F	52 to 54	7.2
	G	54 to 56	7.5
	H	56 to 57	5.1
54+000	D	48 to 50	12.2
	E	50 to 52	24.1
	F	52 to 54	20.9
	G	54 to 56	20.9
	H	56 to 57	7.4
56+000	C	46 to 48	1.8
	D	48 to 50	4.1
	E	50 to 52	11.6
	F	52 to 54	16.4
	G	54 to 56	9.3
	H	56 to 57	6.2
83+000	A+B	42 to 46	1.4
	C	46 to 48	1.1
	D	48 to 50	13.1
	E	50 to 52	13.7
	F	52 to 54	11.2
	G	54 to 56	9.8
87+000	A+B	42 to 46	2.7
	C	46 to 48	5.3
	D	48 to 50	11.5
	E	50 to 52	14.4
	F	52 to 54	21.6
	G	54 to 56	20.1
89+000	A+B	42 to 46	1.8
	C	46 to 48	1.9
	D	48 to 50	14.2
	E	50 to 52	11.2
	F	52 to 54	16.9
	G	54 to 56	16.7

Sediments from the reach defined by Stations +94+000 to +45+000 (originally not proposed for management) are predicted to average 6.67 mg/kg cadmium. With the reaches from Stations +51+000 to 57+000 and +80+000 to 90+000 (reach boundaries determined to be half-way between adjacent sampling points) removed, the remaining portion of the reach from Stations +94+000 to +45+000 averages about 4.6 mg/kg cadmium. The highest cadmium concentration in any lift within this interval is 11.0 mg/kg. Not only is the average concentration within this combination of reaches (Stations +94+000 to +90+000, +80+000 to +57+000, and +51+000 to +45+000) well below the 14 mg/kg cadmium level of concern, but so is any single lift value. No management of these reaches is warranted. Sediments from the reach enclosed by Stations +17+000 to +6+375 contain a layer with a cadmium concentration of 19.2 mg/kg. This reach would also require management.

Table 21c. Table 21 Revised. Characterization of Cadmium Concentrations by Reach*

BEGIN STATION	END STATION	AVERAGE CADMIUM CONC (MG/KG)	MINIMUM-MAXIMUM CORE SEGMENT CONC (MG/KG)	APPROX 10 ⁶ CU YDS (TOTAL)	ENVIRONMENTAL CONCERN DUE TO CADMIUM?
+103+000	+90+000	2.42	1.12 – 10.64	4.980	No
+90+000	+80+125	10.02	1.09 – 21.58	1,555	Yes
+80+125	+57+000	4.62	0.30 – 11.21	5,020	No
+57+000	+51+000	11.95	1.78 – 24.07	2,007	Yes
+51+000	+45+000	4.56	0.04 – 10.57	1,894	No
+45+000	+6+375	19.11	0.11 – 77.09	7,368	Yes
+6+375	-85+000	0.73	0.02 – 2.36	15,855	No

* Quantities for the 48-ft project include proposed advance maintenance from Stations +50+000 to +70+000 and passing lanes from Stations +55+000 to +58+000 and from Stations +16+000 to +19+000. A bulking factor of 1.4 should be used to estimate required upland disposal area capacities.

3.10 Availability of Cadmium

3.10.1 Complete Digestion vs. Standard Digestion.

One aspect of the Savannah Harbor Expansion Phase 2 testing (sampling 2005) involved a comparison of digestion techniques for metals -- the complete digestion technique used by ATM (fluoric acid) vs. standard digestion (nitric/hydrochloric acid). The concern was that the complete digestion technique might detect cadmium that was tightly bound in sediment minerals and not available to organisms, thus overestimating potential availability and environmental impacts.

A total of 34 sediment samples were compared using both digestions, with sediment cadmium levels ranging from non-detect (<about 0.2 ppm) to 74.92 ppm. For sediments where cadmium levels for both extractions were greater than 1 ppm, the standard extraction technique produced cadmium results averaging 0.2 ppm higher than the total extraction (n=24). For sediments where cadmium levels were less than or equal to 1 ppm for at least 1 extraction, the standard extraction technique produced cadmium results averaging 0.2 ppm lower than the total extraction technique (n=10). For all extraction data, the mean difference is $(-0.26)(19) + (-0.06)(5) + (0.17)(10) = -0.1 \text{ mg/kg}$. These results indicate that there was essentially no difference in measured sediment cadmium levels produced by these two extraction techniques. This implied that the cadmium found in the clays might not be tightly bound within the clay structure. This finding led to a decision to investigate in greater detail how tightly cadmium was bound within the sediments to further assess potential bioavailability.

Table 22. Comparison of Digestions Methods Where Sediment Concentrations are Greater than 2.5 ppm

SAMPLE ID	CADMIUM RESULT (PPM)	MDL	PREP METHOD	DIFFERENCE ¹
SH010 + 000 (C)	19.20	0.337	EPA 3052	
SH010 + 000 (C)	12.06	0.037	EPA 3050B	7.14
SH025 + 282 (G)	74.92	0.382	EPA 3052	
SH025 + 282 (G)	71.99	0.043	EPA 3050B	2.92
SH026 + 000 (C)	5.41	0.391	EPA 3052	
SH026 + 000 (C)	4.59	0.041	EPA 3050B	0.82
SH026 + 500 (D)	19.05	0.532	EPA 3052	
SH026 + 500 (D)	20.09	0.059	EPA 3050B	-1.05
SH028 + 000 (E)	29.13	0.427	EPA 3052	
SH028 + 000 (E)	40.18	0.047	EPA 3050B	-11.05
SH030 + 000 (C)	9.17	0.325	EPA 3052	
SH030 + 000 (C)	5.06	0.035	EPA 3050B	4.11
SH034 + 000 (D)	10.02	0.459	EPA 3052	
SH034 + 000 (D)	10.65	0.051	EPA 3050B	-0.63
SH034 + 000 (Z)	7.49	0.401	EPA 3052	
SH034 + 000 (Z)	9.81	0.043	EPA 3050B	-2.32
SH036 + 000 (D)	11.99	0.317	EPA 3052	
SH036 + 000 (D)	19.63	0.05	EPA 3050B	-7.64
SH042 + 000 (G)	8.29	0.576	EPA 3052	
SH042 + 000 (G)	8.66	0.064	EPA 3050B	-0.38
SH048 + 000 (D)	6.46	0.56	EPA 3052	
SH048 + 000 (D)	4.95	0.06	EPA 3050B	1.51
SH050 + 000 (H)	10.57	0.516	EPA 3052	
SH050 + 000 (H)	11.20	0.056	EPA 3050B	-0.63
SH052 + 000 (H)	5.11	0.355	EPA 3052	
SH052 + 000 (H)	4.63	0.04	EPA 3050B	0.49
SH054 + 000 (G)	20.94	0.378	EPA 3052	
SH054 + 000 (G)	20.23	0.04	EPA 3050B	0.71
SH058 + 000 (F)	6.62	0.466	EPA 3052	
SH058 + 000 (F)	5.83	0.05	EPA 3050B	0.79
SH062 + 000 (G)	7.41	0.409	EPA 3052	
SH062 + 000 (G)	7.44	0.046	EPA 3050B	-0.02
SH065 + 000 (G)	9.40	0.433	EPA 3052	
SH065 + 000 (G)	10.09	0.049	EPA 3050B	-0.69
SH087 + 000 (F)	21.58	0.382	EPA 3052	
SH087 + 000 (F)	21.03	0.043	EPA 3050B	0.55
SH091 + 000 (D)	4.63	0.362	EPA 3052	
SH091 + 000 (D)	4.25	0.041	EPA 3050B	0.37

¹ This column shows the difference between the complete extraction (EPA 3052) and the standard extraction (EPA 3050B)

SAMPLE ID	CADMIUM RESULT (PPM)	MDL	PREP METHOD	DIFFERENCE ¹
sum of differences				-5.00
Mean difference				-0.26

3.10.2 TCLP Test Results

Savannah District's February 2006 Dredged Material Evaluation (2005 sampling) discussed the potential availability of cadmium in project sediments and concluded there is reason to believe that cadmium could be released from these sediments. The TCLP test was later conducted on some archived sediments from the 2005 sampling to gain further insight into the possibility for release of cadmium under certain conditions.

The TCLP procedures are designed to provide information concerning the mobility of a constituent in material (soil or other waste) by simulating the leaching of the material by slightly acidic groundwater. In this procedure, a sample of the soil or other material is tumbled with the leaching solution (an acetic acid-Sodium acetate buffer solution of pH close to 4.93) for 18 hours. The solids are allowed to settle and the liquid is separated from the solids by filtering through a 0.6 micron glass fiber filter. Centrifugation is not employed to separate the solids from the leachate. The solids are discarded.

The pH of the liquid (TCLP leachate) is measured and the leachate is then acidified to pH <2 with nitric acid. A known volume (25-mL) of the acidified leachate is digested in the same manner as an aqueous sample (EPA SW Method 6010/6020 for metals), adjusted to a final volume of 50-mL, and then filtered using a 0.45 micron filter only if suspended matter is present. Generally, this filtration step is not necessary for most of the TCLP leachates, since they are already filtered using the 0.6 micron filter prior to digestion. This filtration step is used for the sole purpose of preventing the digestate from clogging up the sample inlet when the original aqueous sample contains suspended matter. The analytical results obtained are the concentrations of the metals (or other substances) in the decanted leachate. The results of the TCLIP analyses performed on three archived 2005 samples are shown below.

Table 23. Results of TCLIP Analyses Performed for Cadmium in April 2006 on Archived Samples

Sample Number	Sediment Cd Concentration (mg/kg)	TCLP Cd Result (ug/l)
SH030+000(H)	77.057	56.8
SH091+000(F)	7.026	35.7
SH087+000(F)	21.58	62.5

These data provide further indications that cadmium could be released to the environment under certain conditions. This evidence supported the decision that a more detailed analysis of cadmium was warranted, including determining how the cadmium would be expected to behave under proposed dredging and dredged sediment handling alternatives.

3.10.3 Cadmium Concentrations in the High and Low Composites Created by EA (2008)

The final round of sediment sampling and testing for the SHEP was conducted in 2007. The scope of work called for collection of samples for porewater extraction and creation of “high” and “low” cadmium composites that would be subjected to a number of laboratory studies, including sequential extraction, bioaccumulation, and plant uptake. Cadmium concentrations of the two composites as revealed by several different analyses are listed below in Table 24.

Table 24. Cadmium Concentrations (in ppm) in Composites (EA, 2008)

Test	Low Cadmium Composite	High Cadmium Composite
Average of Sediment Composite and Duplicate	15.0	29.8
Microwave Digestion (ave of two samples)	13.05	30.95
Plant test sediment	15.1	26.2
Plant test dried sediment	13.5	32
Plant test washed & dried sediment	15.4	36.9
SEP total dried soil	16.6	43.1
SEP total washed & dried soil	15.0	36.8

3.10.4 Calculation of the Ratio of Simultaneously Extracted Metals to Acid Volatile Sulfide (SEM/AVS Ratio)

In low oxygenated environments, metals may precipitate with sulfides, rendering them unavailable for uptake by aquatic organisms. Therefore a SEM/AVS ratio less than one is an indication that the metals are not available. No acid volatile sulfide was detected in either the low or high cadmium composites from the 2007 sampling, so calculation of a ratio could not be made by EA (2008). These results leave open the possibility that metals in the sediment could be available.

3.10.5 Sediment Sequential Extraction Procedures (SEP)

3.10.5.1 Availability of Cadmium in SHEP Sediment. Sequential extraction procedures (SEP) were conducted on both the high and low cadmium composites produced from the 2007 sampling to determine what proportion of the cadmium was loosely bound (available). This procedure would provide information on how easily organisms would be expected to accumulate cadmium from the sediments. Metals in the exchangeable fraction are freely soluble and likely to be bioavailable. Metals in the

exchangeable and carbonate fractions are likely to be available with minor decreases in pH. Metals in the organic fraction may be available given moderate changes over time. Metals in the hydroxide and sulfide fractions are only available under extreme conditions (EA 2008, page 5-5). Results of the SEP investigation show that 76 to 78 percent of the cadmium in the Miocene clay sediment is relatively unavailable and no cadmium is freely available. Furthermore, because of the relatively large portion of cadmium in the organic fraction (20-22 percent), it appears that conditions that would degrade the organic fraction would be expected to increase availability of cadmium.

Table 25. Results of Sequential Extraction of Cadmium from Sediment

	Low Cd Comp	Low Cd Comp Dup	High Cd Comp	High Cd Comp Dup
Exchangeable	0%	0%	0%	0%
Carbonate	1.78%	2.02%	1.96%	1.56%
Organic	20.13%	21.94%	20.50%	20.64%
Hydroxide	74.18%	71.00%	73.52%	73.51%
Sulfide	3.91%	4.62%	3.51%	3.75%
Residual	0%	0.42%	0.50%	0.53%
Relatively Unavailable Hydroxide/Sulfide/Residual	78.01%	76.04%	77.53%	77.79%
Total by Microwave Digestion (mg/kg)	13.1	13.0	29.7	32.2
Separate Sediment Analysis (mg/kg)	15.1	14.5	26.2	33.4

3.10.5.2 Availability of Other Metals. EA (2008) found arsenic, chromium, and nickel in the high and low cadmium composites above ERL levels, but not above ERM levels. Arsenic and chromium were not identified as contaminants of concern and are known to exhibit little bioaccumulation. Because of minimal environmental concern related to these two metals, they were not investigated further.

3.10.5.2.1 Nickel. The SEP results for nickel (Tables 26 and 27) show that about 58 to 64 percent of the nickel in the Miocene clays is relatively unavailable, while 7 to 9 percent is freely available. Furthermore, these data indicate nickel could become more available under conditions promoting the degradation of both carbonates and organics. Although nickel was not identified as a contaminant of concern, its potential for bioaccumulation led to the decision to investigate its availability under aquatic conditions in the bioaccumulation study performed by EA using *Macoma nasuta* and *Nereis virens*. Although nickel was found to bioaccumulate above reference, EA (2008) found tissue levels were below benchmarks, indicating no environmental concern (see Section 4.2.5 for further discussion).

Table 26. Results of Sequential Extraction of Nickel from Sediment (mg/kg dry wt)

	Low Cd Comp	Low Cd Comp Dup	High Cd Comp	High Cd Comp Dup
Exchangeable	2.5	2.3	1.9	2.4
Carbonate	2.5	2.6	2.2	1.9
Organic	7.4	7.5	6.7	5
Hydroxide	2.9	2.9	2.5	2.7
Sulfide	12.8	13.4	8.6	9.3
Residual	5.4	4.8	3.7	4.4
Relatively Unavailable Hydroxide/Sulfide/Residual	21.1	21.1	14.8	16.4
Total by Microwave Digestion mg/kg	23.5	25.3	23.1	27
Separate Sediment Analysis mg/kg	21.6	20.5	17.4	19

Table 27. Results of Sequential Extraction of Nickel from Sediment, as Percent of Total Nickel

	Low Cd Comp	Low Cd Comp Dup	High Cd Comp	High Cd Comp Dup
Exchangeable	7.5	6.9	7.4	9.3
Carbonate	7.5	7.8	8.6	7.4
Organic	22.1	22.4	26.2	19.5
Hydroxide	8.7	8.7	9.8	10.5
Sulfide	38.2	40.0	33.6	36.2
Residual	16.1	14.3	14.5	17.1
Relatively Unavailable Hydroxide/Sulfide/Residual	62.9%	62.9%	57.8%	63.8%

3.10.5.2.2 Zinc. Zinc was not identified as a contaminant of concern as a result of either the 1997 sampling or the 2005 sampling. However, because of its potential to bioaccumulate, it was investigated further by EA (2008) during the 2007 sampling and analyses. Zinc was found to become somewhat more available under dry oxidizing conditions (Section 2.1.5). Zinc uptake in the bioaccumulation tests (wet sediment) was found to be significantly different from reference only in the clam, and only in the low cadmium composite. The observed increase in uptake over reference (9.32 vs. 10.2 mg/kg wet weight) was less than 10 percent and should have no environmental significance. See further discussion at Section 4.2.5. Potential impacts under oxidizing conditions were assessed through the plant uptake test. Zinc uptake was significantly higher than reference for both the low and high cadmium composites, indicating zinc effects could add to potential cadmium effects identified for elevated cadmium sediments placed on the dikes. See further discussion at Section 4.3.1.6.

3.10.6 Sequential Extraction Procedures (SEP) for Cadmium on Washed and Dried Composites

Sequential extraction procedures (SEP) were conducted on washed and dried samples from both the high and low cadmium composites produced from the 2007 sampling to determine what proportion of the cadmium would be loosely bound after the sediments are oxidized.

As shown in the following two tables, SEP data from EA show there is a change in potential availability of cadmium between project wet sediment and dry "soil". Both composites show an increase in the carbonate fraction when dried. The low cadmium composite in addition showed a decrease in the hydroxide fraction. The high cadmium composite showed an increase in all fractions, making interpretation difficult. These changes do indicate cadmium should be more available in the dried soil than the wet sediment.

Table 28. Comparison of Wet and Washed/Dried Low Cadmium Composite SEP Results for Cadmium

	Wet Low Cd mg/kg	Wet Low Cd Dup mg/kg	Washed Dry Low CD mg/kg	Wet Low Cd %	Wet Low Cd Dup %	Washed Dry Low Cd %
Exchangeable	<0.105	<0.11	<0.11	0.60	0.63	0.63
Carbonate	0.31	0.35	2.5	1.77	2.01	14.26
Hydroxide	12.9	12.3	10.1	73.59	70.56	57.62
Organic	3.5	3.8	3.1	19.97	21.80	17.68
Sulfide	0.68	0.8	0.99	3.88	4.59	5.65
Residual	<0.0355	0.073	0.73	0.20	0.42	4.16
Total	17.5305	17.433	17.53	100.00	100.00	100.00

Table 29. Comparison of Wet and Washed/Dried High Cadmium Composite SEP Results for Cadmium

	Wet High Cd mg/kg	Wet High Cd Dup mg/kg	Washed Dry High Cd mg/kg	Wet High Cd %	Wet High Cd Dup %	Washed Dry High Cd %
Exchangeable	<0.095	<0.1	0.18	0.28	0.31	0.42
Carbonate	0.67	0.5	1.8	1.96	1.56	4.25
Hydroxide	25.1	23.5	28.2	73.32	73.28	66.54
Organic	7	6.6	8.9	20.45	20.58	21.00
Sulfide	1.2	1.2	2.9	3.51	3.74	6.84
Residual	0.17	0.17	0.4	0.50	0.53	0.94
Total	34.235	32.07	42.38	100.00	100.00	100.00

3.10.7 Sediment Porewater Analyses

Porewater measurements are often a better indication of potential risk in wet environments than total sediment concentration, as porewater concentrations are considered available to aquatic organisms. Porewater analyses were performed on intact sediment samples by the U.S. Geological Survey (USGS, 2007). The maximum detected cadmium porewater concentration was 0.12 mg/l (see Tables 30 and 31, below). This value is well below USEPA/SC chronic water quality criteria/standards of 9.3 mg/L (total) and 8.8 mg/L (dissolved). These results indicate there should be minimal concern related to potential environmental impacts associated with sediment cadmium in an aquatic environment.

Table 30. Core 8 Porewater Analysis, Station +26+000

Sample depth*1	Cadmium (ug/L)*2	Chloride (mg/L)	Mean Sediment Cd Concentration (mg/kg)
6"	0.06	14,523	31.8
18"	0.03	12,428	31.8
30"	0.02	10,689	49.0
42"	0.01	8,309	49.0
54"	0.00	7,042	53.5
66"	0.01	5,820	53.5

*1 Refers to location of pore-water sample, inches from top of core

*2 Refers to pore-water cadmium, dissolved, in micrograms per liter.

Table 31. Core 3 Porewater Analysis, Station +26+500

Sample depth*1	Cadmium (ug/L)*2	Chloride (mg/L)	Mean Sediment Cd Concentration (mg/kg)
6"	0.12	14,146	42.9
18"	0.01	9,968	42.9
30"	0.01	10,122	46.2
42"	0.06	8,344	46.2
54"	0.01	5,980	64.1
66"	0.01	6,705	64.1

*1 Refers to location of porewater sample, inches from top of core

*2 Refers to pore-water cadmium, dissolved, in micrograms per liter.

3.10.8 Comparison of Surface Water Concentrations to Benchmarks

Two predictions of potential cadmium concentrations in water were made, one based on elutriate results, and the other based on cadmium concentrations measured in the bioaccumulation study tanks (EA 2008, Chapter 10.4.1.c). The elutriate studies found very high total cadmium concentrations, but only 1.5 ug/l dissolved cadmium in the high cadmium composite elutriates (see Tables 33 and 34 for the standard elutriate results). Since it is primarily dissolved cadmium that is believed to be available, this again indicates little environmental concern for cadmium in the aquatic environment. Furthermore, the elutriate test artificially ensured the test sediments were completely suspended prior to testing. The high TSS used in the elutriate tests may not accurately reflect what would happen during the dredging project, as the dredging process would not be expected to result in suspension of a large fraction of the clay particles (EA 2008, Chapter 10.4.1.c).

In the water quality monitoring associated with the bioaccumulation studies, the highest dissolved cadmium concentration was found to be 5.8 ug/L. Since this reading is also below chronic water quality criteria, this is further evidence there should be minimal concern related to potential environmental impacts associated with cadmium in an aquatic environment.

Table 32. Metal Concentrations in Dredging Water (Savannah River) and Receiving Water (Field's Cut) (ug/L), from EA, 2008, Table 6.3

	EPA/SC Acute Criteria	EPA/SC Chronic Criteria	Dredging Water Total	Dredging Water Dissolved	Receiving Water Total	Receiving Water Dissolved
Arsenic	69	36	7.5	20.8	11.7	16.5
Cadmium	40/43	8.8/9.3	<0.074	<0.074	<0.074	<0.074
Chromium	1,100	50	2.4	0.85	2.6	1.5
Copper	4.8/5.8	3.1/3.7	1.6	7.5	1.7	1.9
Lead	210/220	8.1/8.5	0.71	0.69	0.3	0.31
Manganese			15.9	2.2	36.2	26.6
Mercury	1.8/2.1	0.94/1.1	<0.048	<0.048	<0.048	0.053
Nickel	745/75	8.2/8.3	<0.2	4.1	0.66	1
Selenium	290	71	29.6	93.6	50.6	75.4
Silver	1.9/2.3		<0.31	<0.31	<0.31	<0.31
Thallium			0.26	<0.059	0.29	<0.059
Zinc	90/95	81/86	4.4	14.7	4	6.1

3.10.9 Conduct of Animal Bioaccumulation Studies

The sediment bioaccumulation studies conducted on the project high and low cadmium wet sediment composites found accumulation of cadmium and nickel above reference by a polychaete (*Nereis virens*) and accumulation of nickel and zinc above reference by a clam (*Macoma nasuta*). EA (2008) found tissue levels to be below benchmarks and risk analyses found no reason for concern. See paragraph 4.2.5 for further discussion.

3.10.10 Conduct of Plant Bioaccumulation Studies

A plant bioaccumulation study was conducted on project washed (to remove salinity) and dried high and low cadmium composites. Test plants were found to accumulate cadmium, nickel, and zinc significantly above reference for both the low and high cadmium composites. Plant growth was inversely related to cadmium concentrations, but other factors may have been operative (availability of nutrients). See further discussion at Section 4.3.1.5.

4.0 Proposed Action and Identification of Pathways of Concern

It is assumed that the majority of the SHEP dredging will be by hydraulic cutterhead dredge. Production rates make other forms of mechanical dredging impracticable. Hopper dredging is generally not suitable for the highly consolidated new work sediments. However, material from Stations +4+000 to -50+000B is being considered for both pipeline and hopper dredging. Material from Stations -50+000B to -98+000B is being considered for only hopper dredging.

The present plans are for the SHEP inner harbor dredged sediments to be placed by cutterhead hydraulic dredge in a DMCA adjacent to the channel. This should be the least expensive disposal method for sediments with minimal potential environmental impacts. Clamshell or other mechanical dredging equipment may also be used. For sediments requiring management due to concern over cadmium concentrations, ocean disposal is not deemed an option. Cadmium is one of the contaminants specifically prohibited by EPA regulations from ocean disposal at levels greater than trace. EPA regulations at 40 CFR 227.6(b) state "These constituents will be considered to be present as trace contaminants only when they are present in materials otherwise acceptable for ocean dumping in such forms and amounts in liquid, suspended particulate, and solid phases that the dumping of the materials will not cause significant undesirable effects, including the possibility of danger associated with their bioaccumulation in marine organisms." Furthermore, bioaccumulation studies demonstrated accumulation of cadmium above reference for the high cadmium sediment composite and no method has been identified for limiting exposure of these sediments after placement in the ocean.

For the SHEP sediments requiring management due to elevated levels of cadmium, there are three primary dredged material placement alternatives: (1) deposit the sediments in a DMCA, with subsequent management in the rotation plan; (2) deposit the sediments in a DMCA with capping/covering; and (3) deposit the sediments in a DMCA with capping/covering and lining. Management alternatives are discussed in detail at Chapter 6.0.

4.1 Identification of Pathways of Concern

The Upland Testing Manual provides guidance on evaluating the potential for contaminant-related impacts from deposition of dredged sediments within an upland DMCA. This guidance includes details on identifying the pathways by which a contaminant may be released from a DMCA and impact the surrounding environment. In addition, because the Navigation Project DMCAs are managed in a wet state to produce wetland habitat values as part of a wetland mitigation plan, guidance in the Inland Testing Manual is also relevant. This evaluation of potential sediment contaminant-related impacts uses guidance from both the Upland Manual and Inland Manual (where appropriate).

The proposed work contains two separate actions through which cadmium could be released to the environment: dredging and dredged sediment placement. The potential pathways associated with each of these actions are listed below. Assessment of these pathways involves determining if a complete pathway exists (is there a potential for movement of a contaminant and is a receptor of concern present) and then determining the potential for affect to that receptor.

4.2 Potential Pathways through Dredging

4.2.1 Release of Sediment to the Water Column during the Dredging Activity

Discharges of sediment to the water column during hydraulic dredging, seen as increased turbidity in the water column, are normally considered *de minimis*. However, in this case the dredged sediment is expected to contain elevated levels of cadmium. The presence of sediments with elevated levels of cadmium raises the potential for environmental impact. However, the Miocene clays thought to contain elevated cadmium are expected to remain relatively intact during the dredging process and form clay balls that would be deposited in the DMCAs. Relatively minor amounts of clay would be expected to be released to the river water column. Furthermore, standard elutriate analyses on the sediment composites found the dissolved fraction of only three parameters (selenium, nickel, and ammonia) to be above water quality criteria (Table 34). Cadmium was not one of them.

EA (2008) ran the standard elutriate preparation on both the high and low cadmium composites and compared the results to EPA and SC water quality criteria. Total concentrations for several metals were high (EA, 2008, Table 6-5), but are not expected to reflect conditions in the field. This is because the elutriates were made by totally suspending all sediment in a sample, creating extremely concentrated suspended sediment mixtures that would not be expected under normal dredging conditions. This is because most of the clay sediment is expected to remain in large particles when dredged, mostly as clay balls, and not suspended in the water column. EA (2008) suggests the dissolved fraction should be a better estimate of metals that would actually be available to aquatic organisms in the river.

The selenium concentration in the dredging water was 93.6 ug/l (Table 32), making it highly unlikely that selenium in the dredged sediment contributed to the selenium criterion exceedence by the high cadmium composite elutriate (119 ug/L). This water was taken from the Savannah River and was not mixed with any cadmium-enriched sediment. The results for cadmium show there is little expectation for an exceedence of water quality criteria. In the cases of nickel and ammonia, ammonia would require the greatest dilution to meet chronic water quality criteria (factor of 8.7) and acute criteria

Table 33. Standard Elutriate Total Fraction Exceeding Criteria (from EA 2008, Table 6-5)

	USEPA/SC Acute Criteria	USEPA/SC Chronic Criteria	Low Cd Composite	High Cd Composite
Ammonia as N	9.14	1.37	15.5	6.1
Arsenic	69	36	944	1,200
Cadmium	40/43	8.8/9.3	1,790	3,740
Chromium	1,100	50	6,840	11,600
Copper	4.8/5.8	3.1/3.7	660	1,160
Lead	210/220	8.1/8.5	289	510
Mercury	1.8/2.1	0.94/1.1	3.2	6.7
Nickel	74/75	8.2/8.3	1,510	1,740
Selenium	290	71	249	342
Silver	1.9/2.3		21.3	78.2
Zinc	90/95	81/86	9,510	15,400

Table 34. Standard Elutriate Dissolved Fraction Showing Cadmium Results Plus Metals Exceeding Criteria (from EA 2008, Table 6-5)

	USEPA/SC Acute Criteria	USEPA/SC Chronic Criteria	Low Cd Composite	High Cd Composite
Ammonia, mg/L	9.14	1.37	11.9	5.2
Nickel, ug/L	74/75	8.2/8.3	17.1	29.2
Selenium, ug/L	290	71	56	119
Cadmium, ug/L	40/43	8.8/9.3	<0.37	1.5

(factor of 1.3). A dilution factor of 1.3 for acute exceedences means that almost immediate dilution with river water should reduce ammonia levels below acute criteria. Moreover, dilutions of greater than 8 to 1 would be expected far before the 4-day chronic exposure criteria are exceeded. Therefore, there should be little environmental concern related to river water metal concentrations exceeding criteria due to Expansion dredging.

4.2.2 Movement of Cadmium from Sediment in the Water Column to Aquatic Resources within the River

Measurements of pore water cadmium from high Cd sediments (Tables 30 and 31), dissolved cadmium in standard elutriates of both low and high cadmium sediment (Tables 33 and 34), and measurements of cadmium concentrations found in the overlying water for the bioaccumulation tests (Section 3.10.8) were all less than water quality criteria.

These data show there should be little concern for dissolved cadmium to be released to the water column during dredging.

4.2.3 Exposure of Cadmium Containing Sediment within the Channel Banks and Bottom to the Water Column, with Movement of Cadmium from the Sediment to the Water Column and then to Aquatic Resources within the River

In order for a complete pathway to exist from cadmium-containing Miocene sediments to the water column, the Miocene clays have to be exposed to the water column, and cadmium must move from the clays to the water column. To estimate the portions of the channel where channel bottom surface clays would be expected to remain exposed to the water column, several different investigations were conducted. Several of these assessments are discussed at Section 3.8.2. When annual dredging volumes are examined by channel reach, the data show where the majority of dredging takes place. In those reaches with large annual volumes of maintenance sediments, the channel bottom would be expected to be covered by O&M sediments for most of the year. In such areas, there would be little potential for environmental impacts, even if the underlying sediments contained elevated cadmium. Average annual dredging volumes by reach are shown below in Table 35. A volume of about 18,500 cu yds represents an average cover of about 1 foot of maintenance material in a 1,000-foot section of the channel. These data show the reach from Stations +16+000 to +34+000 to be the primary location where channel bottom sediments with elevated cadmium concentrations might be expected to be exposed for any period of time.

Table 35. Annual Volume Dredged by Station 1970 thru 1975, 1981 thru 1985, and 1997 thru 2004 (from *Sedimentation Analysis*, CESAW (Mike Wutkowski, 22 Feb 06))

Station	Annual Volume 1970 - 1975	Annual Volume 1981 - 1985	Annual Volume 1997 - 2004	Cadmium at Bottom Surface after SHEP (mg/kg)
0+000	11,001	8,797	9,683	1.16
1+000	11,001	15,079	9,683	
2+000	11,001	18,823	11,380	1.65
3+000	11,001	19,272	10,010	
4+000	11,001	19,272	21,153	
5+000	8,447	19,272	21,153	
6+000	8,447	19,272	21,367	
7+000	18,585	12,459	837	
8+000	22,019	22,587	1,995	
9+000	22,019	22,587	6,803	
10+000	22,019	22,587	6,659	0.42
11+000	22,019	12,459	4,355	
12+000	21,611	10,694	5,533	
13+000	13,036	10,694	5,621	
14+000	13,036	19,881	9,411	
15+000	13,036	16,709	12,069	
16+000	8,497	16,709	14,940	
17+000	8,497	16,709	15,306	
18+000	20,191	29,664	15,312	
19+000	20,606	22,080	12,786	
20+000	20,606	17,662	12,392	
21+000	8,912	14,832	7,948	
22+000	8,912	14,832	2,053	
23+000	8,912	14,832	1,516	
24+000	8,912	16,425	4,915	57.85
25+000	8,912	32,183	3,731	31.26
26+000	10,520	32,183	19,921	15.50
27+000	18,108	32,183	16,190	12.92
28+000	18,108	509	13,100	7.72
29+000	10,520	509	13,482	
30+000	45,568	9,155	10,411	77.09
31+000	45,568	9,155	10,738	
32+000	45,568	9,155	10,738	1.02
33+000	45,568	3,615	8,577	
34+000	28,481	3,084	5,382	16.86
35+000	14,103	57,629	34,378	

36+000	29,818	57,629	40,242	15.60
37+000	38,433	57,629	28,060	
38+000	40,495	46,069	19,905	6.53
39+000	33,758	46,069	20,292	
40+000	76,149	66,182	12,368	26.12
41+000	116,413	66,182	17,180	
42+000	124,529	66,182	26,794	26.05
43+000	128,368	54,853	34,487	
44+000	142,068	53,224	13,999	9.76
45+000	135,979	43,934	20,683	
46+000	106,296	53,275	16,493	0.06
47+000	133,497	39,085	20,828	
48+000	146,264	45,191	20,529	9.66
49+000	163,380	61,778	21,759	
50+000	141,880	61,778	18,002	10.57
51+000	174,377	71,137	20,598	
52+000	188,639	92,452	20,598	5.11
53+000	193,596	93,785	8,704	
54+000	190,299	115,300	9,277	7.38
55+000	161,113	76,769	5,096	
56+000	160,300	55,987	4,693	6.23
57+000	122,867	52,886	5,454	
58+000	109,962	49,485	4,906	9.08
59+000	133,168	57,258	37,995	
60+000	131,148	45,450	49,241	9.02
61+000	110,486	45,450	61,092	
62+000	106,426	45,551	39,164	10.47
63+000	89,087	53,840	30,262	
64+000	100,260	35,414	15,444	
65+000	101,008	25,862	15,243	5.96
66+000	106,589	16,393	34,283	
67+000	274,687	88,310	69,954	
68+000	266,254	118,417	81,214	
69+000	275,892	117,415	81,214	
70+000	48,582	8,586	74,633	10.97
71+000	48,582	8,586	77,856	
72+000	48,582	2,414	71,549	
73+000	37,644	2,414	8,005	
74+000	0	13,229	12,072	
75+000	0	16,478	17,602	
76+000	18,037	16,120	19,442	
77+000	18,037	17,767	15,030	4.07
78+000	18,037	1,647	15,030	
79+000	19,574	0	3,057	
80+000	20,826	6,988	2,415	

81+000	24,844	6,988	2,415	
82+000	28,076	143	8,156	
83+000	29,352	1,866	11,103	9.81
84+000	32,851	143	1,294	
85+000	27,249	143	1,294	
86+000	25,973	143	13,693	
87+000	22,059	0	30,111	20.14
88+000	36,358	357	51,888	
89+000	145,865	3,547	58,976	16.68
90+000	152,442	3,414	70,584	
91+000	177,433	3,414	74,601	10.64
92+000	32,716	534	44,419	
93+000	32,276	534	1,673	9.20
94+000	9,929	534	1,673	
95+000	9,929	0	1,673	1.93
96+000	23,753	0	1,381	
97+000	82,606	26,268	116,226	2.01
98+000	455,992	63,995	189,772	
99+000	459,867	63,995	399,576	1.76
100+000	434,603	100,592	308,948	
101+000	56,211	64,377	239,898	1.96
102+000	68,420	37,007	49,172	
103+000	90,052	29,667	41,306	1.80
104+000	76,625	9,392	42,106	
105+000	59,900	6,954	32,687	
106+000	16,264	776	2,191	
107+000	16,264	776	2,191	
108+000	16,264	1,256	2,191	
109+000	27,795	3,339	10,857	
110+000	62,488	17,082	17,411	
111+000	62,488	17,082	17,411	
112+000	51,033	17,082	18,226	
113+000	23,238	0	0	

EA (2008) used both sediment profile imaging (SPI) and side scan sonar imaging to assess how much of the channel bottom surface is currently exposed to the water column and how much is covered by O&M sediments. With these techniques, they were able to determine the distribution and proportion of exposed clays relative to other bottom habitat types. While small areas of exposed Miocene clays were identified in some specific portions of the target areas, these regions were isolated and discontinuous throughout the channel bottom (EA 2008, page ES-2).

Side scan sonar was used by EA to document the bottom characteristics between Stations +16+500 and +62+000. They found 28 percent of the channel bottom was comprised of compact clays, coarse sands and gravels. In addition, more intense side scan sonar investigations in the region between Stations +24+000 and +30+000 found active sand wave migration occurring on the order of 4 to 6 feet per tide cycle. The results of the SPI and side scan sonar investigations indicate that only a small portion of the channel bottom currently contains exposed Miocene clay and that the majority of the channel is covered by shifting bottom sediments. Because the District predicts little change in channel sedimentation patterns due to Expansion, this condition is expected to be characteristic of the channel bottom after Expansion dredging is completed. Therefore, between Stations +16+000 and +62+000, Expansion dredging is expected to result in a channel bottom where only a small portion of the bottom would consist of exposed Miocene clays. The channel bottom above Station +60+000 is not expected to contain any exposed Miocene, since high siltation rates are expected to result in a channel bottom covered with silts. In conclusion, the post-project condition is expected to include a channel bottom in which only a small area of Miocene clay would be exposed at any one time. Therefore, the potential for cadmium-related impacts to the water column due to exposed cadmium containing clays is expected to be minimal.

As further support for this expectation, the findings of both the porewater study (Section 3.10.7) and the bioaccumulation monitoring (Section 3.10.8) show cadmium-containing sediments release cadmium at levels below water quality criteria, indicating that if the high cadmium sediments were exposed to the river water column, release of cadmium would be expected to be minimal.

4.2.4 Colonization of Exposed Cadmium-containing Sediments by Benthic Organisms, with Movement of Cadmium through Benthics to the Aquatic Food Chain

Several factors could influence the degree to which cadmium might move from channel bottom sediment to benthics to the aquatic food chain: (1) Would clay sediment with elevated cadmium be exposed so that benthics growing in the clay could support an aquatic food chain? (2) Can Miocene clays support benthic organisms? (3) Would cadmium in the bottom sediments be available to benthic organisms such that the organisms would accumulate cadmium and pass it through the food chain?

EA (2008) conducted a benthic community assessment of the river bottom both inside and outside the channel. They found a substantial benthic community within the channel bottom. In addition, they found that the coarse sand/gravel/clay substrate was used by benthic organisms, although they were unable to determine to what extent benthic organisms might burrow into the clay. They found that the substantial presence of benthic organisms within the channel maintenance sediments indicates that the impact of maintenance dredging is temporary. However, the limited availability of exposed high cadmium sediments within the navigation channel, as discussed above, precludes more than minimal potential for clay dwelling benthic input to the riverine ecosystem. EA found that the clay substrate does support benthic organisms, but this substrate should be

exposed only between Stations +16+000 and +60+000 and should comprise less than 28 percent of the channel bottom between those stations. This finding indicates that benthic organisms residing in exposed Miocene clays should present a relatively small fraction of the benthic organisms within the channel ecosystem. Because of the predicted small fraction of available habitat, potential impacts through bioaccumulation of cadmium by benthic organisms within the Miocene clays appear to be minor, but not zero. To be conservative, the potential for bioaccumulation of cadmium by benthic organisms is addressed in the next section. The bioaccumulation studies discussed below show bioaccumulation in high cadmium sediments to be well below potential levels of effect. Therefore, potential environmental impacts through bioaccumulation of cadmium by benthic organisms is expected to be minimal.

4.2.5 28-day Bioaccumulation Studies Using Miocene Clay Composites

Aquatic Bioaccumulation Studies were performed by EA (EA 2008, Chapter 8). These studies were performed in accordance with EPA protocols for evaluation of dredged sediment proposed for placement in the ocean. The studies used sand worms (*Nereis virens*) and the blunt-nosed clam (*Macoma nasuta*) grown in both the low cadmium and high cadmium wet composites and reference sediment. Although the only contaminant of concern had at that time already been identified to be cadmium, a set of metals detected in the project sediments and deemed most likely to bioaccumulate were evaluated (cadmium, copper, lead, mercury, nickel, zinc) to address any potential concerns that might be raised by others. The results of that study are discussed below. The detailed results of that study are shown in EA, 2008, Table 8-7.

Tissue results significantly different from reference values are shown in Tables 36 and 37, below. The bioaccumulation study found that cadmium and nickel concentrations in the worm tissues statistically exceeded concentrations in reference site tissues for both the high cadmium and low cadmium wet sediment composites. Copper, lead, mercury and zinc tissue concentrations showed no significant difference from reference. The clam tissues showed no differences from reference for cadmium, but did find significant differences for nickel, using both composites. Zinc uptake in the clam was inconclusive, with the low cadmium composite tissues showing a significant but only slightly higher tissue zinc concentration when compared to reference, but the high cadmium composite tissues showing no difference. Given that the low cadmium composite contained 96 ppm zinc compared to 164 ppm zinc in the high cadmium composite, the observed significant difference from reference for zinc in the low cadmium composite is probably due to chance variation and should have no environmental significance. When compared to the clam results, higher uptake levels for cadmium and nickel were shown by the worm (Table 36) and those results (Table 37) are discussed here as the worst case scenario.

Table 36. Mean Tissue Metal Concentrations (mg/kg wet wt) from Bioaccumulation Study (EA 2008, Table 8-7), Showing Results Significantly Different from Reference (in Bold)

	Reference	Low Cd Composite	High Cd Composite
Worm Tissue Cd Conc	0.0164	0.113	0.198
Sediment Cd Conc	0.15	15	30
BCF	0.11	0.0075	0.0066
Worm Tissue Ni Conc	0.248	0.678	0.694
Sediment Ni Conc	4.6	21	18
BCF	0.054	0.032	0.039
Clam Tissue Ni Conc	0.368	0.54	0.484
Sediment Ni Conc	4.6	21	18
BCF	0.08	0.026	0.027
Clam Tissue Zn Conc	9.32	10.2	9.38
Sediment Zn Conc	25.8	96	147
BCF	0.36	0.11	0.064

Table 37. Worm Tissue Results from Bioaccumulation Study (EA 2008, Table 8-7), mg/kg wet wt.

	Reference	Low Cd Composite	High Cd Composite	NOAEL (ERED)
Cadmium	0.0164	0.113	0.198	1.12 ^{*1}
Nickel	0.248	0.678	0.694	2.0 ^{*2}

* 1 Lowest Cadmium NOAEL in ERED database for *Neanthes arenaceodentata*; NOAELs for other polychaetes (*Laeonereis acuta*) range from 0.14 to 0.48 mg/kg.

* 2 Rainbow Trout (lowest NOED/NOAEL for nickel in ERED database, except for a frog).

The sequential extraction and bioaccumulation results provide an expectation that, given the opportunity, some aquatic organisms would be expected to bioaccumulate cadmium and nickel. However, worm tissue levels observed in the bioaccumulation study for both cadmium and nickel were at or below most NOAELs published in the ERED database. The database does contain starfish LOEDs of 0.03 mg/kg Cd(gonad) in males and 0.14 mg/kg Cd(gonad) in females. Starfish are known from bioassay studies to be very sensitive organisms. These data, therefore, show the potential for borderline effects in very sensitive benthic organisms. Overall, these data show there should be minimal environmental concerns for benthic aquatic organisms exposed to the cadmium-containing sediments within the river.

To predict fish tissue levels, an overly conservative assumption that the BAcF=I would predict fish tissue levels would be the same as worm tissue. This assumes the fish would feed entirely on worms living in the cadmium-containing sediments. The ERED database

shows a cadmium NOAEL of 0.3 mg/kg-wet wt. and an LOED of 0.9 mg/kg Cd for developmental impacts to the sheepshead minnow (*Cyprinodon variegates*). Since the cadmium worm tissue concentration in the high cadmium composite was found to be about 0.2 mg/kg wet wt., there should be no environmental concerns related to fish living and feeding in the river.

For predicting potential effects to higher trophic level organisms, a wildlife ingestion model was used by EA (EA 2008, Section 10.2.1) to develop dose-based exposure estimates. The cadmium tissue uptake results were evaluated in a risk assessment by EA (EA 2008, Chapter 10) using winter flounder as a surrogate for short-nosed sturgeon, great blue heron, spotted sandpiper, osprey, river otter, and Canada goose and muskrat as surrogates for wetland herbivores. These estimates were compared to NOAELs and LOAELs. NOAELs were calculated as the geometric mean of NOAELs for growth and reproduction. For birds, the NOAEL endpoints ranged from 0.125 to 12.5 mg/kg-bw day and the geometric mean was 1.47 mg/kg-bw day. For bird LOAELs for growth and reproduction, the data range from 2.37 to 37.6 mg/kg-bw day, with a geometric mean of 5.88 mg/kg-bw day. The lowest bounded LOAEL, 2.37 mg/kg-bw day was selected as an unbiased estimate of the 95 percent LPL (Lower Prediction Limit, EA 2008, 10.3.3 a). Exposure estimates were generated for great blue heron, spotted sandpiper, osprey, and river otter for both low and high cadmium sediments as shown in the table below (from EA 2008, Table 10-13).

Table 38. Cadmium Exposure Estimates for Wet Sediments (from EA, 2008, Table 10-13, and Response to Comments, an Appendix to this Report), (mg/kg bw-day)

	Low Cd Composite	High Cd Composite
Great blue heron	0.212	0.418
Osprey	0.037	0.067
Spotted sandpiper	0.81	1.63
River otter	0.091	0.175

These data show the spotted sandpiper at 1.63 mg/kg bw day (high cadmium composite), slightly above the NOAEL of 1.47, but below the LOAEL of 2.37 mg/kg bw-day.

Because of the conservative assumptions built into the consumption estimates, including the high improbability of any bird feeding on benthic organisms in contact with the high cadmium Miocene clays in the channel bottom, the District's overall assessment is that there would be no environmental concerns related to higher trophic level wildlife feeding along the Savannah River.

4.3 Potential Contaminant Pathways Associated with Dredged Sediment Placement in a DMCA

The Upland Manual contains Corps of Engineers guidelines for assessing the pathways by which a contaminant placed in an upland DMCA may impact the environment. These pathways are listed in the Upland Manual as effluent, surface runoff, leachate, volatiles, plant uptake, and animal uptake (USACE, 2003, page 2-3).

If there is a potential for the presence of a COC in the dredged sediment and an evaluation of pathways is deemed appropriate, the next step in the evaluation process is to identify the relevant pathways of concern (Upland Manual, sections 3.1 and 3.2). Exposure of workers is also a standard item of concern. Corps of Engineers experts in dredged sediment evaluation from ERDC and experts in risk assessment from the Hazardous, Toxic, and Radioactive Waste Center of Expertise (CENWO-HX-S) were consulted to perform screening level assessments of these pathways. Where insufficient evidence was available to make a determination of potential effect, Tier III assessment procedures were followed.

Under the District's rotation management plan, DMCAs are held in a wet state for 3 years and then dried for 3 years. While a DMCA is in a wet state, sediments are expected to remain essentially saturated and for the most part anoxic. In the dry state, sediments will be dry and oxidized. Contaminants can be expected to behave differently under these two sets of conditions. Therefore, contaminant pathways have been examined for both conditions.

The current management strategy for the DMCAs is to hold water in the areas while dredging is being conducted and after dredging is complete. The intent is to maintain the DMCAs in an aquatic state to generate wildlife habitats (as part of the LTMS wetland mitigation plan). After functioning in an aquatic state for a number of years (usually 3), the DMCAs are drained and ditched to dry the sediments. After one to two years of drying, sediments are excavated from the areas and used to raise the dikes. During the drying phase and subsequent placement on the dikes, the sediments oxidize and take on characteristics of soils. Because the availability of sediment cadmium may change as sediment dries and is oxidized, the potential movement of cadmium to the environment from a DMCA is addressed separately for the aquatic state and for the dry condition.

A Tier I assessment of environmental effects within a DMCA involves development of a conceptual model (Section 8.2.2 of the Upland Manual). Paragraph 8.2.3 states the following: "If a reasonable complete exposure route to a ROC population outside the DMCA exists, there is generally no risk of an effect unless there is potential for a sufficient number of individual organisms to be affected in a manner severe enough to threaten the long-term sustainability of viable local populations of the ROC outside the CDF." A conceptual model for the rotational use of the DMCAs is described in PD-EC, 2006. It includes effects within the DMCAs, because the DMCAs are managed to produce wetland habitat and the DMCAs attract large numbers of migratory birds. For any alternatives involving capping/covering of enriched sediments, the bioaccumulation

potential within the DMCAs would be minimal. However, this model clearly shows that with inclusion of enriched sediments in the rotation of the DMCAs, there are complete pathways for several ROCs that could potentially affect the long-term sustainability of local populations. The following sections discuss potential pathways for both the dry and wet scenarios, identify complete pathways of concern, and discuss potential risk to local populations of organisms.

4.3.1 Potential Cadmium Pathways for Drying and Dry Sediments within a DMCA

For drying sediments within a DMCA, the potential pathways by which cadmium could enter the environment outside the DMCA are as follows: volatilization, effluent, surface runoff, leachate, plant uptake (with movement to species that leave the DMCA), animal uptake (Upland Manual, page 2-3), and worker exposure.

4.3.1.1 Volatilization. There is little concern for volatilization of cadmium compounds at levels of potential environmental effect, since cadmium and the compounds in which it would occur in sediments are not volatile (see CENWO, 2006a). No further evaluation of this pathway is warranted.

4.3.1.2 Effluent. Appendix C of the Inland Testing Manual provides guidance on mixing zone evaluations and models to predict compliance with State Water Quality Criteria. The following information includes the available data on cadmium concentrations in waters associated with the Savannah Harbor project.

On September 12, 1997, a Savannah River background water sample was taken at Station -9+800 and found to contain cadmium at an estimated 0.544 ug/L (J flagged). A background water sample was taken at Station +36+200 on September 13, 1997 and found to contain cadmium at an estimated 0.652 ug/L (total fraction, J flagged)(111 mg/L TSS). An elutriate of the Area 1 (Station 36+200) composite (about 4.38 mg/kg Cd) was found to show 0.220 ug/L Cd (total fraction) and <0.208 ug/L Cd (dissolved fraction) (GEL, Dec. 1997, Advance Maintenance Sediment Testing Report).

Two samples of river water (taken from -35 feet MLW Oct-Nov 1997) at Stations +90+000 and +55+000 showed non-detect with a PQL of 0.001 ug/L (dissolved fraction)(Savannah Harbor Deepening, ATM 1998).

Savannah River water metals data were taken during the Agitation Dredging Study in Mar 2001. River samples (surface, mid-level, and bottom) unaffected by the agitation dredging plumes were all found to be non-detect for cadmium (about 55 samples) with a DL of 0.251 ug/L, except for one upcurrent sample that showed an estimated level of 0.45 ug/L (J flagged). About 9 samples downcurrent from the agitation dredging events showed estimated (J flagged) cadmium values ranging from 0.280 to 0.902 ug/L. These are thought to have been taken within the dredge plume. All of the samples were taken from about Stations +71+000 to +92+000 on March 7, 8 and 14, 2001 (ATM, 2002).

The Nov 2004 ENSR Savannah Harbor O&M Sediment Evaluation performed modified elutriate studies on 5 composites of inner harbor O&M sediments. These composites showed the following cadmium concentrations. These concentrations reflect expected cadmium concentrations in water standing in the DMCA's immediately following an O&M dredging event.

Table 39. Predicted Cadmium Concentrations in DMCA Water after an O&M Disposal

Station Composite	Sediment Cd Concentration (mg/kg dry wt)	Dissolved Cadmium (ug/L)	Total Cadmium (ug/L)
Kings Island TB	0.3 U	0.05 U	0.05
60+000 to 90+000	1	0.05 U	0.11
30+000 to 50+000	0.69	0.07	0.06
5+000 to 25+000	0.29 U	0.06	0.08
Sediment Basin	0.34	0.05 U	0.07

ERDC used existing data (including a bulk sediment cadmium concentration of 21 mg/kg) to conservatively estimate a DMCA effluent cadmium concentration for the SHEP of no more than 2.2 ug/L. The marine chronic water quality criterion for cadmium is 8.8 ug/L. The predicted effluent concentration is not likely to violate marine chronic water quality criteria, with no mixing zone required. They found it is not likely that DMCA effluent cadmium concentrations would cause environmental impacts and recommended no further evaluation of this pathway (ERDC, July 06).

To confirm this recommendation, EA conducted the effluent elutriate test on both the low cadmium and high cadmium sediment composites. The effluent elutriate test is designed to estimate contaminant concentrations that may occur within a DMCA and its effluent. The results of their analyses are shown in Table 40.

Table 40. Effluent Elutriate Dissolved Fraction (from EA 2008, Table 6-5)

	USEPA/SC Acute Criteria	USEPA/SC Chronic Criteria	Low Cd Composite	High Cd Composite
Ammonia	9.14 mg/L	1.37 mg/L	9.7 mg/L	4.9 mg/L
Nickel	74/75 ug/L	8.2/8.3 ug/L	15.5 ug/L	21.7 ug/L
Selenium	290 ug/L	71 ug/L	78.6 ug/L	96.6 ug/L
Cadmium	40/43 ug/L	8.8/9.3 ug/L	<0.37 ug/L	0.82 ug/L

As was the case for the standard elutriate results, ammonia estimates exceed both the acute (factor of 1.06) and chronic (factor of 7.1) water quality criteria. As discussed under the standard elutriate results, dissolved cadmium concentrations do not exceed criteria, and selenium exceedences are due to concentrations in the dredging water (see Section 4.1.1). Nickel concentrations exceed the chronic criteria by a factor of 2.6. These dilution factors indicate dilution of effluent in receiving waters should result in no exceedences of water quality criteria well before the 4-day chronic exposure time is met. Therefore, there should be little concern for environmental impacts due to effluent discharge.

Potential impacts associated with organisms living and feeding in ponded water within a DMCA are addressed under the ponded scenario (Section 4.3.2), below.

4.3.1.3. Surface Runoff. There is a run-off water quality screen at paragraph 5.3.1 in the Upland Manual. Using that screen, ERDC conservatively predicted the runoff cadmium concentration to be 26 ug/L, which is less than the Federal marine acute water quality criterion of 40 ug/l. They expected that this concentration would decrease over time as cadmium leaches from the soil, and would be expected to drop below the marine chronic criterion of 8.8 ug/l in a short time (ERDC, July 2006, page 18, par. 4). They concluded it is not likely that DMCA effluent cadmium concentrations would cause environmental impacts and no further evaluation of this pathway was necessary. EA (2008), conducted the SLRP test on both the low and high dried sediment composites to verify the ERDC conclusion. These data show violation of only the SC total criteria, and only for the highly unlikely event of runoff containing 5,000 mg/L TSS (see Table 41, below). Since that TSS level greatly exceeds the 500 mg/L standard that Savannah District uses for discharges from the DMCA's, violation of that criterion is not expected. Taking into consideration that the high cadmium sediment composite contained a much higher cadmium concentration (37.1 mg/kg) than the expected average cadmium concentration from the high cadmium reach from Stations +6+375 to +45+000 (19.1 mg/kg), these data confirm the prediction that runoff from dried sediment should not have an adverse effect on the environment.

Table 41. Results of SLRP (Simulated Runoff Procedure) on Dried High Cadmium Sediment Composite (from EA, 2008, Table 10-7)

	Units	EPA Criterion Acute/ Chronic	SC WQ Standard Acute/ Chronic	Low Suspended Solids	Moderate Suspended Solids	High Suspended Solids
TSS	mg/L			50	500	5000
Total Cadmium	ug/L		43/9.3	0.893	7.77	67.5
Dissolved Cadmium	ug/L	40/8.8		0.367	1.37	8.43

4.3.1.4 Leachate. A Leachate Water Quality Screen is described in paragraph 6.3.1 of the Upland Manual. Cadmium would be expected to leach from both unoxidized and oxidized sediment, but at different rates. Freshly dredged sediment and sediment maintained in a wet state would be expected to remain essentially unoxidized. ERDC conservatively estimated the pore water concentration of cadmium in unoxidized/reduced sediment to be 2.4 ug/L. Actual porewater measurements by USGS found porewater cadmium concentrations of no more than 0.12 ug/L (Section 3.10.7). The drinking water standard is 5 ug/L. Therefore, no environmental impacts should be expected due to leachate from unoxidized/reduced sediment.

If the cadmium-enriched sediments deposited within a DMCA were subsequently used to construct dikes, the cadmium would be expected to oxidize. ERDC conservatively estimated pore water cadmium concentration in oxidized sediments used directly to construct dikes (with no interim period of time where leaching would occur) to be 152 ug/L. Surficial seepage from sediment placed on the dike in that manner and maintained in an oxidized geochemical environment may impact ground water because its pore water concentration in oxidized material is conservatively estimated to be 152 ug/L. Seepage from the DMCA's would interact with foundation soils in the vadose zone and disperse in the surficial aquifer under the DMCA. With the sediment under oxidized conditions, it appears there is a potential for elevated concentrations of cadmium to enter the surficial aquifer in the distant future. However, the surficial aquifer is not used as a drinking water source. ERDC concluded that "No significant breakthrough of cadmium would be expected in thousands of years" (ERDC, July 2006, page 18, par. 2). ERDC evaluated sediments with cadmium levels of 28.4 to 60 mg/kg, although their conclusions are based on a sediment cadmium level of 21 mg/kg. Since they saw no reason for concern from this pathway using a cadmium level of 21 mg/kg, we assume that there would be no leachate concerns related to sediments containing less cadmium (including the reaches averaging about 4.6 mg/kg).

Savannah District geologists assessed the possibility of ground-water impacts from placing the cadmium-bearing soils in the proposed DMCA (EN-GG, 2006). A records search indicated that there are no historical data that show cadmium-bearing soils have impacted ground-water quality in the coastal Georgia region. According to the City of Savannah and the USGS, wells in the Savannah area and the coastal region, whether screened in the confined aquifer or surficial aquifer system, generally do not indicate presence of cadmium in ground water. The assessment also indicated that the physical characteristics and thickness of confining material underlying the DMCA would most likely severely inhibit any potential interactions with the underlying confined aquifer and that the volume of water associated with the cadmium-bearing soils was insignificant when compared with the daily yield of the confined aquifer. This indicates that even if ERDC's estimate of a porewater cadmium concentration of 152 ug/L under oxidized conditions is correct, the volume of water carrying this concentration is so small that there should be no cadmium-related environmental impacts, including no expectation of violation of the cadmium drinking water standard.

4.3.1.5 Plant Uptake in Dry DMCAs. Plant bioaccumulation in a dry soil environment is a pathway of concern with the rotational use of the DMCAs, since the conceptual model (PD-EC, 2006b) shows several species of birds that have plants found within the dry DMCAs as comprising a substantial part of their diet or supporting their food chain. A Tier II Plant Bioaccumulation Screen has been developed by the Corps of Engineers Waterways Experiment Station (same organization as ERDC). This is a procedure to extract metals from sediment using diethylenetriamine-pentaacetic acid (DTPA), with the data requiring analysis with the PUP model (Upland Manual, Appendix H, H.2). This procedure has been used to predict plant bioaccumulation from dredged sediments placed in terrestrial (wetland and upland) environments (Upland Manual, Section 9.3.2). An assessment would then be made of whether birds feeding on these plants or their herbivores are likely to be impacted through bioaccumulation of cadmium.

ERDC conducted the DTPA procedure on archived samples from the 2005 sampling. The results indicate some unusual responses in pH and redox potential, which are key controllers of cadmium availability. As such, the PUP estimates they calculated are considered unreliable for determining cadmium bioavailability through the plant pathway. The highest predicted plant concentration (8.77 mg/kg) which ERDC calculated exceeds the limitations in leafy vegetables and animal feeds set by the World Health Organization and the European Community ranging from 0.1 mg kg⁻¹ (fresh weight) to 1.0 mg kg⁻¹ (dry weight) (ERDC, 2006). Without further information, cadmium bioavailability through the plant pathway could not be ruled out as potentially resulting in impacts to birds feeding on plants within a DMCA. Plant bioassays were subsequently conducted by EA (2008) to provide more reliable quantitative information on which to judge the environmental effects of unrestricted placement of cadmium enriched sediments within a DMCA.

Capping/covering enriched sediments could negate the need for plant bioassays, if cadmium levels in the covering materials themselves are sufficiently low. Based on the plant tissue concentrations predicted by PUP (Table 4), and measured sediment concentrations, ERDC calculated allowable sediment concentrations (yielding a plant tissue concentration of 1 mg/kg dry weight). These data were found to be quite variable, and ERDC's analysis indicated that sediment cadmium concentrations for sediment which could be used as covering material range from 2.39 mg/kg to 77 mg/kg (depending on which data were used for the prediction). More definitive resolution of covering material criteria was not possible with the earlier data. Therefore, plant bioassays were chosen to address potential impacts for all dry sediments averaging over 2 ppm cadmium.

Potential pathways of concern for plant uptake in an upland environment include: (1) plant contact with soil; and (2) plant contact with water. These pathways lead to two pathways by which plant uptake can play a significant role in potential environment impact. These are (1) direct uptake by plants and animals living on dried dredged sediment, and (2) subsequent cycling through food webs both inside and outside the DMCAs. These latter two pathways were selected for evaluation of the dry soil upland placement scenario (EA 2008, Section 10.1.3). The endpoints selected by EA to assess these two pathways were as follows: 1) protection of plants from adverse impact due to

cadmium exposure from water and soil; 2) protection of wildlife (birds and mammals) from adverse impacts due to cadmium exposure from ingestion of water, sediment, and food resources. The results of the assessment of these two endpoints are discussed in the next two sections: Plant Uptake Test, and Animal Uptake in a Dry DMCA.

4.3.1.6 Plant Uptake Test.

As shown in the table below, SEP data from EA show there is a change in potential availability of cadmium between project wet sediment and dry "soil". In the dry "soil" condition, both composites show primarily a decrease in the hydroxide fraction, and an increase in the carbonate and exchangeable fractions. This change indicates cadmium should be more available in the dried soil than the wet sediment. This result confirms the appropriateness of the decision to conduct a plant uptake test on dried soil.

Table 42a. Percent Cd in each SEP Fraction of the Low Cadmium Composite (0 used for non-detects, from Tables 9-8 and 9-9, EA, 2008)

	Low Cd Comp "Wet"	Low Cd Comp Dup "Wet"	Low Cd Dried	Low Cd Dried Washed / Dried
Exchangeable	0.00	0.00	2.18	0.65
Carbonate	1.78	2.02	14.10	14.82
Hydroxide	74.18	71.00	59.60	59.86
Organic	20.13	21.94	19.23	18.37
Sulfide	3.91	4.62	4.42	5.87
Residual	0.00	0.42	0.47	0.43
Total Cd mg/kg	15.1	14.5	16.6	15

Table 42b. Percent Cd in each SEP fraction of the High Cadmium Composite (0 used for non-detects, from Tables 9-8 and 9-9, EA, 2008)

	High Cd Comp "Wet"	High Cd Comp Dup "Wet"	High Cd Dried	High Cd Dup Dried	High Cd Dried Washed Dried	High Cd Dup Dried Washed Dried
Exchangeable	0.00	0.00	1.32	1.34	0.42	0.37
Carbonate	1.96	1.56	4.60	5.23	4.25	4.35
Hydroxide	73.52	73.51	66.54	64.04	66.54	63.94
Organic	20.50	20.64	20.72	22.19	21.00	22.62
Sulfide	3.51	3.75	5.86	6.28	6.84	7.61
Residual	0.50	0.53	0.96	0.92	0.94	1.11
Total Cd mg/kg	26.2	33.4	43.1	NA	36.8	NA

The plant uptake test was conducted in accordance with the Upland Testing Manual (UTM) (USACE 2003) using *Cyperus esculentus*. Sediments were dried for 3 weeks before plants were introduced. Seven days after starting the test, the study was suspended because of low growth and begun again with a higher moisture regime. This second attempt was also stopped after 7 days because of low growth. Salinities ranging from about 25 to 28 ppt were determined to be the issue. After failure of the UTM wash procedure because of failure of the sediment to settle out, a wash procedure using centrifugation was used. After the washing process reduced the salinity to approximately 4 ppt, there was an additional 3 week period of grinding and drying before the test was begun. Tables 42 a and b, above, provide a comparison of the results of SEP procedures on the dried and washed/dried soils, showing the washing had minimal impact on soil cadmium levels. However, the table shows that the test soils did experience a small drop in cadmium when washed. The SEP analyses show this drop was primarily in the exchangeable fraction. In the low cadmium composite, the loss in the exchangeable fraction appears to have been approximately 10 percent of the total cadmium, although the loss did not show up in the total cadmium figures. The loss in the exchangeable fraction through washing is understandable since that fraction would be expected to dissolve in water. This loss does indicate that predictions based on the washed sediment results may not account for all cadmium originally present in the sediments. The washing also tended to affect nutrient levels, but not in a consistent pattern (EA, 2008, Chapter 9.2). This potential loss was taken into account during the final risk assessment for the dry "soil" condition (see discussion at Section 4.3.1.7).

The plant uptake test involved control sediment (potting soil), reference sediment (sediment exposed on the back of the DMCA 12B dike for several years), and the washed and dried low and high cadmium composites.

Cadmium, copper, lead, nickel, and zinc were evaluated in the plant bioaccumulation study due to their potential to bioaccumulate. Other metals were eliminated from further assessment because they do not readily bioaccumulate and were not found in the sediments at levels of potential concern. Tissue concentrations from plants grown in the washed and dried low and high cadmium composites were compared to tissue concentrations in plants grown in the control (potting soil), and the reference soils to determine the potential of project soils to support bioaccumulation of contaminants. The low and high cadmium composites generally produced tissue metal concentrations less than or equal to reference (copper and lead), or 2 to 5 times reference (nickel and zinc). The exception to those general relationships was cadmium (18 to 27 times higher than reference). These metal concentrations are shown in the table below. Mean plant tissue concentrations of cadmium, nickel, and zinc exposed to washed/dried soils statistically exceeded concentrations in tissues from plants grown in the reference soil for both the low and high cadmium composites. This indicates uptake of these three metals. A finding of plant uptake greater than reference, such as found for these three metals, requires assessment of the potential environmental impact on both plant growth and potential impacts to animals feeding on the plants. Animal uptake is addressed in the next section.

Table 43. Mean Plant Tissue Metal Uptake Compared to Reference (mg/kg dry wt). (EA 2008, Table 9-14)*

Analyte	Upland Reference	Low Cd Composite	High Cd Composite
Cadmium	0.383	6.93	10.2
Copper	1.48	0.790	1.10
Lead	0.0172	0.0169	0.0165
Nickel	0.0573	0.120	0.223
Zinc	14	52.9	73.3

* Bold indicates tissue sample concentration significantly greater than reference.

Table 44. Sediment Metal Levels in Composites in mg/kg (from EA 2008, Tables 5-6, and 8-8)

Analyte	High Cadmium Composite Average	Low Cadmium Composite Average	High Cadmium Composite Washed and Dried	Low Cadmium Composite Washed and Dried
Aluminum	14,600	16,000	17,600	17,000
Arsenic	12	11	12.5	12.6
Cadmium	30	15	36.9	15.4
Chromium	104	111	133	122
Copper	13	13	15.2	14.2
Lead	6	4.9	5.9	5.6
Manganese	198	177	207	185
Mercury	0.052	0.032	0.052	0.025
Nickel	18	21	21.7	24.4
Zinc	147	96	171	93.1

According to standard UTM guidance, environmental effects are only a concern if they extend outside the DMCA. Therefore, plant growth within a DMCA may not ordinarily be considered very important. However, the Savannah DMCAs are part of a wetland mitigation plan in which they are managed for shorebird and waterfowl habitat while they are in use. Therefore, potential impact to plant growth is an important consideration in this evaluation.

The high cadmium composite washed/dried soil contained 69 percent silt and clay, whereas the low cadmium composite contained 91 percent silt and clay. Except for cadmium and zinc, metal concentrations were generally similar in the two composites (see Table 43). The low cadmium composite washed/dried soil contained 15.4 ppm cadmium and 93.1 ppm zinc, whereas the high cadmium composite washed dried soil contained 36.9 ppm cadmium and 171 ppm zinc (EA 2008, Table 9-8). At the end of the growth period, laboratory controls showed the heaviest mean tissue wet weight (210.0 g),

followed by the reference (43.0 g), the low cadmium composite (30.0 g) and finally the high cadmium composite (10.9 g)(EA 2008, Table 9-5). The low growth in the high cadmium and low cadmium composites cannot be directly attributed to the high cadmium concentrations, but cadmium cannot be ruled out as the causative agent of the low growth.

The observed cadmium tissue concentrations can be compared to benchmarks to predict potential effects on plant growth. EA (EA 2008, Section 10.3.2) cites a USEPA Ecological Soil Screen Level for cadmium plant NOAELs and LOAELs of 32 mg/kg and a 10th percentile of plant LOAEL values for dissolved cadmium in water by Oak Ridge National Labs of 100 ug/L. EA also cites an 8 mg/kg cadmium NOAEL and 11.4 mg/kg cadmium LOAEL for water hyacinth (wet weight) as appropriate tissue benchmarks for plants. These were converted to cadmium dry weight benchmarks (assuming a plant moisture content of 75%) of 32 mg/kg dry-wt. (NOAEL) and 45.6 mg/kg dry-wt. (LOAEL). The observed high composite cadmium tissue level (10.2 mg/kg dry wt) is substantially below the LOAEL for water hyacinth (45.6 mg/kg). This indicates that the observed tissue cadmium levels may not inhibit plant growth. A comparison between the high and low cadmium composites of BCFs for several metals shown in Table 44 indicates potential inhibition of uptake for some metals (Cd, Zn), but not others (especially Cu, and Ni). These results are not conclusive as to the potential for the high cadmium soil to inhibit plant growth. However, it is unlikely that cadmium concentration was the cause of the low growth. Additional information is provided in the Response to Comments section (responses to USFWS comments 11, 30, and 36) where other studies on cadmium toxicity to plants found no effect at cadmium sediment levels similar to those studied here.

Table 45. BCF Soil to Plant Tissue Cadmium Concentrations (Total washed/dried soil, dry wt. basis, Tissues Dry wt.mg/kg)(from EA 2008, Tables E-11, and 9-13)

Analyte	Control	Reference	Low Cd	High Cd
Cadmium	0.115	0.395	0.45	0.276
Copper	0.0506	0.221	0.0556	0.0724
Lead	0.00372	0.00239	0.00302	0.00280
Nickel	0.00546	0.0122	0.00492	0.0103
Zinc	0.548	0.534	0.568	0.429

When EA (2008) conducted the Simulated Effluent Runoff procedure on the high cadmium composite, the test predicted 8.43 ug/L dissolved cadmium in the runoff. EA (2008, Table 10-17) found potential dissolved cadmium in runoff to be well below the 100 ug/L plant benchmark. This is an indication that runoff would not be expected to inhibit plant growth.

In conclusion, the test plant species experienced less growth in the high cadmium composite soil than other tested media. However, predicted soil and water cadmium concentrations indicate there should be little concern that plant growth would be affected by cadmium levels present in the high cadmium soils.

4.3.1.7 Animal Uptake in a Dry DMCA. A conceptual model was developed by District biologists predicting the pathways by which cadmium could enter the environment through the animal uptake pathway during the drying phase (PD-EC, 2006b). Past observations within the DMCAs have identified only a few reptiles within the DMCAs during the drying phase, primarily a few anoles, fence lizards, snakes (including diamond-backed rattlesnake), alligators and very few amphibians (primarily southern toads, green tree frogs and leopard frogs). A number of mammals inhabit the drier portions of the DMCAs, including deer, hogs, raccoons, opossums, rabbits, armadillos, bobcats, various rodents, and an occasional coyote. There are also a few reports of large cats. However, the primary vertebrates on the site are various species of birds. Birds occur in much higher numbers than mammals and are much more likely to leave the DMCAs and move out into the surrounding environment.

The District model identified the primary classes of birds that dominate the drying DMCAs to be wintering sparrows and insectivores. Primary wintering birds within the dry DMCAs are sparrows. There are lesser numbers of frugivores and insectivores, including mimic thrushes, wrens, and yellow-rumped warblers. A small number of other warblers and vireos are also present. Because the drying sediments do not have time to develop into a structured soil, soil-based prey do not appear to play a significant role in the food chains of the dried areas. For example, birds are rarely seen probing into the soils for food items. Because winter sparrows are by far the most abundant wintering birds within the DMCA dry habitats, those species were judged to be a significant pathway that should be evaluated. Migratory and summering species within the DMCA dry habitats appear to be mostly foliage gleaning insectivores, of which migratory warblers and vireos form the largest segment. Summer insectivores include mostly species that are partial insectivores such as red-winged blackbirds and boat-tailed grackles, mimic thrushes, cardinals, towhees, Carolina wrens, painted buntings, and indigo buntings. No toxicity / bioaccumulation tests are available to directly assess these pathways. Since the pathways all appear to be plant based, the plant uptake test was used to predict plant uptake of cadmium and a consumption model was used to predict the subsequent movement of cadmium through herbivores (primarily insects) to insectivores such as warblers. The consumption model results were compared to tissue benchmarks to predict potential environmental impact.

EA (EA 2008, Section 10.1.4.c) developed a conceptual model in which they selected the Song Sparrow, meadow vole, Marsh Wren, short-tailed shrew, red-tailed hawk, and red fox as representative/or surrogate species for evaluation. They considered the following modes by which animals could uptake cadmium in developing their consumption / exposure model.

- Wildlife dermal contact with soil (normally considered insignificant, EA 2008)
- Wildlife ingestion of soil
- Wildlife inhalation of soil (normally considered insignificant, EA 2008)
- Wildlife dermal contact with water (normally considered insignificant, EA 2008)
- Wildlife ingestion of water
- Wildlife ingestion of plant material
- Wildlife ingestion of herbivores

Exposures were calculated by including estimates for consumption of water, soil, and food. They used estimates of soil ingestion, water ingestion, and food ingestion to calculate exposure. The formula EA (2008) used is shown starting at their Figure 10-2. These estimated exposures were then compared to benchmarks to assess potential environmental effect (EA 2008, Section 10.2.1). EA (2008) selected two benchmark end points for cadmium bird exposure rates using the EPA EcoSSL database – the geometric mean of NOAELs (1.47 mg/kg-bw day), and the lowest bounded LOAEL (2.37 mg/kg-bw-day, EA 2008, 10.3.3.a).

Exposure estimates are detailed in EA (2008), Figures 10-8 through 10-13, and Tables 10-20 through 10-26. For the high cadmium composite, exposure estimates for the song sparrow (2.94/2.97 mg/kg-day) and marsh wren (3.72/3.75 mg/kg-day) under exposures to both effluent and runoff waters exceed the bird LOAEL benchmark. In addition, the exposure estimate for the meadow vole (1.01 mg/kg-day) exceeded the mammal NOAEL of 0.770 mg/kg-day and the exposure estimate for the shrew (2.29/2.262 mg/kg-day) exceeded the mammal LOAEL benchmark of 2.06. These estimates are based on a soil cadmium concentration of 36.9 mg/kg (washed dried soil), derived from the high cadmium sediment with a 29.8 mg/kg cadmium concentration. These estimates are shown below in Table 46 for the runoff exposure estimate (slightly larger than the effluent exposure estimate). These results indicate an expectation of impact to both birds and mammals feeding within dried portions of a DMCA containing sediments similar to the high cadmium sediment composite.

The CENWO-HX-S (CENWO, 2006A) risk assessment found the cadmium sediment data to be non-parametric and advised that the 95% Chebyshev (Mean, Sd) UCL be used in evaluating each reach. The reach with the highest average cadmium concentration (21.5 mg/kg) was found to have a 95% Chebyshev UCL of 36.2 mg/kg cadmium concentration. This value was used for their risk assessment. Their selection of 36.2 mg/kg cadmium as an appropriate value for the risk assessment for the high cadmium sediments shows that the use of 36.9 mg/kg by EA for the washed sediment exposure assessment is appropriate for the risk estimate for the high cadmium reach. This is

further indication that adverse impacts to both birds and mammals could be expected should the high cadmium sediments enter the DMCA's rotation management plan.

Table 46. Dose Predictions for the High Cadmium Composite Under Dry DMCA Conditions, mg/kg bw-day

	Effluent Exposure	Runoff Exposure	NOAEL mg/kg bw-day	LOAEL mg/kg bw-day
Song sparrow	2.97	2.94	1.47	2.37
Meadow vole	1.01	0.990	0.770	2.06
Marsh wren	3.75	3.72	1.47	2.37
Shrew	2.29	2.263	0.770	2.06
Red-tailed Hawk	.000061	.000061	1.47	2.37
Red Fox	0.169	0.160	0.770	2.06

EA also calculated exposure estimates for the low cadmium composite under both effluent and runoff water exposures. These exposures are shown in Table 47, below, for the potential effluent water exposure route and runoff exposure route and compared to benchmarks.

Table 47. Dose Predictions for the Low Cadmium Composite Under Dry DMCA Conditions, mg/kg bw-day

	Effluent Exposure	Runoff Exposure	NOAEL mg/kg bw-day	LOAEL mg/kg bw-day
Song sparrow	1.93	1.784	1.47	2.37
Meadow vole	0.797	0.639	0.770	2.06
Marsh wren	2.48	2.27	1.47	2.37
Shrew	1.52	1.354	0.770	2.06
Red-tailed Hawk	.000048	.000048	1.47	2.37
Red Fox	0.131	0.066	0.770	2.06

These estimates are based on a sediment cadmium total of 15.4 mg/kg and a calculated bioavailable cadmium total of 14.6 mg/kg, a water concentration based on the cadmium effluent total for the low cadmium composite (761 ug/L), 45% uptake by plants from soil based on results of the low cadmium composite plant uptake test, and 110% uptake by invertebrates from plants based on literature review. Only the marsh wren is shown to exceed the LOAEL, and only by 5%. Using the relationship between the 15.4 mg/kg total cadmium sediment level and predicted exposure level for the Marsh Wren of 2.48 mg/kg bw-day, the sediment level associated with the LOAEL of 2.37 mg/kg bw-day should be 14.7 mg/kg cadmium. However, when taking into consideration that the washing procedure may have removed the exchangeable fraction of cadmium (up to 10% of total cadmium), potential additive effects from nickel and zinc, and variability in the measured amount of cadmium in the test sediment, the lowest effect level should be

applicable to sediments containing about 14 mg/kg cadmium. One can also use the cadmium bioavailable level (14.6 mg/kg cadmium) to estimate a bioavailable sediment level associated with the 2.37 mg/kg bw-day LOAEL to be 14.0 mg/kg cadmium. Those estimates led to the selection of 14 mg/kg as the lowest sediment cadmium level expected to have environmental impacts when associated with drying dredged sediments.

4.3.1.8 Worker Exposure. There is a potential risk to workers handling and working in potentially-contaminated dredged sediments. The CENWO-HX-S conducted a Human Health Risk Assessment (CENWO, 2006b). Their assessment assumed exposure to an occupational worker for 10 hrs per day, for 300 days per year, over a 15-year period. It concluded “the calculated non-cancer hazards and cancer risks indicate that exposure to the cadmium-enriched dredged material does not pose a concern for adverse non-carcinogenic or carcinogenic health effects for the occupational worker scenario, and therefore, does not present a risk to human health.” Therefore, this pathway was not evaluated further.

4.3.2 Potential Aquatic Effects From Placement of Cadmium Sediments in a DMCA Where Water is Pondered

There are two major pathways by which cadmium could affect the aquatic ecosystem through placement of cadmium containing sediments within a DMCA: (1) cadmium toxicity to invertebrates feeding within the containment areas; (2) bioaccumulation of cadmium by shorebirds and waterfowl feeding within the containment areas.

4.3.2.1 Cadmium Toxicity to Invertebrates Feeding within the Containment Areas.

This pathway is of little concern since it will for the most part not be complete. Should organisms within a DMCA not be able to survive due to cadmium toxicity, they would not serve as food for birds and waterfowl feeding within the DMCA. Since no organisms associated with this pathway would leave the site, there would be no impact on the outside environment.

4.3.2.2 Bioaccumulation of Cadmium by Shorebirds and Waterfowl Feeding within the Containment Areas. This pathway is of concern since large numbers of shorebirds and waterfowl feed in the wet areas within the containment areas (see Conceptual Model, PD-EC, 2006b). No Tier II evaluation techniques are available for heavy metals, but may become available in the future (Upland Manual Sections 8.2.3 and 8.3.1). Therefore, the Corps’ Hazardous and Toxic Waste Center of Expertise (shown as CENWO-HX-S) was enlisted to conduct a screening level risk assessment for the bioaccumulation pathway within a DMCA (see CENWO, 2006a). The purpose of the risk assessment was to identify the pathways that contain more than minimal risk of adverse effects. Additional Tier III assessments of the bioaccumulation potential would be required for any pathways that remain of concern.

There are other vertebrates on the site that were not evaluated for potential cadmium impacts since they are thought to occur in only small numbers or are not expected to move off site. These include amphibians (primarily tree frogs), reptiles (anoles, various

snakes, including the diamond-backed rattlesnake, fence lizards, turtles, and alligator), and various fish (mosquito fish, striped mullet, sheepshead minnow, and killifish). Based on Planning Division's conceptual model identifying birds as the primary receptors of concern, CENWO-HX-S was asked to evaluate potential effects on birds.

4.3.2.3 Ecological Risk Assessment by CENWO-HX-S. In evaluating the high cadmium reach, CENWO-HX-S (CENWO, 2006a) found that aquatic nesting birds were most likely to be impacted by cadmium, should the dredged sediments be held in an aquatic state where nesting shorebirds would feed. They estimated a daily dose (DI) of cadmium would be about 6.5 mg/kg-body wt/day. This value was compared to a toxicity reference (TRV) value of 1.45 mg/kg-body wt/day (a level found to produce reproductive effects in captive mallard ducks). The ratio of these two values (DI/TRV) is defined as an ecological quotient (EQ). Where conservative assumptions are made, "EQs between 1 and 10 have some small potential for adverse effects" (CENWO, 2006a). They calculated an EQ for the high cadmium sediment to be 4.5. Because they believed their assumptions in calculating the dose value were conservative, they concluded "it is not of significant project-wide concern". There are several indications that this estimate may be closer to a reasonable expectation than a conservative estimate. For example, ERDC felt that the estimate was not conservative (ERDC, 2006). Other evidence that the estimate is not conservative is discussed below.

4.3.2.4 Discussion of Conservative Assumptions in the CENWO-HX-S EQ Estimate.

The CENWO-HX-S (CENWO, 2006a) listed four factors that "were maximized to maintain the conservative nature of this evaluation." These are discussed below, to ascertain the true "conservative" extent of the EQ estimate.

a. Area Use factor. Assumed to be 100% within the contaminated area. For nesting black-necked stilts, this is not particularly conservative, since adults appear to spend most of their time within the containment areas, and young flightless birds spend all of their time there (see the conceptual model, PD-EC, 2006b). For the 3-5 month nesting and rearing season, black-necked stilts could easily spend all of their time within the DMCA's. Black-necked stilts have been observed flying from one DMCA to another to feed. Since the project would most likely deposit the enriched sediments in only one DMCA and should have other DMCA's flooded at the same time, we expect flying stilts would conduct some of their feeding in areas in which the enriched sediments have not been placed.

b. Bioavailability. Assumed to be 100%. Food was considered to have the same concentration as the sediment. A bioaccumulation factor (BAF) is defined as the ratio of the concentration of the contaminant in the tissues of the organism to the sediment concentration to which the organism is exposed. These appear to be somewhat variable, depending on the species. ERDC found that "When considering the bioaccumulation of cadmium in both freshwater and estuarine invertebrates, a BAF of 1.0 appears reasonable for invertebrate species in both freshwater and estuarine portions of Savannah Harbor"

(see ERDC, July 2006). Therefore, this assumption should be considered reasonable (not conservative) for invertebrates within the DMCA's.

c. Estimates of Body Weight and Food Ingestion. Estimates of body weight and food ingestion rates of the ROCs were made conservatively to maximize the dose (i.e., the intake of cadmium-enriched dredged sediment). CENWO-HX-S used published average consumption rates (based on Spotted Sandpiper data) and body weights in estimating doses. This estimate should also be considered reasonable (and not conservative). A conservative assumption would be use of consumption rates beyond normal expectations.

d. Dietary Composition. "Assumed 100% of diet consists entirely of the most contaminated dietary component (i.e., food and dredged material)." Lacking specific data, it is reasonable to assume that the food and dredged sediment would have the same concentration of cadmium. The CENWO-HX-S (CENWO, 2006a) calculated a 95 percentile distribution UCL for the reach with the highest concentration to be 36.2 mg/kg cadmium and used this value in their assumptions, rather than an average value of about 21.5 mg/kg. This is a conservative procedure. However, the food consumption rate (for the Spotted Sandpiper) does not appear to include incidental soil ingestion. Furthermore, the calculated dose does not include ingestion of water. Lack of inclusion of these elements in the dose calculation brings uncertainty into the conservative extent of the dietary composition assumptions.

e. Other Factors. There are other factors that indicate there may be additional uncertainty in the ingestion rate assumption and EQ estimate. For example, feeding rates for the EQ calculation are based on published estimates for the Spotted Sandpiper, derived from a published regression equation for all birds. The Spotted sandpiper has about 1/4 the body weight of the species of concern (Black-necked Stilt). Although the estimated Black-necked Stilt rate is adjusted for body weight, it is not clear that the two species would have the same body weight adjusted feeding rate. Furthermore, the stilt uses an entirely different foraging method (feeds mostly wading), whereas the sandpiper feeds mostly by gleaning food from the surface of damp substrates. This hints that the food composition of the two species is likely to be entirely different. Finally, the toxicity reference value used is based on effects on a much larger and unrelated species (the Mallard Duck). This may be the best available toxicity reference value, but it is uncertain how conservative is the use of such a toxicity reference value. An analysis may be conservative for one species, but we have no information concerning how other species may compare in their feeding rates, body weights, etc., so we may not be able to say it is conservative for all species that use the DMCA's.

4.3.2.5 Decision to Proceed with Additional Risk Assessment. Risk assessments were performed by CENWO-HX-S (CENWO, 2006a) for birds feeding in sediments containing two different levels of cadmium (10.5 mg/kg and 36.2 mg/kg). These levels were the 95 percentile of the cadmium levels for two different reaches (averaging 6.67 mg/kg and 21.45 mg/kg). Daily doses were calculated and compared to a reference toxicity value, and the resulting ratio defined as an EQ (ecological quotient). The EQ calculated by the CENWO-HX-S for the 10.5 mg/kg cadmium reach was 1.3, and the EQ

for the 36.2 mg/kg cadmium reach was 4.5. As mentioned earlier, CENWO considers EQs between 1 and 10 to have some small potential for adverse effects. Because the calculated EQ for the reach averaging 6.67 mg/kg cadmium was found to be only slightly above 1 (at 1.3) based on the 95 percentile UCL, they found there is at most only a small potential for adverse effects from birds feeding on these sediments. Therefore, they found that placement of these sediments (reach averaging 6.67 mg/kg cadmium) within a DMCA would be expected to have minimal and acceptable environmental impacts.

In contrast, since the calculated EQ (4.5) for the reach averaging 21.45 mg/kg (based on a 95 percentile concentration of 36.2 mg/kg) is 4.5 times the toxicity reference value of 1.45 mg/kg-bw day, and this value appears to be based mostly on expected average or standard conditions, sediments from this reach have a much greater potential for adverse effects than the other reaches. As discussed above, it was concluded by the District that these potential effects could not be discounted.

It was determined by the District that additional toxicity and bioaccumulation testing would be necessary before it could be concluded that there would be minimal risk to birds feeding within a DMCA where sediments average 21.45 mg/kg cadmium. Since the calculated daily cadmium dose for Black-necked Stilts feeding within the disposal area was found to be 4.5 times a published toxicity value, it appeared that there was a reasonable potential for adverse effects should the higher cadmium sediments be exposed in an aquatic state within the DMCAs. This prediction was part of the basis for the decision to conduct further assessment using Tier III Bioaccumulation procedures.

Tier III Bioaccumulation assessment using ocean disposal protocols was deemed appropriate to assess potential wet phase impacts from placement of high cadmium sediments within the DMCAs, since most of the water in the DMCAs is expected to be brackish water pumped into the areas during the dredged sediment placement operations. This analysis selected *Nereis* and *Macoma* as test organisms because they thrive in brackish conditions. Results of the bioaccumulation study are discussed at Section 4.2.5.

4.3.2.6 Risk Assessment by EA (2008). EA (2008) conducted the additional sampling and analyses and used their data to conduct a risk assessment of direct uptake by animals living in the river in high cadmium exposed clay within the channel. That assessment found minimal risk associated with the aquatic pathway. The analyses applied to the situation that would occur within the channel after Expansion deepening would also apply to wet sediments held within a DMCA, with the exception that at least some shorebirds could be expected to feed almost entirely on prey organisms within the wet sediments. EA also conducted a risk assessment of direct uptake by plants and animals living on sediment held in a wet condition within the containment areas. These assessments are discussed below along with the assessment by CENWO-HX-S.

The first risk assessment was conducted by CENWO-HX-S. They began by analyzing the sediment cadmium data to determine appropriate concentrations to use in their predictions. They found the sediment cadmium data to be non-parametric and advised that the 95% Chebyshev (Mean, Sd) UCL be used in evaluating each reach. The reach

with the highest average cadmium concentration (21.5 mg/kg) was found to have a 95% Chebyshev UCL of 36.2 mg/kg cadmium concentration. This value was used for their risk assessment of the high cadmium sediments. The reach with an average cadmium concentration of 6.67 mg/kg cadmium was found to have a 95% Chebyshev UCL of 10.5 mg/kg cadmium. This value was used in their risk assessment for that reach. The results of their assessment are discussed at Sections 4.3.2.3 through 4.3.2.5.

EA conducted their risk assessments based on the results of the bioaccumulation testing of the low and high cadmium composites. The 29.8 mg/kg cadmium total for the high cadmium composite is slightly less than the 36.2 mg/kg cadmium average CENWO-HX-S found to be appropriate for assessment of the high cadmium sediments. Decisions based on the high cadmium composite concentration could therefore slightly underestimate overall potential impacts.

EA conducted high cadmium (29.8 mg/kg) sediment exposure estimates including food, sediment, and effluent water exposure for great blue heron, osprey, spotted sandpiper, Canada goose, river otter, and muskrat. The predicted consumption exposure of 1.63 mg/kg-bw day for the spotted sandpiper is above the mean NOAEL cited by EA (1.47 mg/kg bw day) but below the LOAEL of 2.37 mg/kg bw-day. Estimates for the other species were below NOAELs. These results are shown in Tables 10-15 to 10-19 in EA, 2008. It should be recognized that the assumptions leading to this estimate reflect more the expected state, rather than being conservative, especially for young birds feeding within the DMCAs. For example, in the case of young black-necked stilts raised within the DMCAs, they would be expected to spend 100 percent of their time feeding on prey that are in continual contact with cadmium-containing sediments. If the bird LOAEL cited by CENWO-HX-S (1.45 mg/kg bw-day) is used as a benchmark, then the sandpiper estimate slightly exceeds the LOAEL benchmark.

4.3.2.7 Conclusion Regarding Birds Feeding Within a DMCA in an Aquatic State.

The cadmium exposure prediction by EA (2008) for birds feeding 100 percent of the time in high cadmium sediments within the DMCAs is 1.63 mg/kg bw-day for spotted sandpiper. This is less than the original prediction by CENWO-HX-S (CENWO, 2006a) of 6.5 mg/kg bw-day, which did not include ingestion of water in the estimate. EA included ingestion of water in its estimate, but the exposure from water was found to be small. EA used a food ingestion rate (0.294) expressed as kg food (wet wt.) per kg body wt. per day. CENWO-HX-S used a food intake rate (0.0077) expressed as kg food per day. Using the spotted sandpiper body weight of 0.0425 kg cited by CENWO-HX-S, the feeding rate described in their assessment for the spotted sandpiper converts to 0.273 kg wet wt. per kg body weight-day. This indicates both groups used similar feeding rates in their calculations. The difference in exposure estimates can be explained by how the food and sediment ingestion exposures were estimated. The CENWO-HX-S calculation is overly conservative in that it assumes food and sediment would have the same concentration of cadmium (36.2 mg/kg). EA (2008, Chapter 10) used the bioaccumulation results for *Nereis* grown in the high cadmium composite to predict benthos in the spotted sandpiper diet would have a cadmium concentration that was 0.664 percent of the cadmium present in the sediment. In other words, EA used site-specific

information to conclude that a lower cadmium intake should be expected for the spotted sandpiper.

A difference in evaluation criteria led to different conclusions by CENWO-HX-S and EA. CENWO-HX-S used the lowest published bird LOAEL value of 1.45 mg/kg bw-day as a benchmark. EA used the lowest "bounded" LOAEL of 2.37 mg/kg bw-day and the geometric mean of the NOAEL data (1.47 mg/kg bw-day) in the ERED database as benchmarks. However, the major difference in evaluation criteria was the calculation of an ecological quotient "EQ", in accordance with Interim EPA superfund guidance (CENWO, 2006a). The next paragraph provides an explanation of the use of the "EQ" from CENWO-HX-S.

"Ecological risk should be interpreted based on the severity of the effect reported and the magnitude of the calculated EQ (EPA, 1997). For example, EQs between one and 10 have 'some small potential' for adverse effects, EQs between 10 and 100 have 'significant potential' for adverse effects, and EQs greater than 100 indicate 'expected' adverse effects (Menzie et al., 1992). The EQs associated with the risk of cadmium for this project in both cadmium reaches are greater than one, but less than 10, for both ROCs, and therefore, it is not of significant project-wide concern."

It is our conclusion that the exposure estimate (1.63 mg/kg bw-day) for shorebirds feeding within the ponded area of a DMCA containing sediment cadmium levels similar to those in the high cadmium composite shows a level slightly above the lowest published LOAEL for birds (1.45 mg/kg bw-day). Because the DMCAs are managed to produce wildlife habitat for birds, impacts to feeding birds would be unacceptable. Since this exposure estimate is based on birds feeding within a DMCA 100 percent of the time, this estimate would apply only to birds feeding within the DMCAs 100 percent of the time (nesting black-necked stilts and their young). Using the high cadmium sediment composite level of 30 mg/kg cadmium as equating to an exposure level of 1.63 mg/kg bw-day, a 1.45 mg/kg bw-day exposure level would equate to a 27 mg/kg wet sediment cadmium level as the lowest wet sediment level of potential concern within a DMCA.

4.3.2.8 Worker Exposure During Dredging. Although the risk assessment conducted previously CENWO-HX-S concluded that occupational workers' exposure to the cadmium-enriched dredged material would not pose a concern for adverse non-carcinogenic or carcinogenic health effects, the District conducted an additional assessment to confirm those findings.

Workers associated with the dredging and sediment placement operations could experience some exposure as the new work sediments are removed from the channel and deposited within the DMCA. The duration of this potential exposure is not certain, but would extend only during the period of construction. Large dredges expected to be used for this construction could be expected to move along the channel at a rate of about 50 feet per day. At that rate, it should take a dredge 560 days to deepen the 28,000-foot length of channel enriched with cadmium at levels averaging 21 mg/kg. Workers at the DMCAs may experience exposure for a longer period, as the Contractor is typically

responsible to decant the DMCA, a process which often takes 30 days. For those workers, the total exposure time would lengthen to 590 days (560 + 30 days).

A dredge can be expected to operate for 24-hours per day, so two 12-hour shifts would perform the work. The work time for a given worker could be as much as 6,720 hours (560 days X 12 hours/day). The exposure for occupational workers on a dredge would be for a much shorter period of time than the exposure found by CENWO-HX-S to have no effect (6,720 hours rather than 45,000 hours). Similarly, for the Contractor's workers at the DMCAs, the total exposure time would be 7,080 hours. This is also much shorter than what CENWO-HX-S concluded would have no effect.

Therefore, the conclusion for workers during the dredging and sediment placement operations would be the same: exposure to the cadmium-enriched dredged sediment does not pose a concern for adverse non-carcinogenic or carcinogenic health effects.

5.0 Conclusions.

5.1 Potential Contaminants of Concern

Cadmium has been identified as the only contaminant of concern for the Savannah Harbor Expansion Project. Cadmium concentrations within new work sediments have been found to be elevated above levels normally encountered in sediments and soils. An assessment of potential availability of cadmium and associated risk has identified scenarios with little environmental concern and others where environmental concerns dictate management to minimize risk.

5.2 Project Extent

Cadmium sediment concentrations within the channel were investigated from Station +103+000 to the end of the project in deep water in the Atlantic Ocean at Station -63+000B. Extension of the proposed work to Station -98+600B is believed to have no additional sediment contaminant-related impacts since the tested bar channel sediments were found acceptable and the additional length would extend further into the ocean and away from possible sources of contaminants.

5.3 Cadmium Concentrations

As discussed in Section 4.2.5, the lowest cadmium level of potential concern in wet sediments within the DMCAs is approximately 27 mg/kg (dry wt).

As discussed above (Sections 3.9 and 4.3.1.7), a sediment cadmium concentration of 14 mg/kg has been identified as the lowest concentration warranting environmental concern when sediments are placed in a dry environment. This level was used in determining

which reaches contained sediments require management. The highest observed cadmium concentration is 77.1 mg/kg in the -56 to -58 foot (MLW) layer at Station +30+000. The Station with the highest sediment cadmium average (39.4 mg/kg) is Station +26+000. The reaches where potential contaminant-related environmental impacts have been identified and sediment management is required include inner harbor Stations +90+000 to +80+125, +57+000 to +51+000, and +45+000 to +6+375. Average cadmium concentrations associated with each of these reaches is shown in Table 21c.

In response to concerns raised by the USFWS, the District agreed that a cadmium “trigger” level should be identified for this project below which there should be no contaminant concerns associated with a proposed cover/cap. In deriving this “trigger” level, the District used the dose (exposure) prediction procedure discussed at 4.3.1.7, data from the low cadmium composite, and very conservative assumptions to predict an exposure estimate for the Marsh Wren (the most sensitive target species investigated by EA). Those assumptions included: all sediment cadmium would be bioavailable (15.4 mg/kg cadmium dry wt), cadmium concentration in water would be the total effluent concentration from the low cadmium elutriate study (761 ug/L), a sediment to plant transfer factor of 1, and a plant to invertebrate transfer factor of 1.1. The Marsh Wren cadmium exposure under these conditions was estimated to be 4.81 mg/kg bw-day. By relating this exposure level to the total cadmium sediment level of 15.4 mg/kg, the predicted cadmium sediment level associated with the lowest published effect level of 1.45 mg/kg bw-day would be 4.64 mg/kg dry wt. sediment cadmium. Acknowledging there is some degree of uncertainty associated with this prediction, the District determined the dry sediment level associated with no effect on birds could be considered with a high degree of certainty to be no more than 4.0 mg/kg cadmium. Therefore, 4.0 mg/kg dry wt. cadmium was selected as the cover criterion below which environmental concerns should be minimal.

5.3 Contaminant Concerns Related to Water Quality

Potential adverse contaminant impacts on water quality related to the required dredging were found to be minimal.

5.4 Potential Contaminant Impacts within the Savannah River

Potential contaminant impacts associated with exposed high cadmium sediments within a deepened channel have been found to be minimal, primarily because sediment cadmium was found to be unavailable and bioaccumulation tests found cadmium uptake below levels of concern. The essentially anoxic state of the channel sediments should preclude significant movement of cadmium to the environment. Furthermore, it is expected that exposure of the riverine environment to high cadmium clays would be restricted since the majority of the exposed clays are expected to be covered by O&M sediments.

5.5 Potential Contaminant Impacts associated with Dredged Sediment Placement

Potential contaminant impacts related to sediments held in a wet state within a DMCA were found to exist only for birds that feed within a DMCA 100 percent of the time. This would refer primarily to nesting black-necked stilts and their young. To minimize environmental risk, high cadmium sediments should be managed in a way that excludes exposure to nesting black-necked stilts.

5.6 Other DMCA Pathways

Potential impacts associated with other pathways by which a contaminant might leave a DMCA (leachate to groundwater, runoff, effluent, volatilization) were found to be minimal.

5.7 Potential Impacts Associated with the DMCA Rotation Management Plan

The DMCA rotation management plan involves keeping a DMCA flooded for 3 years and then maintaining the DMCA in a dry state for the next 3-years. During the “dry” cycle, sediments within a DMCA dry for 2 years, and then the dried sediments are relocated to the dikes in the third year. Studies found that drying the sediment changed the behavior of cadmium in the sediment. Sequential extraction procedures on washed and dried sediment showed that cadmium becomes more available in the dried sediment and a plant uptake study found that plants can accumulate cadmium from dried sediments. Exposure models found that both bird and mammals exposed to the dry high cadmium sediments are likely to accumulate cadmium at levels shown to cause impacts. To minimize potential contaminant risk, high cadmium sediments within the DMCAs should not be allowed to be dried and exposed to a degree that allows plant growth and feeding by birds and mammals. In addition, the high cadmium sediments should not be placed so that they would be exposed on the surface of the containment area dikes.

5.8 Nearshore Placement of Bar Channel Sediments

No contaminants of concern were found to exist for new work sediments oceanward of Station +6+375. Therefore, there should be no contaminant-related environmental concerns associated with proposed placement of new work entrance channel sediments in the ODMDS, nearshore submerged berms, or nearshore feeder berms. The placement of dredged material into the nearshore sites has been removed from the project.

6.0 Placement Alternatives for High Cadmium Sediments

6.1 Project Dredged Sediment DMCA Placement Alternatives

There are four primary dredged sediment placement alternatives for the Expansion Project sediments containing elevated levels of cadmium: (1) Deposit the sediments in a DMCA, with subsequent management in the rotation plan; (2) Deposit the sediments in a DMCA, with isolation of the sediment through capping/covering; (3) Deposit the sediments in a DMCA, with isolation through capping/covering and lining; and (4) Deposit the sediments in the Sediment Basin or other open water site.

6.2 Deposit the Sediments in a DMCA, with Subsequent Management in the Rotation Plan

This alternative is unacceptable because of the potential environmental impacts associated with accumulation of cadmium by birds and mammals feeding within the DMCA.

6.3 Deposit the Sediments in a DMCA, with Isolation within One or More DMCAs with Capping/Covering

This alternative is acceptable from an environmental perspective since it would preclude movement of cadmium from sediments to populations of concern outside the DMCAs, including birds and mammals.

6.4 Deposit the Sediments in a DMCA, with Isolation within One or More DMCAs with Capping/Covering and Lining

This alternative is acceptable but appears to be unnecessary. A liner would be appropriate to prevent cadmium movement to groundwater as leachate, should the leachate contain cadmium at levels of concern. Studies discussed in this assessment found cadmium to be tightly bound within wet sediments and clay porewater concentrations were found to be very low. Therefore, movement of cadmium through leachate is expected to be minor and of minimal environmental concern.

6.5 Deposit the Sediments in a Sediment Basin or Other Open Water Site

Under our current level of understanding, elevated cadmium sediments placed in an anoxic open water site would be expected to release minimal cadmium to the environment. However, placement of these sediments in the high current Back River Sediment Basin with a pipeline dredge could not guarantee the sediments would be localized in one area and remain anoxic. Movement of these sediments throughout the estuary could result in future unforeseen impacts. Potential environmental impacts make this alternative unacceptable with pipeline dredging. Clamshell dredging with bulk placement of the sediments would reduce sediment resuspension and subsequent offsite spread of those sediments. This could render this option acceptable, but further consideration of potential impacts would be necessary before confirming that determination.

7.0 Recommendations

7.1 Isolate High Cadmium Sediments

New work sediments from Stations +90+000 to +80+125, +57+000 to 51+000, and +45+000 to +6+375 should be isolated within a DMCA and capped/covered with sediment from another reach. More than one DMCA may be needed to store the volume of new work sediments resulting from some channel depth alternatives. The high cadmium sediments should not be disturbed further and should not be allowed to be later excavated and placed in any exposed upland area.

7.2 Potential Method of Isolation

Once a DMCA is selected to receive the sediment, the high cadmium sediments should be pumped into the area first. Once placement of sediments from this reach is completed, markers should be placed on the surface of the sediment to allow easy determination of when the proper cap/cover depth has been attained. At least 2 feet of additional sediment from another reach (the cover material) should then be placed in the area as soon as practicable, but as part of the SH Expansion Project, to ensure minimal environmental impacts from birds feeding within the DMCA. Once the sediments have consolidated, a covering of crushed limestone, coal or similar marking material should then be placed on the surface of the area to ensure that the surface of the cover can be located in the future and the cover left undisturbed.

7.3 Monitoring and Contingency Plan

7.3.1 Placement of Dredged Material

An hydraulic dredge will be used to place material averaging approximately 14 ppm cadmium or greater into Dredged Material Containment Areas (DMCAs) 14A and/or 14B. Material placed in the DMCAs will remain in a "ponded" state (inundated) until the material is covered/capped by placing an approximately 2-foot layer (i.e., cap) of dredged material averaging ≤ 4.0 ppm cadmium. It should be noted that the dredged material containing 14 ppm cadmium will not be allowed to dewater and/or desiccate to the point that it would come into contact with the atmosphere. Cadmium-laden sediments would not be diluted with other sediments to reduce concentration during dredging nor allowed to mix substantially with cap/cover material when the cap/cover sediments are placed.

To ensure even distribution of dredged material throughout the disposal area, a floating discharge with a spreader may be required to allow the head section to be relocated as necessary using a system of winches and cables as heavier material will fall out and tend to accumulate close to the head section. Bulldozers adapted to aqueous work would be required to keep dredged material submerged to minimize contact with the atmosphere and ensure a level surface. After a period of 3-6 months, the cap material would be placed using the same approach as the cadmium material was placed. Prior to deposition of the cover/cap material, light-weight settlement plates or other appropriate settlement measuring devices will be distributed across the disposal area in a grid and marked so that the contractor will be able to tell when 2 feet of covering sediment has been deposited.

Another approach for actual placement of material is also under review. This approach would use a float hose with a y-valve and an operator at the end of the line, which could control the discharge by directional pumping. This method would require first depositing material closest to the weirs and piping off to move the head section to the front of the disposal area. Discharge would begin near the front of DMCA 14A near the weirs and then shift away to allow suitably clear water to be discharged. Deposition would progress toward the rear of the disposal area, around the finger dike, and back to the front of the disposal area. Assuming a 47' project, the remainder of the cadmium material to be managed would most likely be placed in DMCA 14B using the same approach as identified with DMCA 14A. With respect to this alternative approach, a 2-foot covering layer would still be used.

7.3.2 Monitoring Sediments During Placement in DMCA

The goal of this analysis is to characterize the cadmium concentrations that are actually deposited in the confined disposal area. Samples of the sediment slurry would be collected from the head section discharge pipe on a weekly basis and analyzed for total cadmium. Total solids would be reported on a g/L basis and cadmium concentration would be reported on a dry-weight basis (mg/kg). If clay balls are being discharged, a typical clay ball would be collected on a weekly basis at the same time the slurry sample is collected and the total cadmium concentration reported for both the slurry and clay ball on a dry-weight basis (mg/kg).

7.3.3 Sampling of Effluent During Placement of Sediment in DMCA

The goal of this analysis is to ensure effluent from the DMCA satisfies TSS limits and cadmium water quality standards. At the beginning of the deposition of new work sediments in the DMCA, the contractor would construct a 500mg/L TSS standard and determine turbidity (in NTU's) associated with the standard. The contractor would then visually compare effluent turbidity at each of the discharging weirs to the standard on a daily basis. The contractor would measure turbidity on a weekly basis at each outfall pipe with a discharge. Measurements would include dissolved oxygen, salinity, conductivity, temperature, and turbidity. Measurements would be made with a Hydrolab or similar instrument. At the same time the turbidity measurement is made, every two weeks the contractor would collect a water sample for chemical analysis. Sample would be obtained from the outfall pipe. Analyses would include NTUs, total suspended solids (TSS) in mg/L and cadmium concentration in ug/L (dissolved). Should the effluent dissolved cadmium concentration be found to be higher than the State standard (i.e., 8.8 ug/L for South Carolina), sampling would be repeated within two days and would include both the outfall pipe sample and a receiving water sample taken approximately 100 feet down-current of the point at which the effluent enters the receiving water. Should the receiving water sample be found to violate the State standards, corrective action would be undertaken to eliminate the violation. Any violations of the turbidity or TSS standards would be immediately addressed by corrective action to eliminate the violation. Corrective action may include boarding up the weir to reduce or eliminate effluent discharge, or reducing sediment discharge rate into the disposal area.

7.3.4 Sampling of Cadmium-Laden Sediments

Once placement of cadmium-laden sediments has been completed in a DMCA, grab samples would be collected to characterize the cadmium levels of the surficial sediments. This would occur prior to placement of the sediment cover/cap. Approximately 86 grab samples would be collected from the top 15 cm of the surface of each disposal area used to deposit sediments containing ≥ 14 ppm cadmium. It is expected that this sampling will require use of a water craft, since the area must remain inundated until the high cadmium material is covered by cap/cover material. Samples would be evenly spaced across the DMCA. A sampling depth of 15 cm would be used for these saturated sediments as cadmium transfer to the water column or other organisms should be minimal below this

depth. These samples would also be analyzed for cadmium concentration on a dry-weight basis (mg/kg).

7.3.5 Sampling of Capping/Covering Layer

Eighty-six grab samples would be collected after the cover has been placed on the DMCA in order to characterize the cadmium levels of the exposed, surficial "capping" sediments. The same procedure for sample collection would be used as previously described. Approximately 86 samples would be collected from the top 30 cm of the cover/cap for each disposal area used to deposit sediments containing an average of ≥ 14 ppm cadmium. These samples would be evenly spaced across the DMCA and the location of these sites recorded using a GPS system. These samples would be analyzed for cadmium concentration on a dry-weight basis (mg/kg). If the distribution of sediments with cadmium concentration ≥ 4 ppm extends over a cumulative area of 25 acres or greater, then O&M sediments will be placed over the cap/cover, at the earliest possible time. Once the layer of O&M material has been placed in the DMCA, the surface sediments (to a depth of 30 cm) will be sampled (86 grab samples) and analyzed for cadmium. The process of placing O&M material in the DMCA and testing for cadmium would be repeated until the cadmium concentration in the surface sediments is less than 4 ppm.

7.3.6 Wildlife Use of the DMCAs

The District would perform monthly wildlife use surveys of the DMCAs used for placement of cadmium-laden sediments. These one-day surveys would record all birds and other major vertebrates seen within each of the appropriate DMCAs. Weekly monitoring of target species to determine arrival dates and ensure capture within two weeks of arrival will be conducted, most likely in April and September. Monitoring would be performed during placement of sediment (including any required cover) and for 3 years after any required placement is complete. If there is a concern about the number of birds or other animals or a particular species using the DMCA, some type of hazing may be appropriate. Any hazing decisions would be coordinated with the USFWS.

7.3.7 Vegetation Sampling

Should analyses of the cap/cover material show that concentrations of cadmium are equal to or exceed 4 ppm in a cumulative area of 25 acres or more, vegetation sampling will be required. This vegetation sampling would be conducted on a quarterly basis. Sampling of vegetation would be initiated in defined "hot spots" to determine cadmium uptake by plants. Samples collected from the DMCA of interest would be compared to control samples derived from other, cadmium-free environments found in adjacent DMCAs. Where at all possible, vegetation comparisons to reference will be by species and sampling will include all dominant species growing on the cover/cap (where dominant species are determined by the specie exhibiting the highest stem count or percent cover plus all other species equaling at least 20 percent of the total). If vegetation samples have significantly elevated cadmium concentrations, then efforts would be initiated to

eradicate vegetation and/or place additional, low-cadmium sediments over the original covering layer. These contingency measures would eliminate wildlife exposure should vectors for cadmium uptake be identified. Once an additional layer of material has been placed on the covering layer, then soil/sediment sampling would resume. When sampling confirms that all the amended covering layer contains sustained cadmium concentrations of <4 ppm, the vegetation monitoring requirements would be complete. Specific details on the vegetation monitoring are described below at Section 7.4.3.1.4.

7.3.8 Tissue Monitoring

The District does not expect to encounter large numbers of birds feeding in elevated cadmium sediments during the dredged material disposal operations. This is because the proposed disposal design calls for sediments to be placed in an area where water is being held above the level of the placed sediments. Avian access to these inundated sediments is expected to be limited to birds that feed by swimming and diving. The species expected to be encountered in the highest numbers in the inundated areas include American Coot, Common Moorhen, Mottled Duck, feral Mallard Duck, Double-crested Cormorant, and in winter only, Northern Shoveler, Green-winged Teal, Ruddy Duck and Pied-billed Grebe.

Tissue monitoring would be conducted during placement of cadmium-laden sediments and the cap/cover and for 3 years after the placement is complete. Since the DMCAs will reenter the rotation program after the covering sediments are placed, the DMCAs may be dry or wet, depending on the year. Their hydrologic condition would drastically alter their bird use, as different species use the DMCAs in those two conditions. The season also drastically affects bird use of the DMCAs.

If/when the DMCAs are dry, individuals from two species would be sampled at the beginning and end of the nesting season (April and August) chosen from the following nesting species: Red-winged Blackbird, Mourning Dove, Eastern Towhee (white or yellow-eyed), Brown Thrasher, and Northern Mockingbird. Similarly, if/when the DMCAs are dry, individuals from two species would be sampled at the beginning and end of the wintering season (October/November and March/April) chosen from the following wintering species: Eastern Towhee (white or yellow-eyed), Brown Thrasher, Northern Mockingbird, House Wren, Song Sparrow, and Savannah Sparrow.

If/when the DMCAs are wet, migratory birds predominate at the sites. Sampling would be timed to correspond when the majority of each species arrives and is about to depart, which corresponds to approximately April and September. Sampling in April should maximize exposure time for wintering species (September through April), while sampling in about September should maximize exposure time for summer nesting species (April through September). Individuals of two species would be sampled in April and September. The proposed species to be sampled under wet conditions are the following: Northern Shoveler (open-water winter species), Avocet (edge-feeding winter species), Mottled Duck (open-water summer species), and Black-necked Stilt (edge-feeding summer species). The proposed species to be sampled under dry conditions are the

following: Red-winged Blackbird (summer nester), Mourning Dove (summer nester), Savannah Sparrow (winter), and House Wren (winter). Other species listed above in the first paragraph may be substituted for one of these species upon mutual agreement between the District and the USFWS.

One of two types of tissue monitoring may be used. Liver and other tissue may be collected from three individuals of each target species. Blood/feather monitoring is currently deemed to be the appropriate method as it will allow collection of higher numbers of tissue samples. Specific details of the blood/feather monitoring are provided at Section 7.4.3.1.2.

7.3.9 River Bottom Sampling of Cadmium: Post-Construction Mapping

At the end of construction, sediment samples would be taken from the exposed channel bottom sediment surface and analyzed for grain size and metals (aluminum, iron, arsenic, beryllium, cadmium, chromium, copper, lead, manganese, mercury, nickel, selenium, silver, and zinc). Samples would be cores taken to a depth of 15 cm. Where both O&M and new work sediments appear in the core, each would be analyzed separately. Samples would be taken within the channel every 2,000 feet from Stations +100+000 to 0+000 (26 samples) randomly selecting either the center line of the green side or red side. Five stations would be randomly selected to have two adjacent samples collected, from both the red and green side (10 samples). These last samples would be used to define the variability in bottom sediment metal concentrations across the channel. In addition, 5 samples would be run in duplicate (lab duplicates). Analysis of the river bottom would provide an assessment of anticipated cadmium concentrations in sediment at the sediment water interface.

7.4 Summary of Cadmium Management and Monitoring

7.4.1 Placement of Cadmium-laden Sediments

All cadmium-laden sediments would be placed in DMCAs 14A and/or 14B. Material would be placed so that it remains covered with water until after placement of the cover is completed. This material would not be allowed to dewater and/or desiccate to the point that it would come in contact with the atmosphere until placement is complete.

7.4.2 Placement of Cover/Cap

The covering material should come from reaches averaging less than 4 ppm cadmium. A capping layer of at least 2 feet of sediment should be placed above the cadmium-laden sediments. Once the cover has been determined to be sufficient, a marking layer (limestone, coal, etc.) would be placed on the surface. These sediments are not to be exposed in the future.

7.4.3 Required Cadmium Monitoring

7.4.3.1 Biological Monitoring

The District would perform monthly wildlife and avian/abundance surveys and avian blood tissue monitoring at the DMCA's used for placement of cadmium-laden sediments. Avian liver tissue monitoring and vegetation monitoring would take place only if results from the proposed blood/feather monitoring and or sediment cap monitoring indicate specific criteria are exceeded.

7.4.3.1.1 Wildlife and Avian Abundance Surveys

The District proposes to conduct these surveys monthly to monitor avian and terrestrial wildlife (large mammals) use of the DMCA's. This monitoring would be conducted independent of cadmium concentrations in the deposited sediments (in the two DMCA's that will receive the cadmium-laden sediments). Weekly monitoring of target species to determine arrival dates and ensure capture within two weeks of arrival will be conducted, most likely in April and September. The monitoring would be conducted during SHEP construction and would continue for at least 3 years after sediment placement is complete. Wildlife and avian monitoring will be extended as necessary until results from cadmium monitoring of sediment, vegetation, avian tissue and effluent indicate that cadmium concentrations are below levels of concern for 3 years post-construction. Cadmium levels of concern are considered to be 4.0 mg/kg sediment dry wt., chronic water quality criteria and standards within a DMCA or receiving water after mixing, 5.0 mg/kg plant tissue dry weight, avian blood tissue concentrations significantly greater than reference, and 45 ug/g wet liver tissue weight.

NOTE: the values and calculations for determining this threshold are the same as those for used the Savannah Harbor Expansion Project Phase II Risk Assessment and are based on the song sparrow (not the marsh wren) using the 'cadmium washed/dried sediment composite and effluent' scenario. For a total cadmium uptake dose to not exceed the No Observable Adverse Effect Level (NOAEL) benchmark of 1.47 mg/kg body wt/day (using the same assumptions regarding food, water, and incidental soil ingestion rates, cadmium bioavailability, and soil-to-plant bioaccumulation of cadmium), the cadmium concentration in plant material (e.g., seeds) for the sparrow would have to be ≤ 5 mg/kg dry wt (assuming the same cadmium uptake from water at a concentration of 0.1517 mg/kg body wt/day based on the low cadmium composite effluent).

7.4.3.1.2 Avian Blood Tissue Monitoring

This monitoring will also be conducted independent of the concentrations of cadmium in the cover/cap and will be conducted both during and for 3 years after construction. It would be extended as necessary to ensure monitoring results are below levels of concern for 3 years post-construction.

The District believes that the overall purpose of the cadmium tissue monitoring is to ensure that the proposed sediment placement does not impact biota within the DMCA's, with concern focused on birds since they are thought to be the most important class of vertebrates that lives both inside and on the periphery of the DMCA's. This class is also important because most species move into and out of the areas at least during migrations. The District proposes that this monitoring be conducted primarily by analysis of blood collected from target species. A baseline data set would be collected, with a target of 30 blood samples from two target species from each season (approximately 120 blood samples) prior to commencement of dredging in the inner harbor in DMCA's 14A and 14B. The Corps may also collect additional baseline data upon the migratory arrival of the species in a given year. The actual number of baseline and project blood samples may vary depending on the ease with which each species can be captured, but should not be less than 10 per species. The baseline data set would provide information on ambient or background blood tissue cadmium levels. Project sampling events would be performed each year on the target species at mid-season in the DMCA (at least 10 samples) and the resulting data compared to the baseline data set for identification of any potential effects from their use of the DMCA's. This sampling procedure would be repeated during each year of construction and for 3 years following construction. Should the project samples show a significant difference from the baseline data (95% confidence interval) for any species, liver tissue sampling would be performed on that species. Target species must be collected prior to their departure from the DMCA. This procedure would be repeated for any species and any season where significant differences in cadmium blood levels are observed.

Of prime importance for this monitoring is the establishment of baseline blood tissue data for comparison to levels observed prior to a species leaving the DMCA's each year. There appears to be two potential methods for establishing these data: (1) collect the baseline data prior to construction, or (2) collect the baseline data upon arrival of species in the DMCA's. There are advantages and disadvantages for each as outlined below:

Collect baseline data prior to construction

Advantages: Ensures collection of adequate data prior to construction. The ease with which collection of bird blood samples can be accomplished at the sites is currently unknown. Sampling before construction occurs would allow refinement of collection techniques without the time restraints associated with collection at the arrival of the target species. This method would still require a small number of confirmatory samples (at least 3 to 5) at the beginning of the arrival of each species in the areas. This yearly confirmatory sampling should remove uncertainty in whether target species have been influenced by site cadmium levels prior to their yearly arrival to the DMCA's. If the confirmatory samples differ from the baseline data (at 95% C.I.), then additional baseline data would be obtained. This eventuality is not considered likely and is not included in Appendix D.

Disadvantages: Adds uncertainty to the results due to potential yearly variation in cadmium concentrations within target species when they arrive at the DMCA's. There is

the potential for selected target species to not return to the DMCAs in a given year during construction in sufficient numbers, thus requiring selection of an alternate species.

Collect baseline data upon arrival of species

Advantages: Accounts for potential yearly variation in cadmium concentrations within species. Ensures target species are actually present at the construction site during construction.

Disadvantages: Requires adequate data be collected in a short period of time (soon after arrival at the DMCAs each year). Failure to collect adequate data in a given year could result in collection of inadequate baseline monitoring data. Since arrival dates for target species can only be estimated, target species could begin arrival prior to detection and begin uptake of cadmium prior to their capture. This potential adds uncertainty to whether baseline data collected in this manner are actually baseline.

The selected method of baseline data collection for the bird blood tissue monitoring is a combination of the two methods described above. A baseline data set will be collected the year before start of the inner harbor dredging. This will include all target wet and dry species. In addition, at least 3-4 samples of target species will be collected within two weeks of their arrival within the DMCAs. For resident dry species targeted for sampling (Red-winged Blackbird and Mourning Dove), augmenting baseline samples could only be taken the first year. These samples will be compared to the baseline dataset. Should the new samples fall outside the original dataset (95%CI), that would be considered an indication of population changes in tissue cadmium levels occurring outside the influence of the DMCAs. Should the results indicate such changes are occurring, a new baseline dataset would have to be established in consultation with the USFWS.

7.4.3.1.3 Potential Avian Liver Tissue Monitoring

Should data for cadmium blood levels for any bird species be shown to be significantly different from the baseline data (95% confidence level), six liver tissue samples would be collected for that species and cadmium concentrations compared to lowest published avian liver cadmium toxicity levels (screening level). These levels are currently thought to range from 45 to 70 ug Cd/g wet weight liver tissue (Cadmium in Birds, Mark Wayland and Anton M. Scheuhammer, in Environmental Contaminants in Biota, Jekker Frederick Warne & Co.). Liver values significantly above these screening values would trigger additional management options. The District may also choose to collect baseline liver tissue data to which project liver tissue data would be compared. Project liver tissue data would have to significantly exceed baseline data and the threshold value to trigger additional management options.

Blood tissue monitoring would continue until 3 years have passed where either no blood tissue samples are found statistically significantly above the baseline or no liver samples have been found statistically significantly above both baseline and screening values.

The District concurs with the USFWS recommendation that 45 ug Cd/g wet weight liver be the threshold concentration that would trigger additional management options. While the citation listed above provides a threshold toxicity range, that range includes values that indicate potential toxicity to other organs such as kidneys or testes. Eisler (1985) has stated that cadmium residues in vertebrate kidney or liver that exceeds 10 ppm fresh weight should be viewed as evidence of probable Cd contamination. Also, Furness (1996) suggested that 40 ppm in the liver should be viewed as a tentative threshold tissue concentration above which cadmium poisoning in birds might be expected. The District believes that the combined evidence of elevated Cd blood concentrations and Cd liver concentrations at or above published toxicity threshold concentrations (using 45 ug Cd/g as the most recently published lower threshold concentration) should warrant management action.

7.4.3.1.4 Potential Vegetation Tissue Monitoring

Vegetation sampling would be conducted on a quarterly basis should areas of elevated cadmium be found in the covering sediment. This monitoring is not included in Appendix D because it is not certain that it will be required. Should sampling of the cover show areas with cadmium concentrations greater than or equal to 4.0 mg/kg dry wt. and representing a total cumulative area of 25 acres or greater of the covering layer (not necessarily contiguous), such areas would be considered "hot spots". Vegetation sampling would be conducted at each sampling point within a "hot spot" where the cover sediment cadmium concentration is equal to or greater than 4.0 mg/kg dry wt. Vegetation sampling would be conducted in these defined "hot spots" to determine the potential for cadmium uptake by plants.

A plant tissue concentration of 4 mg Cd/kg dry weight as a threshold for further action can be derived from comparing the predicted exposure to a Marsh Wren of 3.75 mg/kg bw-day from a high cadmium sediment concentration of 10.2 mg/kg to the NOEL exposure of 1.47 mg/kg bw-day (a no effect level). On the other hand, when using the LOAEL of 2.37 mg/kg bw-day as the comparison (a lowest effect level), the predicted associated soil level would be 6.4 mg/kg. Based on these two estimates, we believe that a 5 mg/kg dry weight plant tissue level is appropriate as the threshold for further action.

Samples collected from DMCA's 14A and/or 14 B (or any other area receiving cadmium laden sediments) would be compared to control samples from other, cadmium-free environments found in adjacent DMCA's, and to the cadmium plant tissue threshold level of 5 mg/kg (dry wt.). If vegetation samples have significantly elevated cadmium concentrations with respect to both control and the plant tissue threshold level, efforts would be initiated to eradicate vegetation, and/or place an additional covering sediment layer in the DMCA, and or conduct hazing of species inhabiting the "hot spots".

Proposed Vegetation Tissue Monitoring Plan.

1. Vegetation sampling will only occur if sediment sampling of the cover/cap layer finds a "hot spot".

2. A "hot spot" is a cumulative area of 25 or more acres, not necessarily contiguous, in which the cadmium sediment concentration is equal to or greater than 4.0 mg/kg dry wt. as determined by 30 cm core samples, each representing approximately 9 acres.
3. Vegetation to be monitored includes higher plants that could for the basis of movement of cadmium to species of concern (birds), either through support of potential herbivore prey or seed production.
4. Monitoring would occur at each sampling point determined to be within a "hot spot" where the sediment cadmium concentration is equal to or greater than 4.0 mg/kg dry wt.
5. Sampling of vegetation would occur within a radius of approximately 350 feet of the sampling point.
6. Dominant higher plant species would be determined by stems in contact with randomly placed straight lines through the site or by either areal coverage or stem counts within randomly placed 1 meter squares. Enough lines or squares would be used until the dominant species are evident. All dominant species (the most dominant species and any additional species comprising at least 20% of the samples) would be collected.
7. For each dominant species, above ground tissues will be collected, dried, and homogenized into one sample for each species. Sufficient tissue would be collected to perform all required tests.
8. This pattern would be completed for each identified "hot spot sampling point".
9. Cadmium vegetation tissue concentrations (in both wet wt. and dry wt.) would be determined for all dominant higher plant species (as defined in Par. 1). Analytical standards would be in accord with EPA Region IV/COE Southeast Regional Implementation Manual for Section 103 Evaluations (SERIM).
10. Control samples of the same species (at least 5 samples) would be collected from other areas with low cadmium content found in adjacent DMCA's.
11. Data from all sampling points within a "hot spot" would be assembled by species and the average of each species compared to the control samples and the 5 mg/kg dry wt. plant tissue threshold. Should species-specific tissue data from a "hot spot" be significantly higher at the 95% confidence level than both the control samples and the plant tissue threshold, additional management action by the District would be required.

7.4.3.2 DMCA Sediment Sampling During Placement

Samples would be taken weekly from the inflow during placement operations and analyzed for cadmium. Sampling could include a slurry sample and clay ball sample (if clay balls are being discharged).

7.4.3.3 DMCA Sediment Sampling Following Placement of Cadmium-Laden Sediments

Following placement of cadmium-laden sediments within a DMCA (and before placement of the cap), eighty-six (86) grab samples would be collected from a depth of 15 cm to characterize the cadmium levels of surface sediments. Samples would be evenly spaced across the DMCA, and they would be analyzed for cadmium concentration on a dry weight basis.

7.4.3.4 Cover/Cap Sampling

A cover/cap of sediments obtained from areas of the channel where concentrations of cadmium are believed to be 4 mg/kg or less would be placed on the cadmium-laden sediments in DMCAs 14A and/or 14B. Following placement of the cover, eighty-six (86) grab samples would be taken from a depth of 30 cm and analyzed for cadmium.

In summary, the District would sample the deposited cadmium-laden sediments when the DMCAs are still inundated. These grab samples would be collected to a depth of 15 cm. To speed the collection of the next round of sampling (after placement of the covering sediments), the District would also likely sample the completed cover when the DMCAs are still inundated. These grab samples would be collected to a depth of 30 cm. If the DMCA is drained and the sediments are allowed to dry, the cover sampling would still be taken to a depth of 30 cm.

7.4.3.4.1

If the analysis of the sediment samples taken from the cover indicates that concentrations of cadmium are less than 4 mg/kg, monitoring of the cover is complete.

7.4.3.4.2

If the analysis of the sediment samples taken from the cover indicate that concentrations of cadmium are equal to or exceed 4 mg/kg in a cumulative area of 25 acres (not necessarily contiguous) or more of the covering layer, then three actions would be required irrespective of when any additional cover is placed. In addition, if there is a concern about the number of birds or other animals or a particular species using the DMCA, then some type of hazing may be appropriate. Hazing techniques would require the approval of the USFWS prior to implementation. The three required actions are as follows:

1. The DMCA would be kept flooded to keep the sediments wet/moist.
2. The DMCA would receive a cover of O&M material at the earliest possible time. Once the layer of O&M material has been placed in the DMCA, the surface sediments (to a depth of 30 cm) will be sampled (86 grab samples) and analyzed for cadmium. The process of placing O&M material into the DMCA and testing

for cadmium would be repeated until cadmium concentrations in the surface sediments are less than 4 mg/kg.

3. Vegetative monitoring would begin.

7.4.3.5 Water Quality Monitoring Requirements for Cadmium-Laden Sediments

The effluent from all DMCA's would be monitored during dredging operations. The effluent from DMCA's 14A and/or 14B would be specifically monitored for cadmium levels. All DMCA 14A weirs discharge to the Savannah River. The main weir for DMCA 14B discharges to Fields Cut. It is possible that minor discharges to Wright River could occur from the other weirs in DMCA 14B. Cadmium concentrations in the effluents from DMCA's 14A and/or 14B from all weirs discharging at 0.1 cfs or greater would be monitored weekly. Should one of the constituents exceed State water quality standards, the additional sampling procedure outlined in the DEIS for sampling effluent during placement of sediment in DMCA's (Appendix M, 7.3.3) would be followed.

The District would perform a quarterly metals scan (including ammonia) on the cadmium-laden DMCA effluent at each outfall pipe discharging at 0.1 cfs or greater. This monitoring would cease one year after installation of the final cover unless a metal constituent is found to exceed chronic water quality criteria or standards. In that case, monitoring for metals would occur on a quarterly basis until no chronic criteria are violated at the outfall pipe for one year.

A copy of all sampling results will be provided to the USFWS.

Monitoring of the effluent from DMCA's 14A and/or 14B would continue as long as a discharge is present and until all sediments have been covered, dewatered, and stabilized. Following the installation of a clean cover, cadmium would be monitored in the effluent on a monthly basis for one year.

7.4.3.6 Other Monitoring Requirements

7.4.3.6.1

At the end of construction, sediment samples would be taken to 15 cm from the exposed river channel bottom sediment surface and analyzed for grain size and metals (including cadmium). This would provide an assessment of cadmium concentrations in sediment at the sediment-water interface that are exposed at the end of deepening, before normal sedimentation occurs.

7.4.3.6.2

As requested by Georgia DNR-EPD, sediment analysis would be required prior to maintenance dredging in channel reaches with cadmium-laden sediments. Samples are

to be taken and analyzed for cadmium from two locations for at least two maintenance dredging cycles and furnished to Georgia DNR-EPD at least 45 days prior to dredging.

Steve Calver
Biologist
Planning Division
U.S. Army Engineer District, Savannah
29 September 2008
Revised 20 October 2009
Revised 29 June 2010
Revised 22 June 2011
Revised 12 December 2011
Revised 26 January 2012, 7 March 2012

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SAVANNAH DISTRICT, CORPS OF ENGINEERS
100 W. OGLETHORPE AVENUE
SAVANNAH, GEORGIA 31401-3640

Programs and Project Management

MAY 5 2008

Ms. Donna Katula
Environmental Manager
International Paper
Post Office Box 570
Savannah, Georgia 31402

Dear Ms. Katula:

The US Army Corps of Engineers, Savannah District (USACE), is studying the feasibility of deepening the Savannah Harbor's 42-foot deep authorized navigation channel to as deep as 48 feet below Mean Lower Low Water (mllw). Our research indicates that the International Paper pipeline at harbor station 89+250 will retain 8 feet of clearance on the northern side of the channel after the channel is deepened. This clearance is based on the difference between the elevation of the pipeline as provided by your staff, and the maximum dredging depth of 13 feet below the existing 42-foot project depth. The maximum dredging depth includes 6 feet of deepening, 2 feet of advanced maintenance, 2 feet of allowable overdepth, and 3 feet of dredging disturbance.

The USACE has sought to determine if an adequate factor of safety would exist over the pipeline during deepening and future maintenance dredging. Based on the clearance that would remain and given our current dredging practices, the USACE will not require the pipeline to be removed. However, there may be other factors unknown to the USACE which may present risks that International Paper cannot accept.

Unless I am informed otherwise by your engineering staff, the project planning will move forward with consideration given to the best method for dredging over your utility line without damaging it. The USACE will specify that its contractors stay within prescribed limits as determined by as-built drawings provided by International Paper. If you desire further information on the Savannah Harbor Expansion Project please contact, Alan Garrett, Project Manager, at 912-652-5172.

Sincerely,

Peter A. Oddi, P.E., PMP
Deputy District Engineer for
Programs and Project Management



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MAY 5 2000

Programs and Project Management

Mr. Javier Garcia
Southern Natural Gas
Encroachment Coordinator
569 Brookwood Village
Suite 501
Birmingham, Alabama 35209

Dear Mr. Garcia:

The US Army Corps of Engineers, Savannah District (USACE), is studying the feasibility of deepening the Savannah Harbor's 42-foot deep authorized navigation channel to as deep as 48 feet below Mean Lower Low Water (mllw). Our research indicates that the Southern Natural Gas pipeline at harbor station 51+500 will retain between 9.0 to 10.5 feet of vertical clearance between the maximum proposed channel disturbance depth and the top of the southernmost pipeline. This clearance figure is based on the difference between the elevation of the pipeline as provided by your staff, and the maximum dredging depth of 17 feet below the existing 42-foot project depth. The maximum dredging depth includes 6 feet of deepening, 6 feet of advanced maintenance, 2 feet of allowable overdepth, and 3 feet of dredging disturbance. I understand that a similar clearance limit is also anticipated for your northernmost pipeline as both lines were installed in the same trench.

The USACE has sought to determine if an adequate factor of safety would exist over the pipelines during deepening and future maintenance dredging. Based on the clearance that would remain and given our current dredging practices, the USACE will not require the pipelines to be removed. However, there may be other factors unknown to the USACE which may present risks that Savannah Natural Gas cannot accept.

Unless I am informed otherwise by your engineering staff, the project planning will move forward with consideration given to the best method for dredging over your utility lines without damaging them. The USACE will specify that its contractors stay within prescribed limits as determined by as-built drawings provided by Savannah Natural Gas. If you desire further information on the Savannah Harbor Expansion Project please contact, Alan Garrett, Project Manager, at 912-652-5172.

Sincerely

Peter A. Oddi, P.E., PMP
Deputy District Engineer for
Programs and Project Management

A. Project Requirements

The Savannah Harbor Expansion Project is studying the feasibility of the deepening the Savannah Harbor navigation channel to as deep as -48 feet mllw. This maximum additional depth of 6 feet is accompanied by advance maintenance of up to 6 additional feet in areas of utility crossings. To avoid damaging any existing utilities which cross the navigation channel, it was necessary to determine a) the location, both horizontal and vertical, of the utilities and b) the amount of overburden required to provide an adequate factor of safety for the pipelines after deepening of the channel. Consideration was also given to future maintenance of the channel in the pipeline areas.

B1. Regulatory Agency Cover Requirements

Pipeline industry standards for clearance guidance stated that 4 feet of cover was required in areas of new pipeline placement (Pipeline and Hazardous Materials Safety Administration, DOT Rules and Regulations, section 192.327 Cover, paragraph (e)...**"all pipe installed in a navigable river, stream, or harbor must be installed with a minimum cover of 48 inches"**). The Engineering Research and Design Center (ERDC) Dredging Operations Technical Support (DOTS) program was also contacted to request the US Army Corps of Engineers (USACE) policy regarding dredging over pipelines. ERDC confirmed that no engineering design standard exists but it is noted that the Corps of Engineers Safety Manual (EM 385-1-1) stipulates that the Corps identify the location of utility lines and analyze the potential for damage due to marine activities. Once completed, recommended steps to prevent interference or damage will be specified.

B2. Research

All available District permits applicable to river crossings in the project area were collected. The results of this effort are documented in Table 1 and Appendix A. This effort helped to determine which areas had potential conflict with the harbor deepening based on as-built drawings on file with regulatory permits. In addition, a response was solicited from industries and property owners adjacent to the navigation channel by public notice (see Appendix B_XX?) in April 2007, informing them of the USACE's intention to study the proposed deepening of the harbor and inquiring to gather information on any existing or proposed utility crossings. The results of the investigation are as follows:

a) It was determined that Georgia Power crossings are all overhead lines and the former "in-channel" crossings discovered by research of district permit applications no longer exist.

b) It was determined that all underground utility crossings to Hutchinson Island at approximate Stations 68+000, 72+000, and 78+000 would not conflict with the proposed

deepened channel based on drawings received from Hussey, Gay, Bell & DeYoung.(see Appendix). The depths of these lines were 31, 33, and 23 feet respectively below the proposed channel bottom alleviating any concern for their safety.

c) Areas of potential conflict after channel deepening were confined to the Southern Natural Gas (SNG) pipelines at Harbor Station 51+500 (4.5 feet of clearance based on 1977 as-built drawings) and the International Paper (IP) pipeline at Harbor Station 89+250(8 feet of clearance). (Note: the amount of clearance is based on the difference between the elevation of the pipeline and the maximum dredging depth of 15 feet below the existing 42 foot project depth which includes 6 feet of deepening, advance maintenance(varies from 2 feet to 8 feet based on reach of channel), 2 foot allowable overdepth, and 3 foot dredging disturbance.(DOTS study – Appendix C)

The USACE met with local officials from SNG to present its concerns. The SNG representatives subsequently forwarded USACE provided drawings (Figure 1 and 2)of the area of concern to their parent company (Texas El Paso) in Birmingham, Alabama. SNG stated that they normally require at least 5 feet of cover over their pipelines. The issue was discussed with Mr. Lynn Roberts who is now the point of contact concerning their pipeline. He stated their intention to “pig” their two pipelines in late October. The “pig” is a remote controlled electronic inspection device for the pipeline which can also provide accuracy to within 1 meter of the location of the pipeline. Mr. Roberts stated in follow-up conversation in Oct 07 that he hoped to have accuracy within 1 foot with the hydrographic survey to be done in Oct 07 and “pigging” in December 2007.

In February 2008, the USACE received final results from SNG of the survey of their pipeline crossing done by T. Baker Smith in October 2007. After correspondence with T. Baker Smith in which accurate proposed channel location coordinates were provided and the difference in vertical datum was resolved, it was determined that there is between 9 to 10.5 feet of clearance between the maximum proposed disturbed channel depth and the top of the southernmost pipeline (Figure 3). The northernmost pipeline is scheduled to “pigged” in June to July 2008. Similar results are anticipated as both lines were installed in the same trench.

The USACE also contacted International Paper’s (IP) point of contact to advise them of plans for deepening the harbor. IP provided an electronic file showing a cross section of their pipeline. The USACE provided the design template for the deepened channel including disturbance depth on the cross section (Figures 4 and 5). To date, there has not been a follow-up response. Preliminary indications are that the IP pipeline will retain 8 feet of cover in addition to 3 feet allowed for dredging disturbance on the Northern side of the channel after Deepening.

C. Dredging Methodologies in Areas of Pipeline Crossing

When contacted about a USACE standard for dredging offsets over pipelines, ERDC suggested contacting the district offices in New Orleans and Mobile to inquire of their standards. It was also suggested that the Savannah District solicit industry’s input to determine their level of accuracy in dredging over pipelines. Industry input is summarized in the following paragraph.

Industry input

Conversation with Graham Payne/Norfolk Dredging revealed that his company routinely dredges within a 3-4 feet horizontal distance away from pipelines in Philadelphia District (Schuylkill River – 400 foot wide cut). The pipeline locations are well documented and the dredging firm takes precautions, (i.e., swing slow, cut off cutter-head over line, etc.) The dredge operator can tell when he is dredging over previously dredged material. This issue was also discussed with Armond Riehl/Great Lakes Dredge and Dock, Inc.. He stated that from his experience, the dredge can remove material within 5 foot vertical distance of a pipeline based on the distance between the overdepth prism and top of pipe. He also stated that if the dredge operator was not absolutely sure of the pipeline location he could also use the mechanical dredge to come within 25 feet of either side of the pipeline to remove material and recommended using suction without the cutterhead turning if material is soft over the pipeline

New Orleans District Input

Armond Riehl also referred to Bobby Guichet, of the New Orleans District who has a great deal of experience in dredging over pipelines having administered over a hundred contracts dealing with this issue in Mobile, Galveston, New Orleans, Vicksburg, and Philadelphia. He provided specifications listing necessary precautions involving dredging over pipelines and stressed the need to insure correct calibration of cutterhead positioning. He did express concern that we have to deal with greater tidal exchange than what he normally deals with on the Gulf coast. This fact complicates tidal height calculations in Savannah Harbor. Mr. Rick Broussard in the New Orleans district office was also contacted and from his experience in dredging over pipelines, dredging is usually limited to 10 feet below project grade or 8 feet below required depth with 2 feet for advance maintenance and allowing 1 foot for overdepth.

This equates to a 7 foot dredging tolerance over pipelines. He agreed with the tolerance of 8 feet being used for Savannah which includes 3 feet of dredging disturbance as part of the tolerance.

Savannah District Input

Engineering Division initially recommended dredging up to but not over the SNG pipeline and allowing river currents to remove remaining new work dredged materials. The same practice would apply to O&M dredging operations. This recommendation has been revised. Velocities were examined in vicinity of the SNG pipelines to determine if this approach was feasible as this is the current practice adjacent to Old Fort Jackson. Even though current velocities in the Old Fort Jackson reach are influenced by ebb tides coming out of the Back River, the current velocities near the SNG facility are similar.

Detailed investigations determined the velocities to be comparable in front of Old Fort Jackson (maximum bottom 1.4 – 1.8 fps, maximum surface 3.7 – 4.2 fps) and over the SLNG pipeline (maximum bottom 1.4 – 1.8 fps, maximum surface 3.7 – 4.5 fps). Maximum velocities over the International Paper pipeline were somewhat smaller (maximum bottom 1.6 fps, maximum surface 3.4 fps). These measurements suggested that it may be possible to provide adequate

depth over the SNG pipeline by dredging on either side of the pipeline and allowing the currents remove maintenance material similar to how the area in front of Old Fort Jackson is maintained.

However, additional research revealed that although the reach in front of Old Fort Jackson is not currently dredged as part of the maintenance contract, it was initially deepened to 44 feet by a cutterhead dredge. Dredge scars in the Miocene layer of clay are still visible in the Miocene material in photos taken by side scan sonar. Since these cuts are still evident and have not been "smoothed out" by currents, it is unwise to assume that currents are swift enough to remove deepening, new work materials. The clays of the Miocene layer are too stiff to be removed by anything other than mechanical equipment. The clays reside at elevation -45 feet to -47 feet MLLW in front of Old Fort Jackson and from -43 feet to -46 feet MLLW in the SNG pipeline area, and around -44 feet MLLW at the International Paper pipeline.

D. Risk Analysis/Areas of Concern

The USACE has sought to determine if an adequate factor of safety would exist over the pipelines after deepening in regard to dredging. Based on the factors used to determine the amount of clearance that would remain after deepening and current dredging practices in place, the USACE would recommend moving forward with the project without requiring the pipelines to be removed. However, other factors may still present a level of risk that industries may not be willing to accept. Risks that may be greater due to a reduction in the amount of overburden over the pipeline include:

- a) Ships that lose steering capability in the navigation channel must drop and/or drag their anchor in the navigation channel to maintain position. The amount of remaining cover over the pipelines may or may not be adequate to prevent possible damage should this occur in their vicinity.
- b) Although the USACE has confidence in industry recommendations as to the accuracy of the position of the dredge cutterhead in the dredging process, dredges work in a dynamic environment subject to waves and currents, which can result in dredge position errors. The exact locations of the pipelines is essential (both in the horizontal and vertical axes). Without this knowledge, there is a chance that the dredge could be out of position and spud down on top of the pipeline. (Spuds are 20 ton cylindrical tubes used as pivot points for dredge movement).
- c) Some question still remains as to the buoyancy of the IP pipeline and whether or not the pipeline would have a tendency to float as the amount of overburden is decreased. SNG has confirmed that their pipeline would not be impacted by a change in the amount of overburden as the original pipeline installation called for external concrete coating in a thickness and weight to bring the pipe to a negative buoyancy.

E. Mitigation During Construction

Based on the proximity to the pipelines, the USACE would specify the following constraints during construction dredging:

- a) Signs and ranges would indicate “no dredge” areas in the field and would be indicated on the drawings as well during construction and operations and maintenance (O&M) dredging
- b) SNG would be contacted in advance of dredging and advised to shut off flow of gas into pipeline and IP would also be notified of channel dredging activities.
- c) Cutterhead turning would be suspended within 25 feet of the pipelines and an attempt would be made to remove material using only suction from the dredge pump. If material is too difficult to remove over pipeline, the contractor may be required to incorporate clamshell operations to more safely remove material.

F. Conclusion/Recommendation

The process of dredging in the SNG and IP pipeline areas will follow the accepted practice of approaching utility crossings from both upstream and downstream without “spudding” or dredging directly over the pipelines. The Savannah District will specify strict adherence to these procedures and will specify that its contractors stay within prescribed limits as determined by as-built drawings provided by utility owners.

Engineering Division recommends adopting the current dredging policy in areas of concern by:

- 1) Not “spudding” over the pipelines but allowing dredging over and within the vertical limits established by construction (5 feet for gas pipeline).
- 2) Limiting the amount of advance maintenance in the affected areas to provide necessary clearance if the pipeline location falls within 5 feet of required clearance and use precautions listed above.
- 3) If new work material is unable to be removed by suction without turning the cutterhead, the contractor may have to employ mechanical dredge to initially remove material.

Attachments:

- Table of permit actions (Table 1)
- Correspondence related to pipeline research (Appendix A)
- Public notices, certified letter w/ dates, etc. (Appendix B)
- DOTS document on dredging disturbance (Appendix C)
- Plan view and cross section of LNG pipeline area (Figures 1-3)

Plan view and cross section of LP pipeline area (Figures 4-5)

Sedimentation Analysis

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Introduction

The Savannah Harbor deep draft navigation channel is located on the lower 21.3 miles of the Savannah River and 11.4 miles of channel through the ocean bar in the Atlantic Ocean, Figure 7-1. The shoaling in the upper 18 miles of the river channel is primarily silt and clay while the lower river channel has sand shoals derived from an ocean source.

In order to predict the effect of future channel depth increases on the shoaling, the effects of past construction activities were analyzed to gain an understanding of how the system responds to changes. This understanding of how the system responded to past changes was used as the basis to make predictions of future changes.

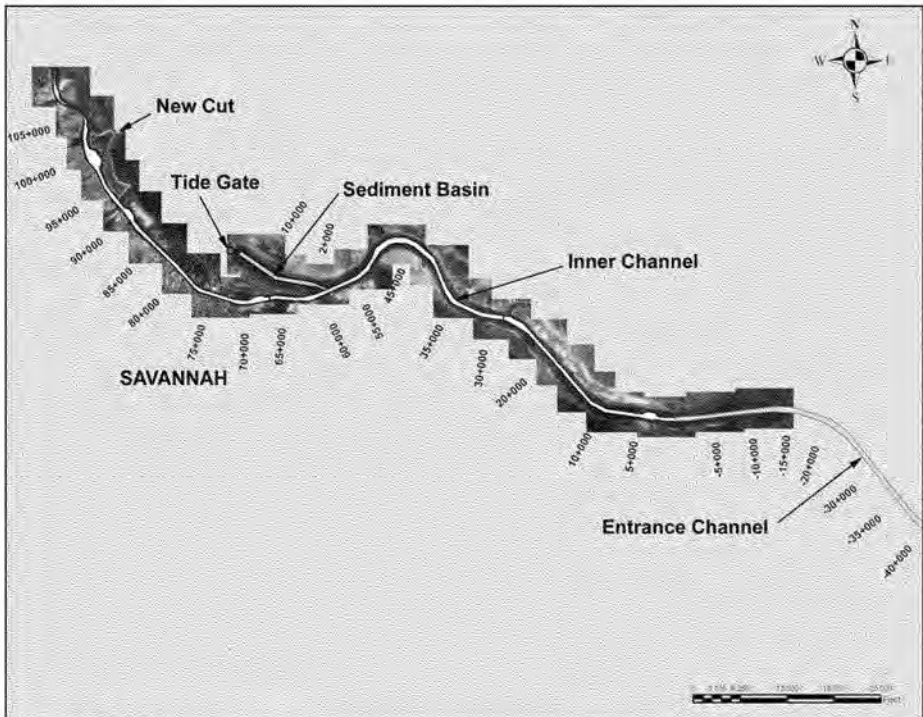


Figure 7-1 Savannah Harbor.

Above station 28+000, the inner harbor channel captures all of the clay and silt which enters the harbor from an upstream source. The amount of sediment entering the harbor is dependent on river discharge while current velocities and the location of the mixing zone between fresh and salt-water influence the distribution of the shoaling. Past channel depth increases have improved the channel conveyance to the point where the full tidal prism reaches the upstream limit of the harbor. The last channel deepening did not change the shoaling

volume or distribution. Since the channel already captures all of the sediment that enters the harbor, future depth increases will not increase the volume dredged in the channel. An additional feature of future channel deepening, which supports the prediction of no dredging volume increases is that the future depth increases will extend down along the existing channel side slopes. Deepening along the existing side slopes actually decreases the bottom width of the channel.

The inner harbor below station 28+000 to the mouth of the harbor shoals with material from an ocean source. The shoaling in the lower harbor did not increase after the last channel deepening and the shoaling is not predicted to increase due to future channel depth increases.

The entrance channel is a sediment sink that is a total interdiction of the littoral transport. Increases in depth will not increase the channel's ability to capture sediment. The average annual shoaling volume record did show an apparent increase in shoaling after the last deepening but this was due to the short post-deepening record not including both a high and low shoaling period as did the pre-deepening record. A small volume increase was predicted based on an increase in channel length.

Advance maintenance areas, with the exception of the Kings Island range, are generally allowing an annual maintenance cycle without unacceptably encroaching above the authorized channel depth. The shoaling pattern is not predicted to change with future depth increases and therefore present advance maintenance areas do not need to be shifted due to future depth increases.

7.2.3 Shoaling Conditions With and Without Project Conditions.

7.2.3.1 Inner Harbor

7.2.3.1.1 Sediment Sources.

The major sources of sediment to Savannah Harbor are the Savannah River and the offshore sediments carried into the harbor by tidal currents, Reference 2.1. The sediment supplied by the Savannah River is primarily fine silt and clay. An analysis of a suspended sediment sample taken at Clyo, GA is listed in Table 7-1. Clyo is located about 65 miles above the mouth of the Savannah River.

Clyo Sample	Sand Coarser than 0.074 mm	Silt	Clay
Flocculated	1%	17%	82%
Not Flocculated	5%	9%	86%

Table 7-1 Quantitative Analysis of Suspended Sediment at Clyo, GA. (Ref 2.1)

The bed load material transported by the Savannah River is deposited in the extreme upper reaches of the Savannah Harbor above station 103+000. The shoal material in these reaches are principally sand and account for no more than 5 % of the total volume material dredged from the harbor.

Grain size distributions for the inner harbor and entrance channel are listed in Table 7.2 and are displayed in Figures 7.2 and 7.3. The inner harbor sediments are primarily silts and clays from station 56+000 to station 103+000. The reach from station 25+000 to station 56+000 is a transition reach that has a higher percentage of sand in its distributions than the sediment distributions of the upstream reach. A notable exception is in the vicinity of station 36+000, which has a high percentage of silt and clay and almost no sand. This location is near the confluence of the inner harbor channel with both Elba Island and Fields Cuts. This location will have significance in the following dredging and velocity analyses. The inner channel sediment distributions from station 25+000 to the mouth of the Savannah River are primarily sand, which indicates that the source of sediment from this reach is offshore.

The upstream source of sediment for the upper river reaches and the ocean source for the lower river reach are consistent with the observation in Reference 2.8 that essentially all of the shoaling material from upstream sources is being trapped within the system.

The entrance channel sediments are primarily sand with exceptions between the jetties and at station 45+000, which have large silt and clay components.

ID	Station	Channel	% SAND	% SILT	% CLAY
NB-13 *	-45+000	Entrance	8.7	66.8	24.5
NB-12 *	-35+000	Entrance	83.9	0	16.1
NB-11 *	-25+000	Entrance	78.2	5.8	15.8
NB-10 *	-15+000	Entrance	67.1	12.3	20
NB-9 *	-5+000	Entrance	30.8	53	16
IH-8 *	5+250	Inner	94.4	4.4	0.3
IH-7 *	15+000	Inner	88.2	2	9.1
IH-6 *	25+000	Inner	93.7	0	2.5
IH-5 *	35+000	Inner	12.1	62.4	25.5
SH-7 **	36+000	Inner	0	65.3	34.7
IH-4 *	44+000	Inner	32.2	32.3	35
IH-3 *	55+750	Inner	27.2	45.5	27
SH-6 **	56+000	Inner	10.6	75.7	13.7
SH-5 **	61+500	Inner	13.4	53.5	33.1
IH-2 *	64+000	Inner	2.7	59.8	37.5
SH-4 **	67+250	Inner	78.4	13.5	8.1
IH-1 *	75+000	Inner	5.7	49.8	44.5
SH-3 **	90+000	Inner	9.6	55.6	34.6
SH-1 **	99+000	Inner	14.4	54	31.6
SH-8 **	2+750	Sediment Basin	17.5	49.4	33.1
SH-9 **	5+250	Sediment Basin	0	72.8	27.2
SH-10 **	8+000	Sediment Basin	0	66.9	33.1
SH-11 **	10+500	Sediment Basin	17.6	46.2	36.2

Table 7-2 Sediment Grain Size Distributions, *Reference 2.3 ** Reference 2.2

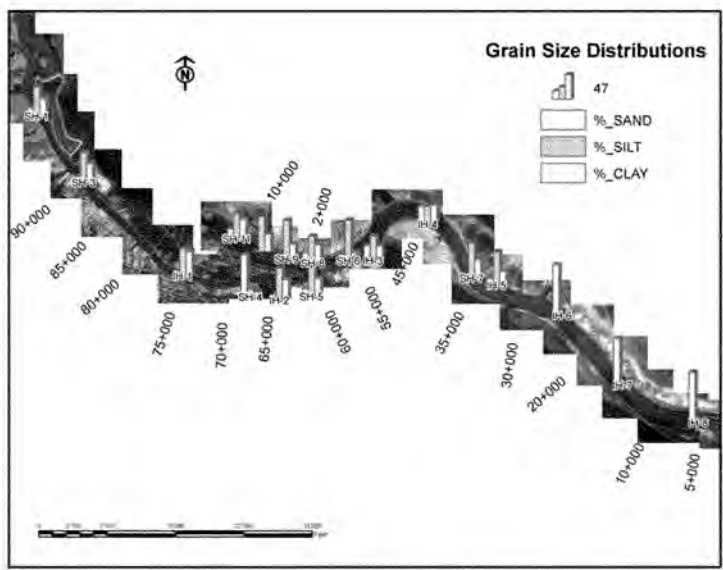


Figure 7-2 Inner Harbor Grain Size Distributions.

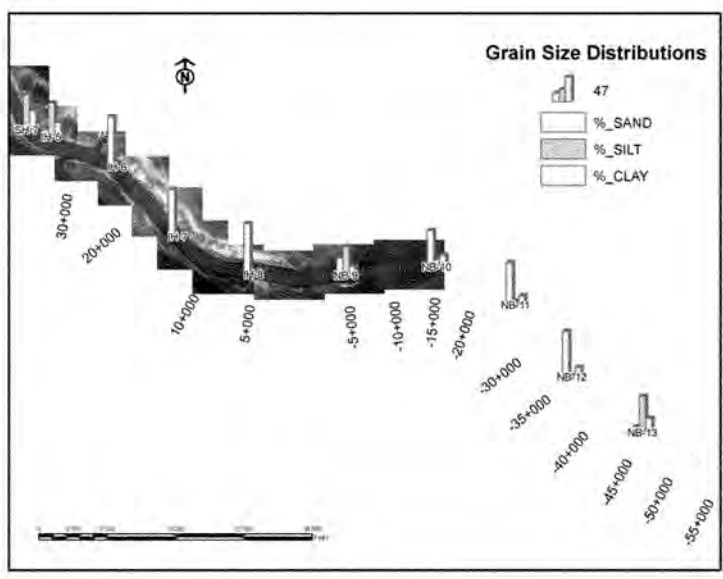


Figure 7-3 Entrance Channel Grain Size Distributions.

7.2.3.1.2 The Shoaling Process.

In the mid harbor reach, stations 28+000 to 67+000, and upper harbor reach, stations 67+000 to 103+000, silts and clays form low-density shoals in areas with low velocities or eddies. Areas with low velocities have low bottom shear stresses which allow deposition and the circular flow of the eddies promote flocculation and trap sediment. Salinity affected currents cause a flow converging area at the location of zero net bottom flow, which becomes an area of high shoaling. The salinity effects also cause the bottom flows in the lower harbor reach to have a net upstream flow, which traps ocean derived sand.

The source of shoaling material in the upper and mid reaches of the harbor is silt and clay eroded by rain runoff in the piedmont. The clay particles have a negative charge and a diffuse layer of positive ions surrounds the particle. The diffuse layer that surrounds the clay particles makes them mutually repulsive. The individual clay particles have an extremely slow settling rate, which allows them to travel hundreds of miles downstream from the piedmont to the estuary. The saline water of the estuary has a high ionic concentration, which compacts the diffuse layer and allows the particles to come closer together. When the particles enter a mixing flow they collide and the attractive forces, which exist between all colloidal particles (van der Waals' forces), enables the particles to form aggregates. The aggregates can become relatively large and settle rapidly. When the aggregates are carried to areas with weak currents, they form low-density shoals. These shoals are more than 80% water, Reference 2.1. The delicate structure of the aggregates and low density of the shoals make them responsive to the strength of the flow velocities. An area that has weak currents or eddies will be high shoaling area and an area of strong currents will be a low shoaling area. The nature of these low-density shoals can make volumetric analysis of shoaling patterns difficult. If a low-density shoal were disbursed and the aggregates broken up, new shoals that form from the shoal material could be denser or so thinly spread out that they are not recorded at all.

Savannah Harbor is in a partially mixed estuary in which the vertical mixing of salt and freshwater is not complete over the length of saltwater intrusion, Reference 2.8. Surface salinities are appreciably less than the bottom salinities and there is a large zone of mixing between fresh and saltwater. Seaward of this mixing zone, the net bottom flow over a tidal cycle is upstream. Landward of this mixing zone, the net bottom flow is downstream. The converging bottom flows carries shoaling material to the location of no net bottom flow, which tends to be an area of high shoal volumes.

Shoaling in the Savannah inner harbor channels below station 28+000 is due to sand carried into the channel from the ocean by the strong bottom flood currents. The shoal material in the lower river is almost entirely sand while the shoal material upstream of station 28+000 is silt and clay, Figure 7-2. The sand is deposited during slack tide and the weaker bottom ebb currents cannot carry the

sand back to the ocean source. Results from the physical model tests, Reference 2.5, indicate that the bottom flood currents at station 4+000 are a foot per second faster than the bottom ebb currents and that the net bottom flow in the lower portion of the harbor is upstream.

7.2.3.1.3 Major Construction Activities

The major construction activities that have influenced shoaling in Savannah harbor since 1975 are listed in Table 7-3.

Activity	Date
New Cut Opened	1975
Kings Island Turning Basin Enlarged	1976
Tide Gate Begin Operation	1977
Sediment Basin - Maintenance	1977
Tide Gate Ceased Operation	1991
New Cut Closed	1992
Savannah Harbor Widening	1990 - 1992
Savannah Harbor Deepening 38 ft to 42 ft.	1993 - 1994
Advance Maintenance	Sporadic Implementation

Table 7-3 Major Construction Activities.

7.2.3.1.3.1 New Cut, Tide Gate and Sediment Basin

The first three activities of opening New Cut, operation of the Tide Gate, and construction of the Sediment Basin were components of a plan to reduce the annual cost of maintenance for the harbor and provide better maintained navigation channels, Reference 2.4. These three construction activities increased the bottom velocities in front channel by as much as 3 feet per second and initially trapped 2.8 million cubic yards of sediment in the Sediment Basin.

The location of the Sediment Basin, the Tide Gate and New Cut are shown on Figure 7-1. The Tide Gate consisted of 14 flap gates across a 600-foot span. It allowed flow to pass through the gates on the flood tide into Back River, Figure 7-4, and prevented the flow from passing through the gate on ebb tide.

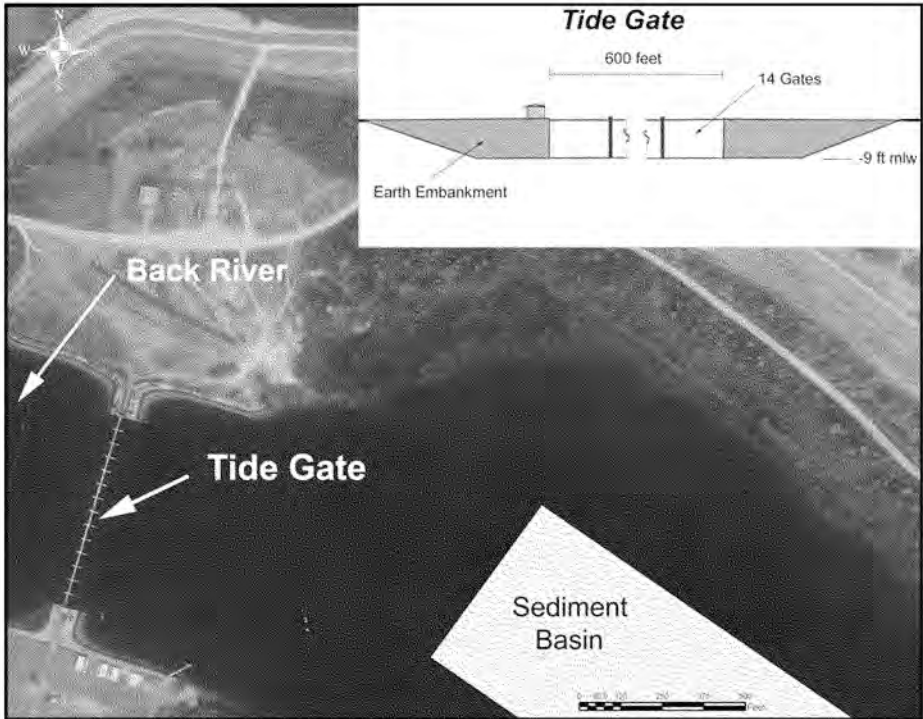


Figure 7-4 Tide Gate.

The Back River tidal prism was forced to flow out through New Cut into the inner harbor channel. New Cut had a width of 300 feet and a depth of 15 feet.

Physical model tests for the design of the Tide Gate were conducted at the U. S. Army Engineer Waterways Experiment Station and Figures 7-5 through 7-7 are results from those tests, Reference 2.1. Figure 7-5 is a drawing of a plan similar to the one constructed but with the Tide Gate located further upstream. Plots of model velocities indicate that the bottom flows in the inner harbor channel upstream of the confluence with the Sediment Basin increased from 1.5 feet per second at station 95+000, Figure 7-6, to 3.0 feet per second at station 74+000, Figure 7-7.

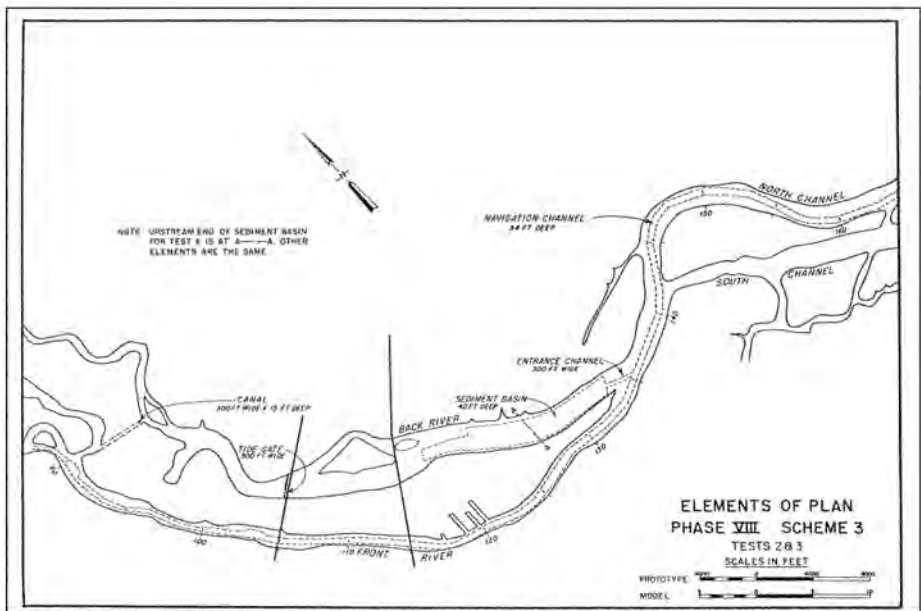


Figure 7-5 Physical Model Test Scheme for a Tide Gate, Drainage Canal, and Sediment Basin.

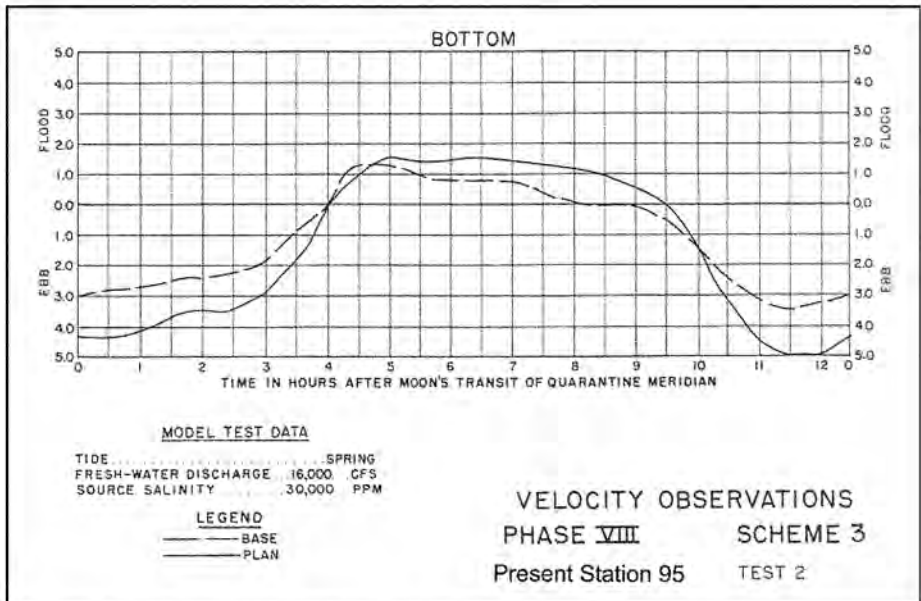


Figure 7-6 Velocity Observations Station 95+000.

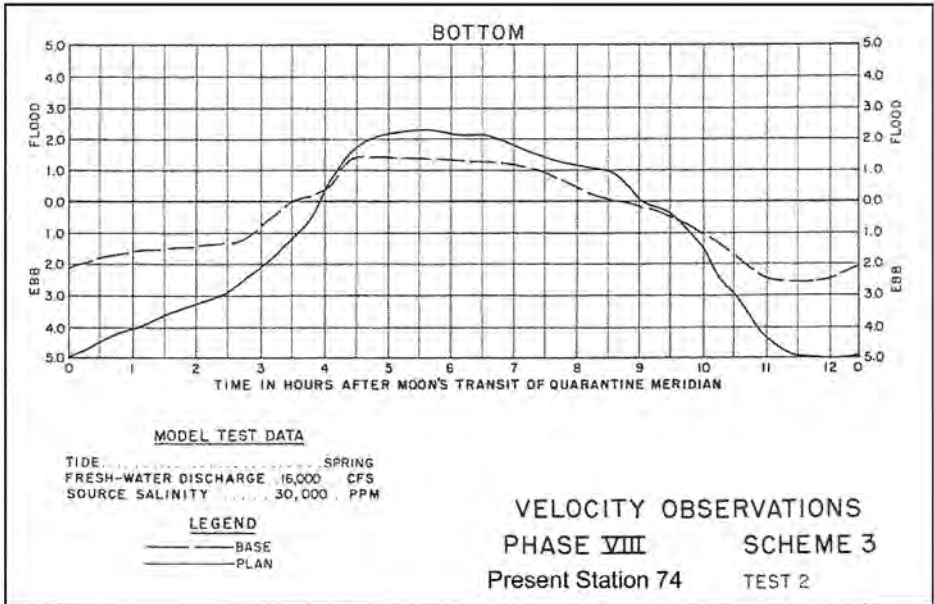


Figure 7-7 Velocity Observations Station 74+000.

The velocities below the confluence of the inner harbor channel and the Sediment Basin responded with smaller increases of 0.5 feet per second at station 51+000, Figure 7-8, and a decrease of 1.0 feet per second at station 41+000, Figure 7-9.

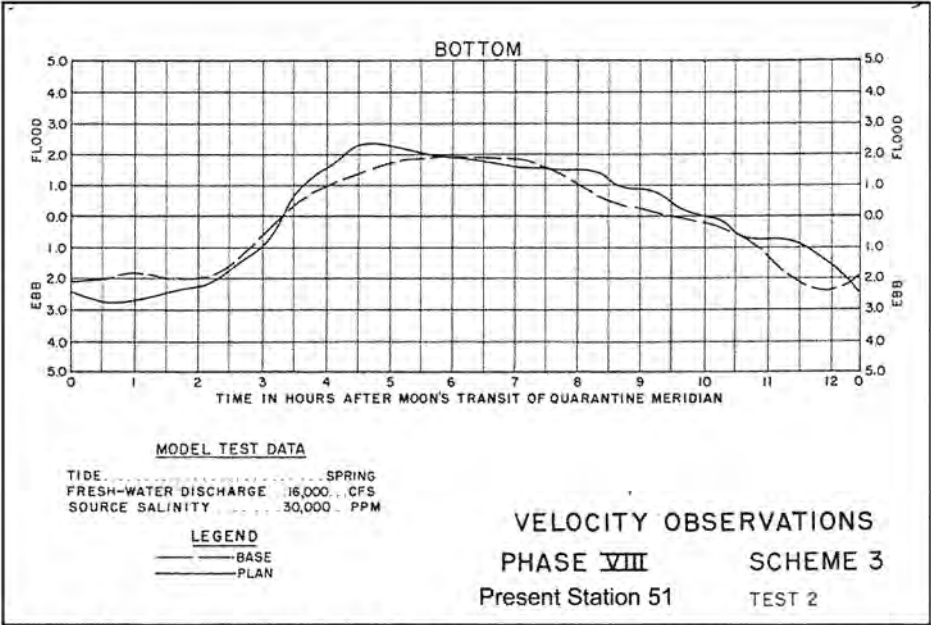


Figure 7-8 Velocity Observations Station 51+000.

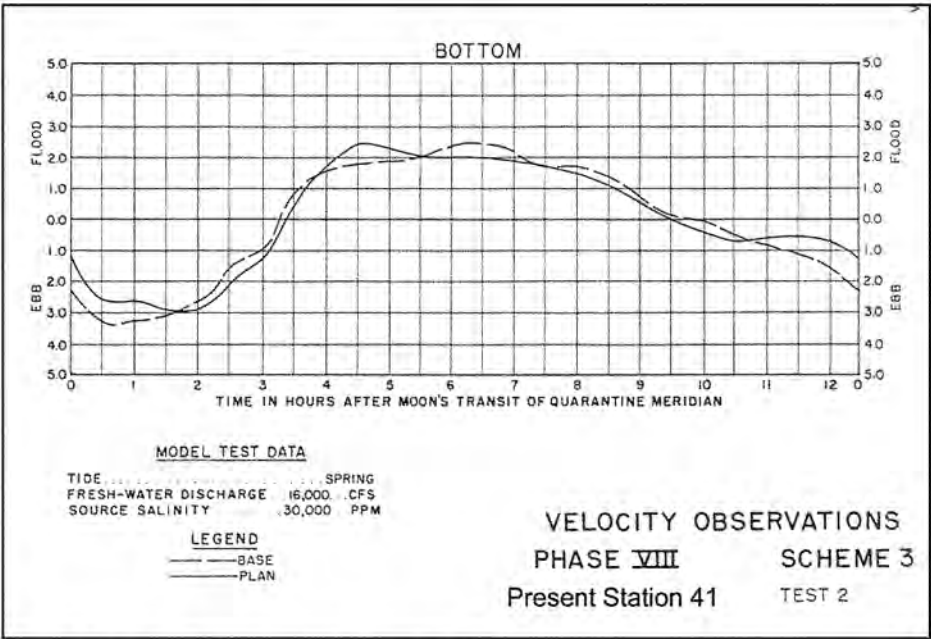


Figure 7-9 Velocity Observations Station 41+000.

The Sediment Basin, Figure 7-10, consists of an entrance channel, which is 1,600 feet long and 300 feet wide. The entrance channel depths vary from -38 feet mlw at the entrance to -40 feet mlw in the trap. The sediment trap is 2 mile long and 600 feet wide. The Sediment Basin was initially dredged in 1972 but regular maintenance of the Sediment Basin did not begin until 1977. Physical model tests were performed prior to construction to determine the effectiveness of the Sediment Basin, Reference 2.5. The plan tested is shown in Figure 7-11. Note that the stations shown are different from those that are presently in use. The old stationing decreased in an upstream direction and the confluence of the Sediment Basin with the inner harbor channel was approximately at old station 134+000.

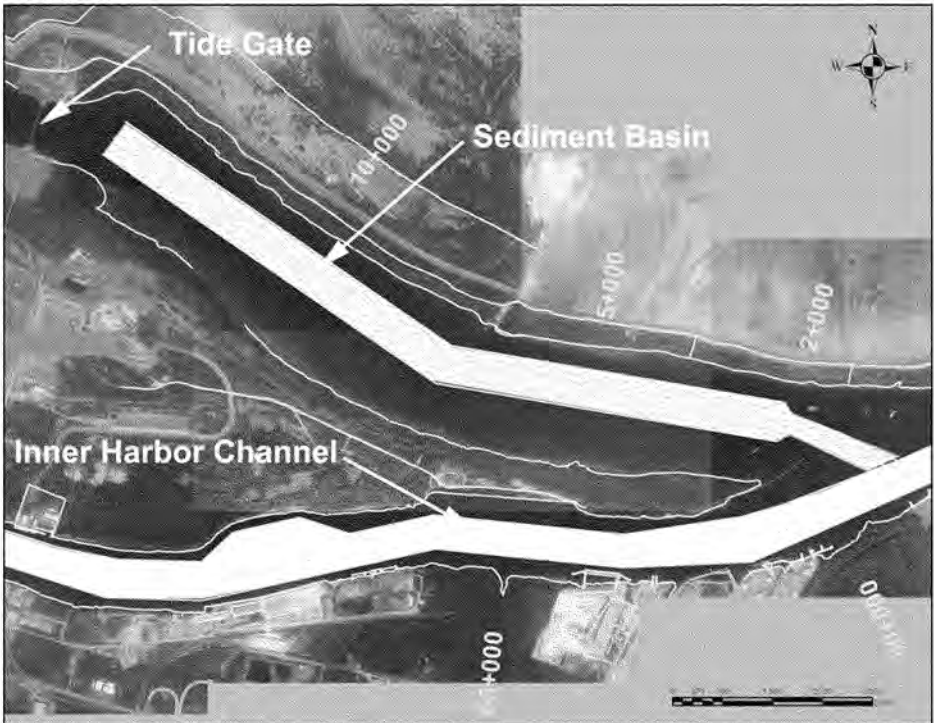


Figure 7-10 Sediment Basin.

The shoaling tests were conducted using gilsonite as a model shoaling material. One third of the shoaling material was introduced into Front River above the old station 143+000 and the remainder was introduced below station 143+000. The results of the test after 29 tidal cycles are shown in Figure 7-12. There was a large reduction in the shoaling in the upper reaches where the current velocities had increased due to the operation of the Tide Gate. The reduction in the mid-river reaches was not proportionately as large. A second test was performed for

119 tidal cycles and the result from this test is shown in Figure 7-13, Reference 2.7. For the longer duration test, there was a large reduction of shoaling in the mid-river reaches and an increase in shoaling in the Sediment Basin. This result indicates that the Sediment Basin is acting as filter for the mid-river reaches, which continues to trap sediment for months after the sediment is initially carried into the harbor.

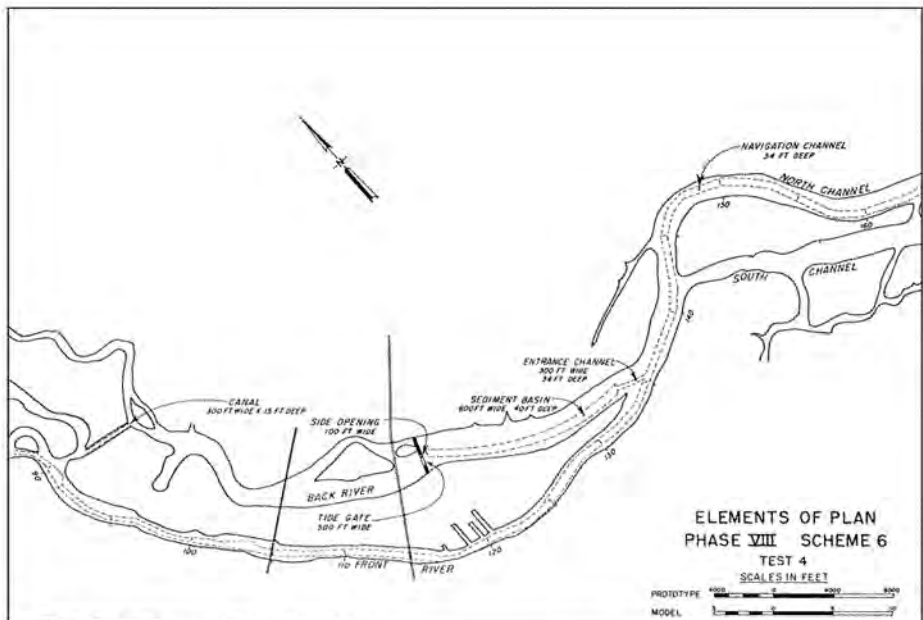


Figure 7-11 Sediment Basin Test Plan.

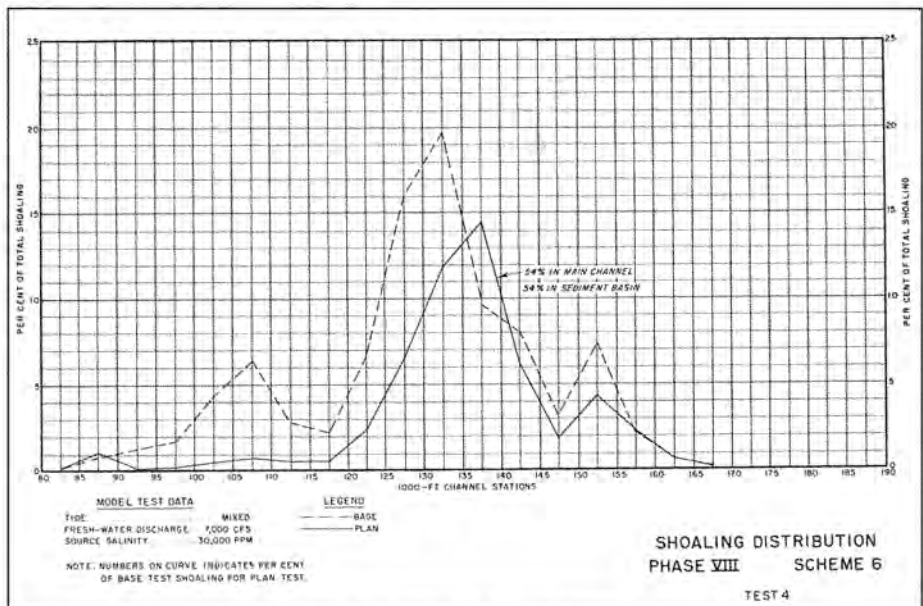


Figure 7-12 Result of the Shoaling Test After 29 Tidal Cycles.

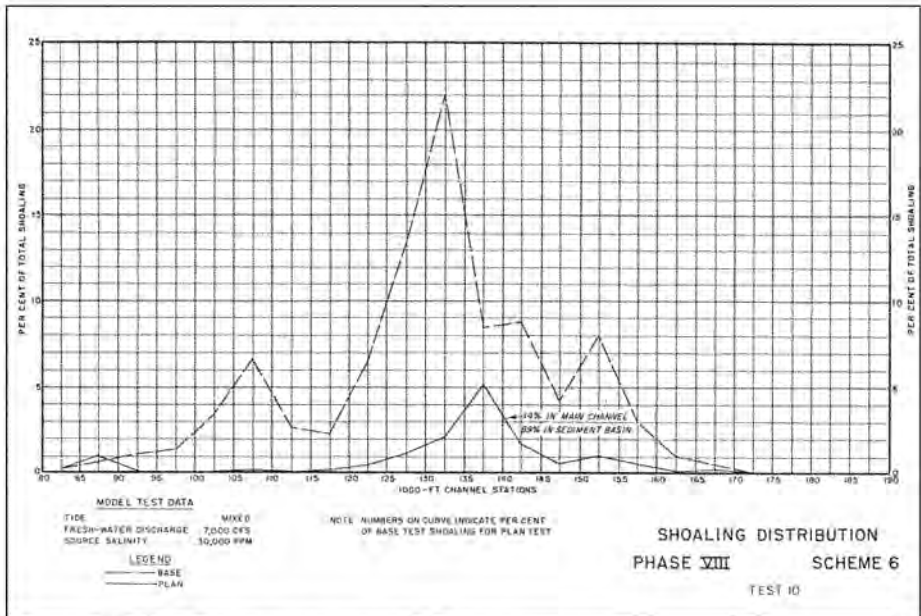


Figure 7-13 Shoaling Test Results After 119 Tidal Cycles.

As part of a Section 1135 project to restore the fresh water plant species and associated fish and wildlife populations in the Savannah National Wildlife Refuge, operation of the Tide Gate ceased in 1991, New Cut was closed in 1992 and the tide gates were removed in 1996. These actions should have reduced the current speeds in the upper reaches of the inner harbor channel to strengths near the pre-1977 values.

7.2.3.1.3.2 Kings Island Turning Basin Enlarged

In 1976, the Kings Island Turning Basin was increased from 900 x 1,000 feet to 1,500 x 1,600 feet, which more than doubled its size.

7.2.3.1.3.3 Savannah Harbor Widening

Between 1990 and 1992 the navigation channel was widened from 400 to 500 feet between Fig Island Turning Basin (Station 70) and Kings Island Turning Basin (Station 100).

7.2.3.1.3.4 Savannah Harbor Deepening 38 ft to 42 ft

Under WRDA 1992, the authorized depth in the entrance channel was increased from 40 feet to 44 feet and the inner harbor authorized depth between Stations 0+000 and 103+000 was increased from 38 feet to 42 feet. Construction was completed in June 1994.

7.2.3.1.3.5 Advance Maintenance

Over the years, advance maintenance changes to the Savannah Harbor Project have been implemented sporadically. Table 7-4 lists the present advance maintenance sections.

BEGIN STATION	END STATION	AUTHORIZED ADV. MAINT. (FT)	REQUIRED CONTRACT DEPTH (FT, MLLW)
Inner Harbor			
112+500	105+500	2.0	32.0
105+500	103+000	2.0	38.0
103+000	102+000	0.0	42.0
102+000	100+000	2.0	44.0
100+000	79+600	2.0	44.0
79+600	70+000	2.0	44.0
70+000	50+000	4.0	46.0
50+000	37+000	4.0	46.0
37+000	35+000	6.0	48.0
35+000	24+000	4.0	46.0
24+000	0+000	2.0	44.0
Port Wentworth TB		0.0	30.0
Argyle Is TB		0.0	30.0
Kings Is TB		8.0	50.0
Marsh Is TB		0	34.0
Fig Is TB		4.0	38.0
Entrance Channel			
0+000	-14+000(B)	2	44.0
-14+000(B)	-60+000(B)	0	44.0

Table 7-4 Advance Maintenance Locations.

7.2.3.1.4 Shoaling Response to Major Construction Activities

7.2.3.1.4.1 Shoaling Response to New Cut, the Tide Gate, and the Sediment Basin

To determine the shoaling response to past construction activities in Savannah Harbor, the dredging records going back to 1970 were analyzed. The construction of New Cut and the Tide Gate decreased the shoaling in the upper river reach by increasing the velocities and shifting the location of the no net bottom flow into the mid-river reach. Some of the shoaling decrease in the mid-

river reach due to the Sediment Basin was offset by the increase in shoaling associated with the location of no net bottom flow being shifted into the reach. The lower river reach, which accounts for 5 to 10% of the inner harbor shoaling and is controlled by sediment transport from the ocean showed a slight increase in shoaling. The total inner harbor shoaling showed a decrease from the pre construction period to the post construction period due to a decrease in river discharge.

The annual volume dredged, as calculated from the dredging records, is plotted in Figure 7-14. The gap in the record is due to the new work dredging associated with the harbor deepening from 38 to 42 feet mhw. A 3-year moving average has been applied to the data to smooth out variations due to dredging contracts spanning more than one year. The smoothed data shows a range of annual dredged volumes from 3 to 9 million cubic yards. To help explain some of the variations in dredged volumes the average

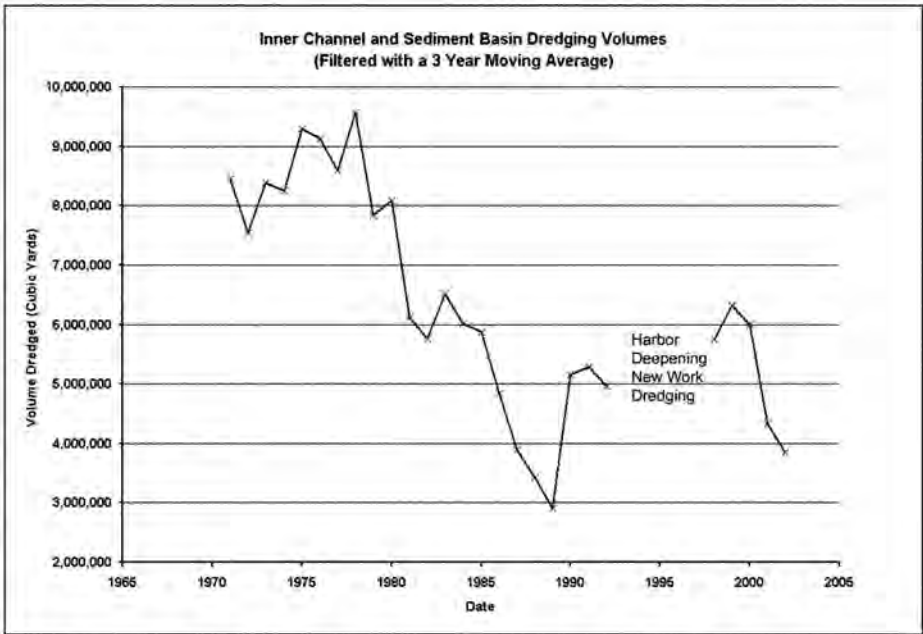


Figure 7-14 Inner Harbor Channel and Sediment Basin Annual Dredge Volumes.

annual stream flow discharge at Clio, GA was plotted along with the average annual dredge volumes in Figure 7-15. It is apparent from the plot that the annual volume dredged rises and fall with the annual river discharges. The annual volume dredged versus annual river discharge is plotted in Figure 7-16 and listed in Table 7-5. The plot of volume dredged versus discharge contains widely dispersed data points. The R squared values for the linear and power

trend lines fitted to the data indicate that less than half of the variation in the volume dredged can be attributed to river discharge.

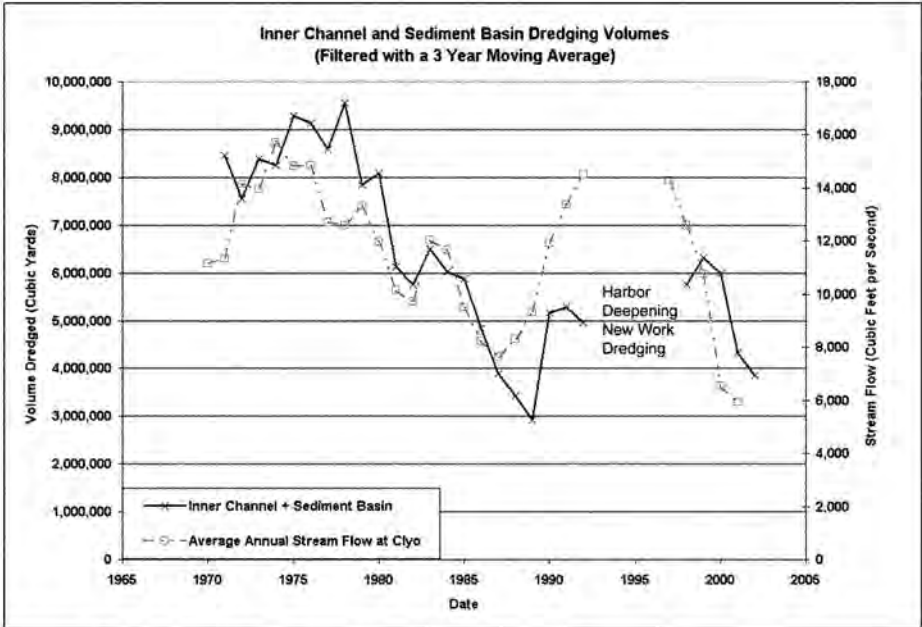


Figure 7-15 Dredged Volumes and River Discharge.

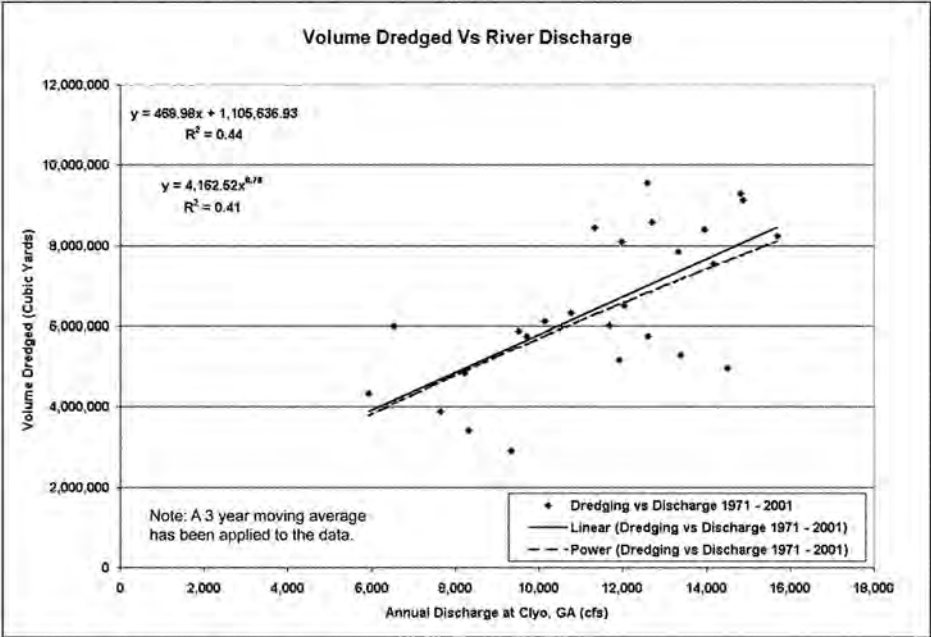


Figure 7-16 Volume Dredged Versus River Discharge.

Year	Annual Discharge at Clio, GA (cfs) *	Annual Volume Dredged (Cubic Yards)*
1971	11,323	8,448,212
1972	14,163	7,547,415
1973	13,953	8,390,344
1974	15,697	8,245,671
1975	14,810	9,293,157
1976	14,860	9,131,699
1977	12,700	8,587,769
1978	12,577	9,565,055
1979	13,320	7,842,043
1980	11,979	8,086,702
1981	10,137	6,121,163
1982	9,703	5,758,349
1983	12,038	6,508,602
1984	11,685	6,023,986
1985	9,501	5,876,340
1986	8,208	4,845,292
1987	7,644	3,891,766
1988	8,313	3,421,242

1989	9,333	2,913,855
1990	11,908	5,157,454
1991	13,373	5,281,491
1992	14,507	4,957,658
1998	12,593	5,754,487
1999	10,760	6,318,380
2000	6,541	5,999,601
2001	5,921	4,323,270
		*Moving Average Applied.

Table 7-5 Annual River Discharge and Annual Volume Dredged.

To aid in identifying changes in the dredging record that can be attributed to construction activities, the annual volume dredged in the Sediment Basin is separated out from the inner harbor dredging volumes and the average annual dredging distribution was calculated for periods before and after construction. The volumes dredged from the inner harbor channel and the volumes dredged from the Sediment Basin are plotted separately in Figure 7-17 as unfiltered data and in Figure 7-18 as filtered data. The averaged data is listed in Table 7-6. The unfiltered data has large yearly fluctuations, which can be attributed to parts of separate dredging operations being performed in the same calendar year, while the averaged data is smoothed and it is easier to see trends. Of interest in Figure 7-18 is that from 1975 to 1977 the volume dredged in the inner harbor decreased by over 3 million cubic yards while the combined volume dredged in the inner harbor and Sediment Basin followed a gradual decrease that coincided with the declining river discharge. The period 1975 to 1977 is the same time period that New Cut, the Sediment Basin and the Tide Gate became operational and the decrease in channel shoaling and the lack of a decrease in total shoaling reflects the successful shift of shoaling from the channel to the Sediment Basin.

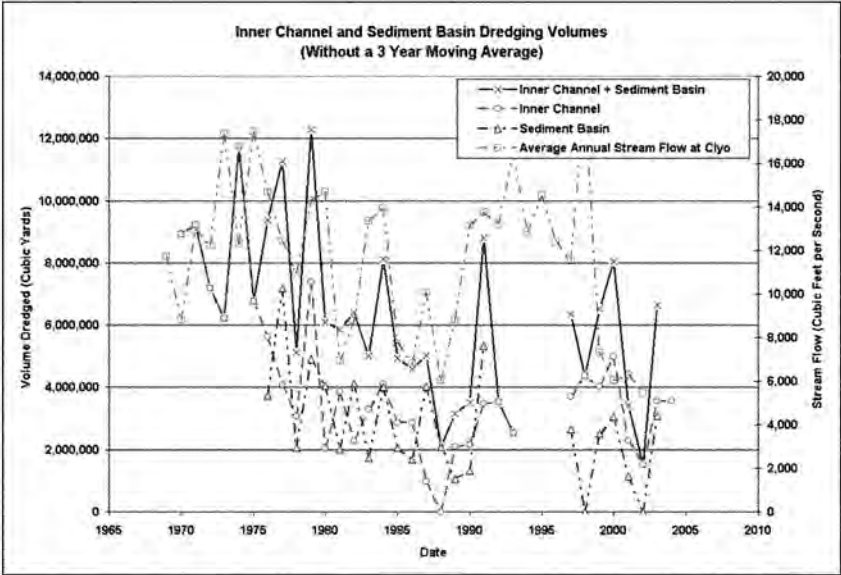


Figure 7-17 Inner Harbor and Sediment Basin Dredging Volumes without a 3-Year Moving Average.

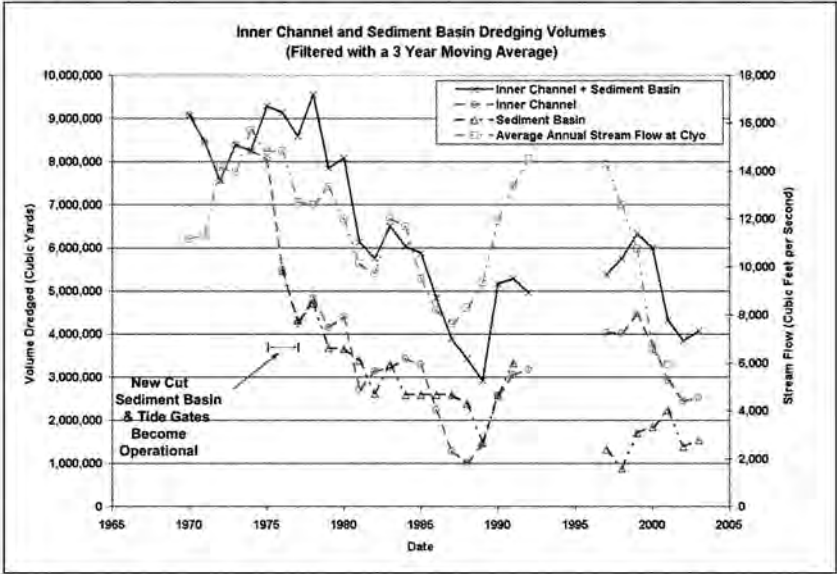


Figure 7-18 Inner Harbor and Sediment Basin Dredging Volumes with a 3-Year Moving Average.

Year	Inner Channel	Sediment Basin	Total	Discharge
1970	9,073,965	-	9,073,965	11,156
1971	8,448,212	-	8,448,212	11,323
1972	7,547,415	-	7,547,415	14,163
1973	8,390,344	-	8,390,344	13,953
1974	8,245,671	-	8,245,671	15,697
1975	8,046,098	-	9,293,157	14,810
1976	5,490,999	5,461,050	9,131,699	14,860
1977	4,260,213	4,327,556	8,587,769	12,700
1978	4,844,191	4,720,863	9,565,055	12,577
1979	4,162,833	3,679,209	7,842,043	13,320
1980	4,421,446	3,665,256	8,086,702	11,979
1981	2,719,019	3,402,144	6,121,163	10,137
1982	3,133,631	2,624,718	5,758,349	9,703
1983	3,219,862	3,288,740	6,508,602	12,038
1984	3,421,527	2,602,459	6,023,986	11,685
1985	3,286,302	2,590,038	5,876,340	9,501
1986	2,243,737	2,601,555	4,845,292	8,208
1987	1,286,672	2,605,094	3,891,766	7,644
1988	1,023,680	2,397,562	3,421,242	8,313
1989	1,420,997	1,492,858	2,913,855	9,333
1990	2,580,020	2,577,434	5,157,454	11,908
1991	3,058,664	3,334,240	5,281,491	13,373
1992	3,178,568	-	4,957,658	14,507
1993	-	-	-	14,203
1994	-	-	-	14,630
1995	-	-	-	13,240
1996	-	-	-	12,800
1997	4,033,331	1,329,811	5,363,142	14,280
1998	4,031,815	886,540	5,754,487	12,593
1999	4,462,466	1,722,671	6,318,380	10,760
2000	3,765,651	1,855,915	5,999,601	6,541
2001	2,925,451	2,233,950	4,323,270	5,921
2002	2,447,147	1,397,819	3,852,376	5,868
2003	2,532,901	1,540,792	4,073,693	-

Table 7-6 Inner Harbor, Sediment Basin Dredging Volumes, and Discharge at Clio with a 3-Year Moving Average.

In addition to the shift of shoaling from the inner harbor channel to the Sediment Basin, there was shift in shoaling distribution within the inner harbor channel. A plot of the volume-dredged distribution in the inner harbor for periods before and after New Cut, the Sediment Basin and the Tide Gate became operational is presented in Figure 7-19. The before period was chosen to be 1970 to 1975, which was the period for which dredging data was available prior to the

construction activities. The after period was chosen as 1981 to 1985. From Figure 7-18, it can be seen that in 1981 the rapid decline in volume dredged stabilized and after 1985 there was a drought, which greatly reduced the volume dredged. The volume-dredged distribution can be divided into three regions. (1) The upper river region, upstream of station 67+000, is characterized by turning basins in which large volumes of sediment are dredged. The total volume dredged from this reach for the 1970 to 1975 period is 3,982,000 cubic yards, Figure 7-20, and the shoaling material in this reach is primarily silts and clays. (See Figure 7-2)

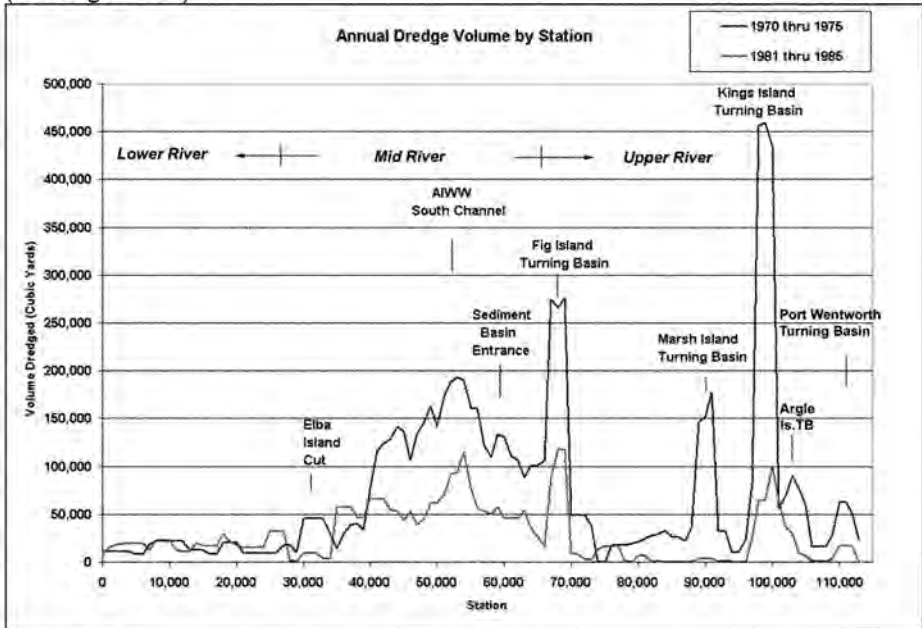


Figure 7-19 Annual Volume Dredged by Station 1970 thru 1975 and 1981 thru 1985.

(2) The mid-river reach is from station 28+000 to 67+000 and it shoals with a mixture sand, silt and clay. The total volume for this reach for the 1970 to 1975 period is 3,972,000 cubic yards and is approximately equal to the volume dredged from the upper river reach. The location of the highest volume dredged in the mid-river reach is at station 53+000, which is the confluence of the AIWW South Channel with the inner harbor channel. This reach also contains the entrance to the Sediment Basin.

(3) The lower river reach, which is downstream of station 28+000 to the mouth of the Savannah River, is characterized by a relatively low volume dredged, 409,000 cubic yards. The sediment is primarily sand, and as discussed in section 7.2.3.1.1 the source of the sediment is off shore.

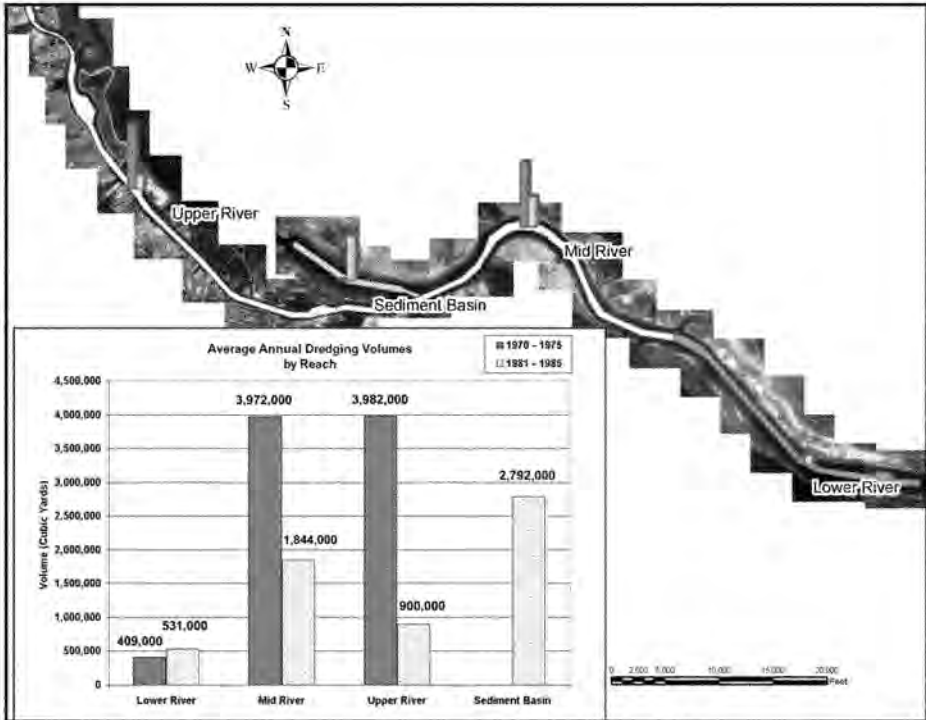


Figure 7-20 Average Annual Dredge Volumes by Reach 1970 to 1985.

The changes in volume dredged by station from the period 1970 through 1975 to the period 1981 through 1985 are plotted in Figure 7-21. The upper river reach had a general decrease in the volume dredged with major reductions occurring in the turning basins. The one area that did not show a decrease in the upper river reach was around station 75+000. A possible explanation for the localized increase is the agitation dredging performed by Savannah Marine Services, which may have increased the shoaling in this area. Unfortunately, quantitative agitation dredging records are unavailable for this time period and this explanation cannot be confirmed. There are two factors that contributed to the general decrease in the upper river dredge volume. First is the 1.5 to 3.0 feet per second increase in the current speed due to the opening of New Cut and the operation of the Tide Gate, section 7.2.3.1.3.1. The higher velocities would have re-suspended the low density shoals and kept the sediment in suspension until it reached a lower energy environment where it could be deposited and not re-suspended. The second factor is the location of zero bottom flow predominance. Partially mixed estuaries like the Savannah River Estuary have a transition zone between fresh and saline water. The net bottom flow downstream of the transition zone is upstream and the net bottom flow upstream of the transition zone is downstream. The converging bottom flows carry sediment to the location

of the transition zone or zero net bottom flow, which has been shown in References 2.8 and 2.9 to be associated with the region of heaviest shoaling. The model tests that were conducted for the design of New Cut and the Tide Gate indicated that these features would push the location of zero net bottom flow downstream. Documentation for the physical model tests are contained in Reference 2.7, and test results are shown for a plan similar to the one constructed in Figure 7-22. The test results show that the opening of New Cut and operating of the Tide Gate pushed the location

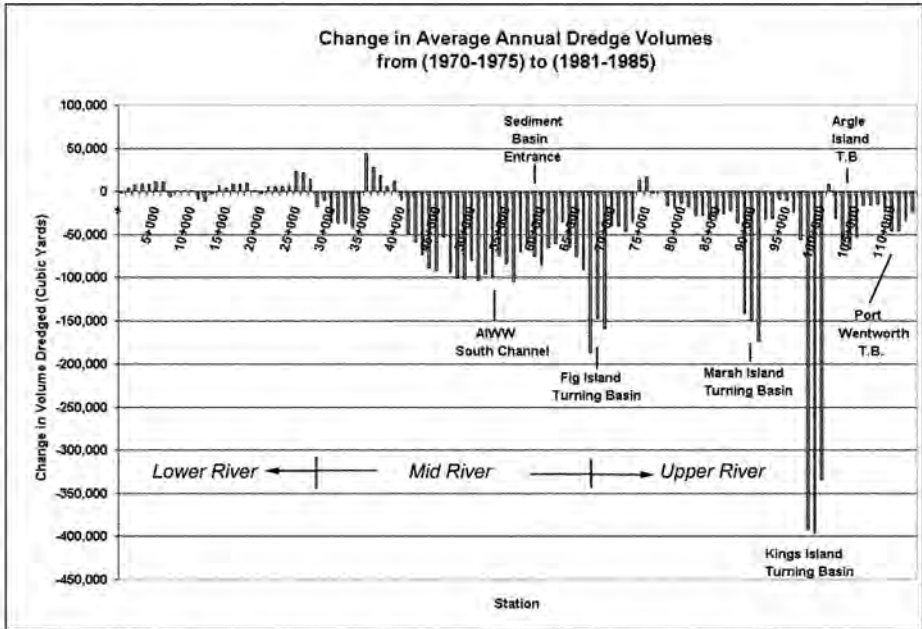


Figure 7-21 Changes in Average Annual Volume Dredged by Station from 1970-1975 to 1981-1985.

of zero net bottom flow from around station 77+000 in the upper river reach to about station 60+000 in the mid-river reach. Stations 77+000 and 60+000 in the present stationing corresponds to stations 116+000 and 133+000 in the old stationing used in the model tests. The shift in zero net bottom flow is in agreement with the measured 10,000-foot shift in Front River of the poorly defined saltwater wedge caused by the operation of the Tide Gate, Reference 2.6. The shift in zero net bottom flow from the upper river reach to the mid-river reach would have been expected to be accompanied by a shift in shoaling from the upper river reach to the mid-river reach.

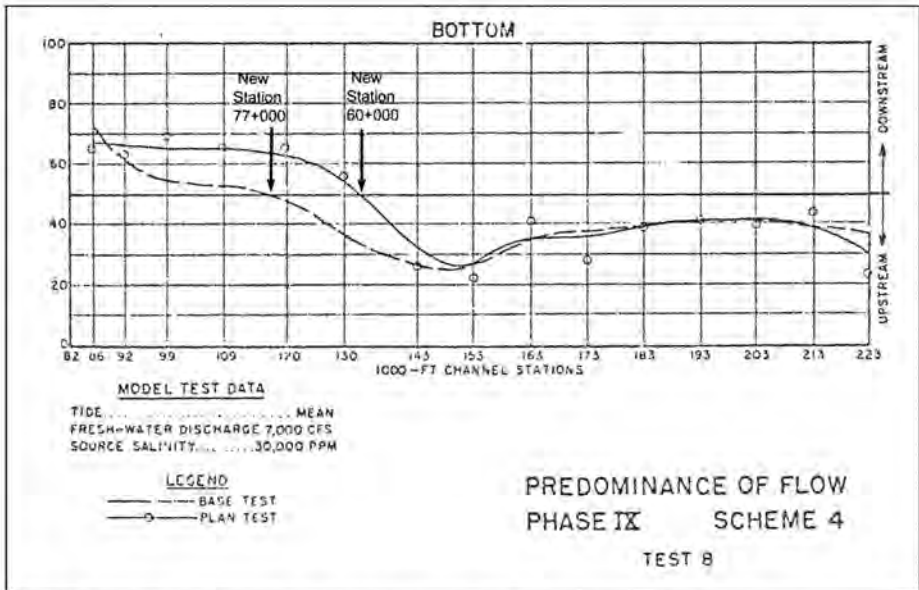


Figure 7-22 Shift in Zero Net Flow Location for the Tide Gate and New Cut Plan.

However, even with the shift in shoaling from the upper river reach to the mid-river reach, the mid-river reach exhibited a general decrease in the volume dredged due to sediment being trapped in the Sediment Basin. One exception to the general decrease in dredging was between stations 35+000 to 39+000. In the sediment source section 7.2.3.1.1, the sediment samples taken in this area had high silt and clay components which defied the along channel trend of higher sand components. The shoaling in this area does not conform to the along channel trends because it is controlled by the converging flows of multiple channels since it is close to the confluence of the inner harbor channel with both Elba Island and Fields Cuts. The overall shoaling reduction for the mid-river reach cannot be attributed to velocity increases since model test results indicate small or no velocity increases, Figures 7-8 and 7-9. And since the location of zero net bottom flow was pushed into this area, the reduction cannot be attributed to changes in salinity-controlled currents. Dredging of the non-Federal Southern Liquid Natural Gas (SLNG) turning basin at station 40+000, removed an average annual volume of 361,000 cubic yards from 1981 to 1985, Table 7-7. Taking the SLNG dredging into account leaves an unaccounted for volume reduction of 1,767,000 cubic yards in the mid-river reach. The only other major change during these time periods was the construction of the Sediment Basin. The Sediment Basin has already been shown in section 7.2.3.1.3.1 to filter the sediment in the mid-river area. The location of the mid-river reach is plotted on Figure 7-23 to show the predicted effect of the Sediment Basin on the shoaling in the mid-river reach. From the process of elimination and the physical model

tests it is evident that the reduction in the volume dredged in the mid-river reach is due to the Sediment Basin.

Year	Volume Dredged
1978	1,536,131
1979	1,352,951
1980	1,734,440
1981	1,443,417
1982-2000	0
2001	839,038
2002	400,000
2003	1,762,990
2004	895,133

Table 7-7 Volume Dredged in the Southern Liquid Natural Gas Turning Basin.

The lower river reach, which has an offshore sediment source, showed minor increases in shoaling and was not affected by upstream changes.

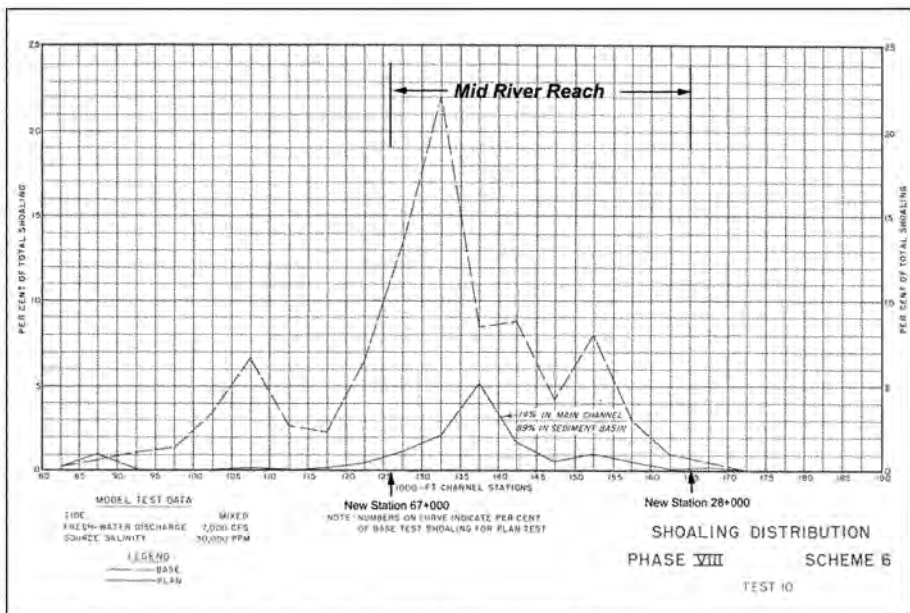


Figure 7-23 Shoaling Test Results After 119 Tidal Cycles, Reference 2.7.

The average annual volume dredged in the inner harbor channel for the period from 1970 to 1975 is 8,363,000 cubic yards. The average annual volume dredged in the inner harbor channel for the period 1981 to 1985 is 3,275,000 cubic yards. The reduction in the volume dredged in the inner harbor channel for the two periods is 5,088,000. The average annual volume dredge in the Sediment Basin for the period 1981 to 1985 was 2,792,000 cubic yards. This leaves 2,296,000 unaccounted for. Of this unaccounted for volume, 1,157,000 cubic yards can be attributed to a reduction in river discharge by the linear regression equation in Figure 7-16. The period from 1970 to 1975 had an average discharge of 13,510 cfs and the period 1981 to 1985 had an average discharge of 10,159 cfs. The river discharge reduction combined with an additional 361,000 cubic yards dredged from the SLNG turning basin reduces the unaccounted volume to 364,000 cubic yards. This remaining unaccounted for volume can either be due to the error in the regression equation that has a 0.44 R-squared value, survey accuracy or due to the nature of the shoals. The shoals in the mid and upper river have an average density of 1,144 gram per liter or 20 percent solids by weight, Reference 2.1. Since the shoal are mostly water and are composed of flocculated aggregates of clay particles, it is possible that the shoal material does not deposit in a low velocity area that allows the aggregate structures to remain intact. If the sediment is then spread over a large area, it could be undetected.

7.2.3.1.4.2 Shoaling Response to Closing New Cut, Ceasing Operation of the Tide Gate, Channel Widening, and Deepening from -38 feet to -42 feet.

The closing of New Cut, ceasing the operation of the Tide Gate, widening the upper river channel, and increasing the channel depth from -38 feet to -42 feet occurred in the time period from 1991 to 1994. The closure of New Cut and ceasing the operation of the Tide Gate reversed the changes that construction of these features created. The velocities in the upper river reach decrease 1.5 to 3.0 feet per second and the location of zero net bottom flow shifted back from the mid-river reach to the upper river reach. In response to these changes, the shoaling distribution in the upper river reach reverted to a pattern similar to the pattern to the 1970-1975 period. The shoaling volume in the upper river reach increased as shoaling shifted from the mid-river reach and the Sediment Basin to the upper river reach. The lower river reach had a slight decrease in shoaling volume. The combined shoaling of the three reaches showed a decrease in shoaling from the period 1981-1985 to 1997-2004, which was unrelated to river discharge.

To determine the shoaling changes caused by the closing of New Cut, ceasing the operation of the Tide Gate, widening the upper river channel, and increasing the channel depth from -38 feet to -42 feet, the volume dredged distributions were analyzed. The volume dredged distributions for the periods 1970-1975, 1981-1985 and 1997-2004 are plotted in Figure 7-24 and listed in Table 7-8. The volume dredged distributions for just the periods 1981-1985 and 1997-2004 are

plotted in Figure 7-25 and the changes between these two periods is plotted in Figure 7-26.

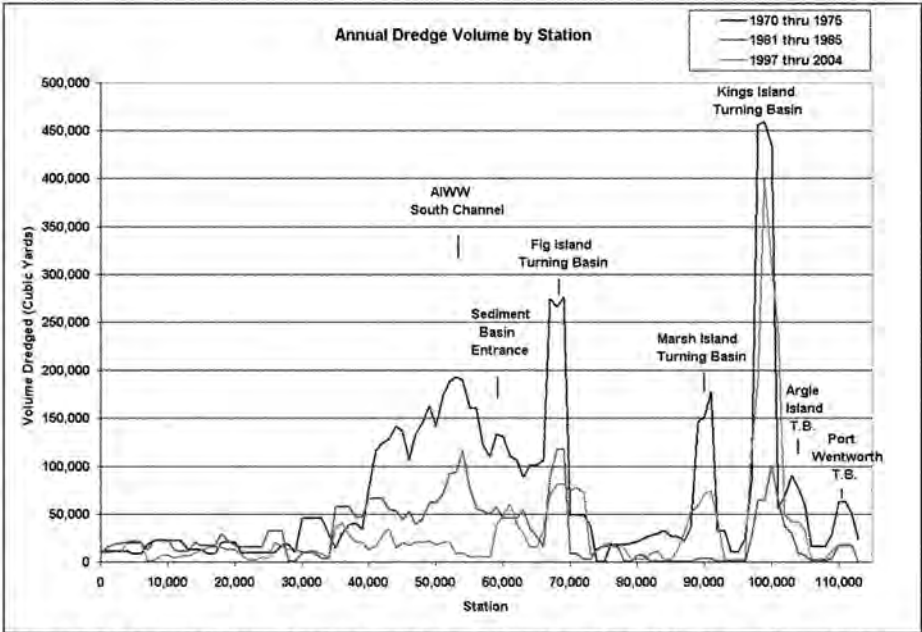


Figure 7-24 Annual Volume Dredged by Station 1970 thru 1975, 1981 thru 1985 and 1997 thru 2004.

Station	Annual Volume 1970 - 1975	Annual Volume 1981- 1985	Annual Volume 1997- 2004
0	11,001	8,797	9,683
1000	11,001	15,079	9,683
2000	11,001	18,823	11,380
3000	11,001	19,272	10,010
4000	11,001	19,272	21,153
5000	8,447	19,272	21,153
6000	8,447	19,272	21,367
7000	18,585	12,459	837
8000	22,019	22,587	1,995
9000	22,019	22,587	6,803
10000	22,019	22,587	6,659
11000	22,019	12,459	4,355

12000	21,611	10,694	5,533
13000	13,036	10,694	5,621
14000	13,036	19,881	9,411
15000	13,036	16,709	12,069
16000	8,497	16,709	14,940
17000	8,497	16,709	15,306
18000	20,191	29,664	15,312
19000	20,606	22,080	12,786
20000	20,606	17,662	12,392
21000	8,912	14,832	7,948
22000	8,912	14,832	2,053
23000	8,912	14,832	1,516
24000	8,912	16,425	4,915
25000	8,912	32,183	3,731
26000	10,520	32,183	19,921
27000	18,108	32,183	16,190
28000	18,108	509	13,100
29000	10,520	509	13,482
30000	45,568	9,155	10,411
31000	45,568	9,155	10,738
32000	45,568	9,155	10,738
33000	45,568	3,615	8,577
34000	28,481	3,084	5,382
35000	14,103	57,629	34,378
36000	29,818	57,629	40,242
37000	38,433	57,629	28,060
38000	40,495	46,069	19,905
39000	33,758	46,069	20,292
40000	76,149	66,182	12,368
41000	116,413	66,182	17,180
42000	124,529	66,182	26,794
43000	128,368	54,853	34,487
44000	142,068	53,224	13,999
45000	135,979	43,934	20,683
46000	106,296	53,275	16,493
47000	133,497	39,085	20,828
48000	146,264	45,191	20,529
49000	163,380	61,778	21,759
50000	141,880	61,778	18,002
51000	174,377	71,137	20,598
52000	188,639	92,452	20,598
53000	193,596	93,785	8,704
54000	190,299	115,300	9,277
55000	161,113	76,769	5,096
56000	160,300	55,987	4,693

57000	122,867	52,886	5,454
58000	109,962	49,485	4,906
59000	133,168	57,258	37,995
60000	131,148	45,450	49,241
61000	110,486	45,450	61,092
62000	106,426	45,551	39,164
63000	89,087	53,840	30,262
64000	100,260	35,414	15,444
65000	101,008	25,862	15,243
66000	106,589	16,393	34,283
67000	274,687	88,310	69,954
68000	266,254	118,417	81,214
69000	275,892	117,415	81,214
70000	48,582	8,586	74,633
71000	48,582	8,586	77,856
72000	48,582	2,414	71,549
73000	37,644	2,414	8,005
74000	0	13,229	12,072
75000	0	16,478	17,602
76000	18,037	16,120	19,442
77000	18,037	17,767	15,030
78000	18,037	1,647	15,030
79000	19,574	0	3,057
80000	20,826	6,988	2,415
81000	24,844	6,988	2,415
82000	28,076	143	8,156
83000	29,352	1,866	11,103
84000	32,851	143	1,294
85000	27,249	143	1,294
86000	25,973	143	13,693
87000	22,059	0	30,111
88000	36,358	357	51,888
89000	145,865	3,547	58,976
90000	152,442	3,414	70,584
91000	177,433	3,414	74,601
92000	32,716	534	44,419
93000	32,276	534	1,673
94000	9,929	534	1,673
95000	9,929	0	1,673
96000	23,753	0	1,381
97000	82,606	26,268	116,226
98000	455,992	63,995	189,772
99000	459,867	63,995	399,576
100000	434,603	100,592	308,948
101000	56,211	64,377	239,898

102000	68,420	37,007	49,172
103000	90,052	29,667	41,306
104000	76,625	9,392	42,106
105000	59,900	6,954	32,687
106000	16,264	776	2,191
107000	16,264	776	2,191
108000	16,264	1,256	2,191
109000	27,795	3,339	10,857
110000	62,488	17,082	17,411
111000	62,488	17,082	17,411
112000	51,033	17,082	18,226
113000	23,238	0	0

Table 7-8 Annual Volume Dredged by Station 1970 thru 1975, 1981 thru 1985 and 1997 thru 2004.

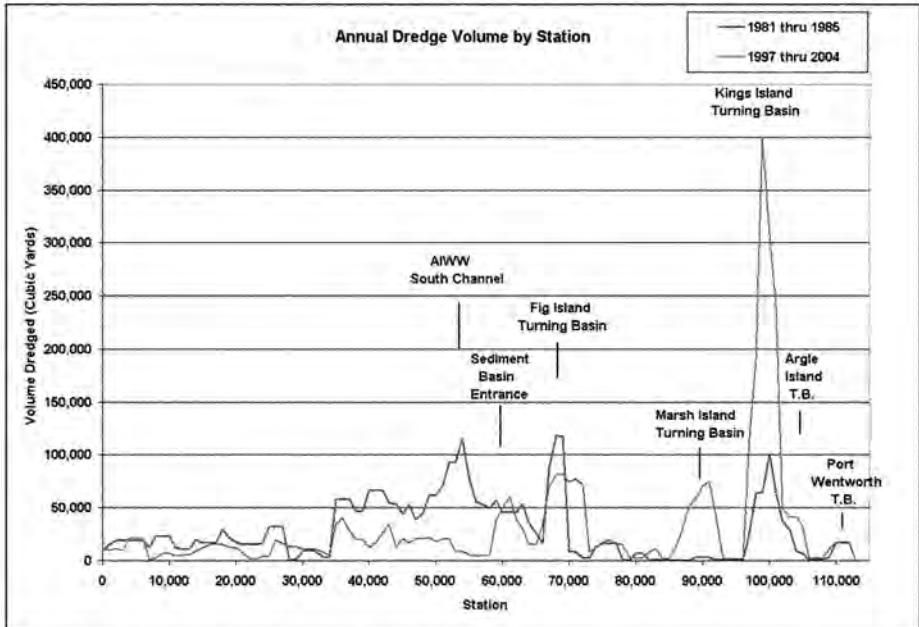


Figure 7-25 Annual Volume Dredged by Station 1981 thru 1985 and 1997 thru 2004.

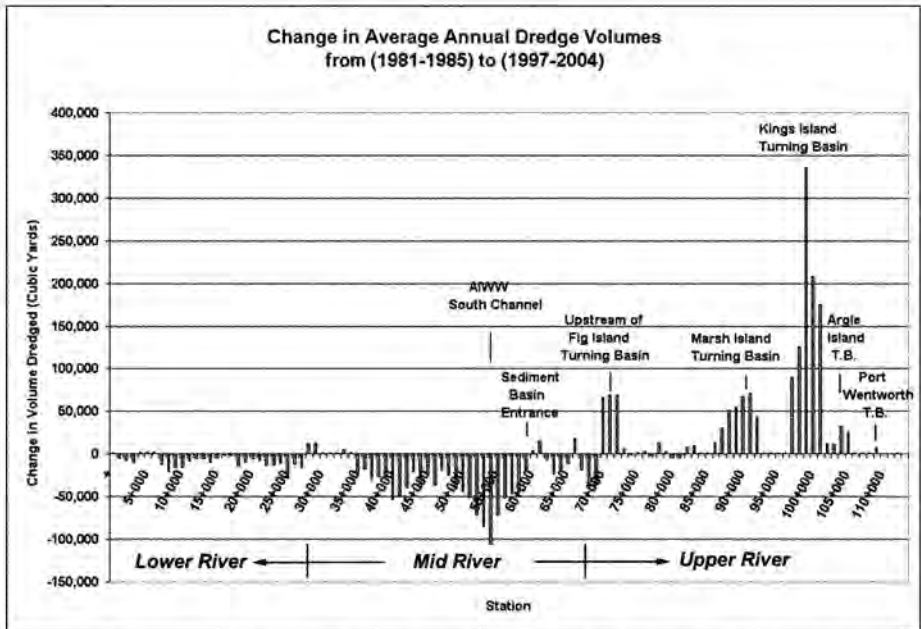


Figure 7-26 Changes in Average Annual Volume Dredged by Station from 1981-1985 to 1997-2004.

Closing New Cut and ceasing operation of the Tide Gate reversed the current changes and the shift in the zero net bottom flow location that their construction created. The changes were documented in 7.2.3.1.3.1. The volume dredged in the upper river reach, 2,414,000 cubic yards, increased by 1,514,000 in response to the velocity reduction due to the closure of New Cut and the shift of the location of zero net bottom flow back from the mid-river reach into the upper river reach. The volume dredged increases in the upper river reach occurred primarily in the Kings Island and Marsh Island turning basins, which had been high shoaling areas prior to the construction of the Tide Gate and New Cut. The area immediately upstream of the Fig Island turning basin also showed a large increase. The cause of this increase can be determined by examining the plots of before dredging surfaces. Figures 7-27 to 7-32 are plots of before dredging surveys circa 1990. While 1990 is not in the period 1981 to 1985, it was before the changes of concern were implemented. The before dredging surveys were not available for the period 1981-1985. Figures 7-33 to 7-38 are plots of before dredging surveys circa 2003. A surface of differences between the 1990 surface and the 2003 surface are plotted in Figures 7-39 to 7-44. Figure 7-29 contains the 1990 before dredging surface above Fig Island turning basin. Two large scour areas are present. Figure 7-35 contains of plot of the 2003 before dredging surface. The two scour areas are not as prominent. Figure 7-41 contains the difference between the 1990 and 2003 surfaces and even though in 2003 the project depth was 4 feet deeper than in 1990 the scour areas had

higher elevations in 2003 than in 1990. It appears from the surface plots that the strength of the flow pattern in this area oscillates from one side of the channel to the other causing the scour areas as the flow impinges on the side of the channel resulting in an increase in velocity. The reduction of the scour areas appears to be due to the channel widening, which spreads the flow out and lessens the effect of the flow impinging on the side of the channel. This change in the shoaling pattern does not appear to be related to the closure of New Cut or the removal of the Tide Gate since it also appears when comparing the shoaling distributions from 1970-1975 to 1997-2004, Figure 7-24. It is also unlikely related to agitation dredging since the volume change is an order of magnitude larger than the volume dispersed by the nearest agitation dredging permit holder East Coast Terminal.

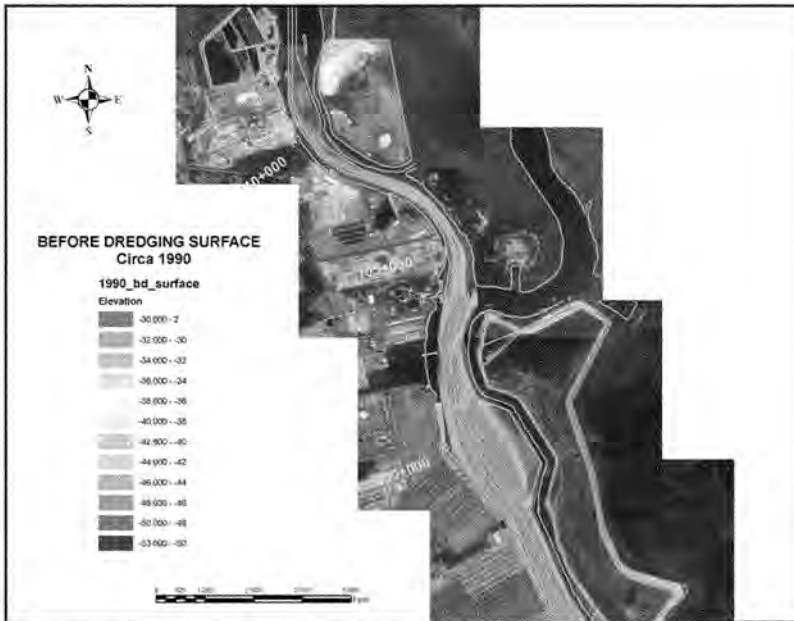


Figure 7-27 Before Dredging Surface Circa 1990 Stations 100+000 to 110+000.

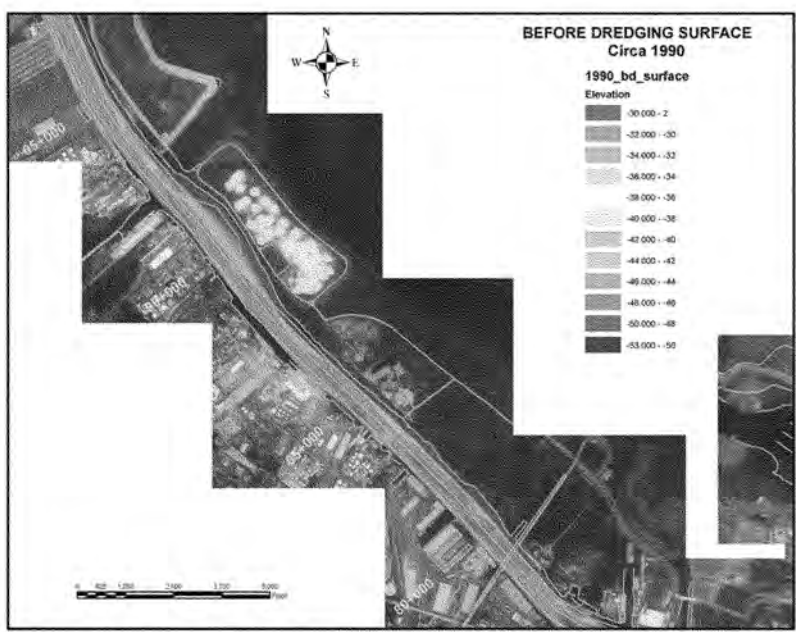


Figure 7-28 Before Dredging Surface Circa 1990 Stations 80+000 to 95+000.

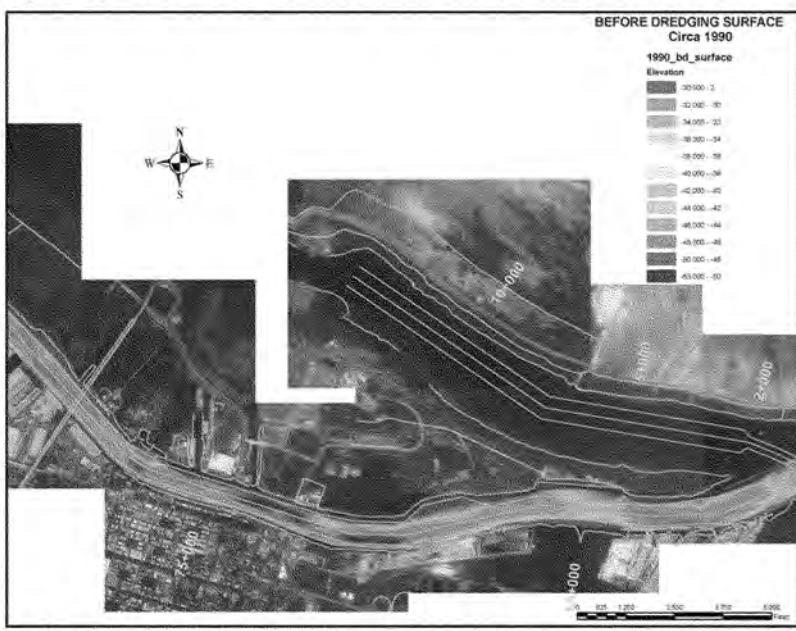


Figure 7-29 Before Dredging Surface Circa 1990 Stations 60+000 to 75+000.

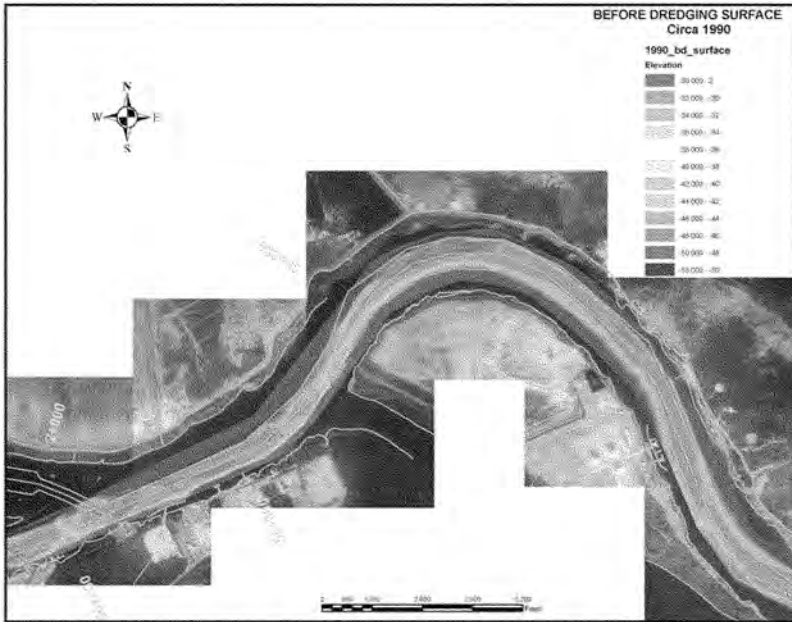


Figure 7-30 Before Dredging Surface Circa 1990 Stations 40+000 to 60+000.

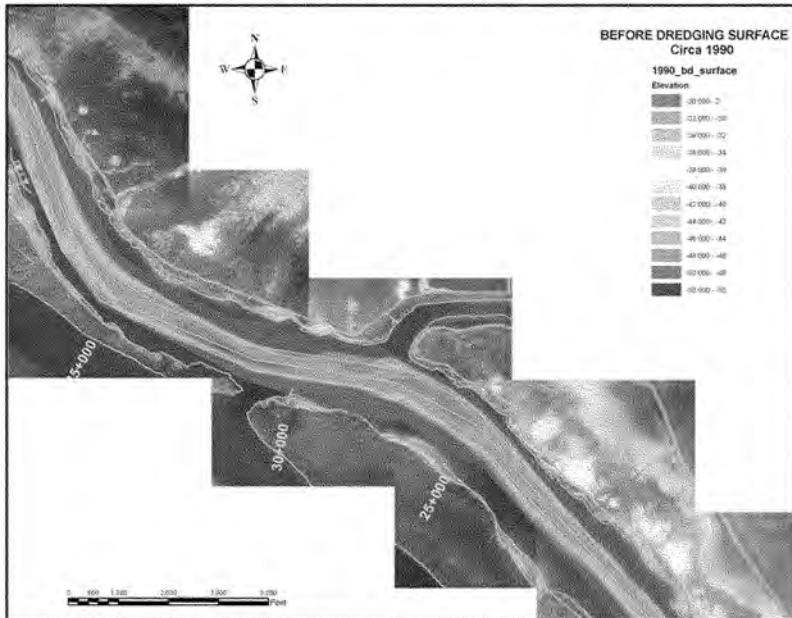


Figure 7-31 Before Dredging Surface Circa 1990 Stations 25+000 to 35+000.

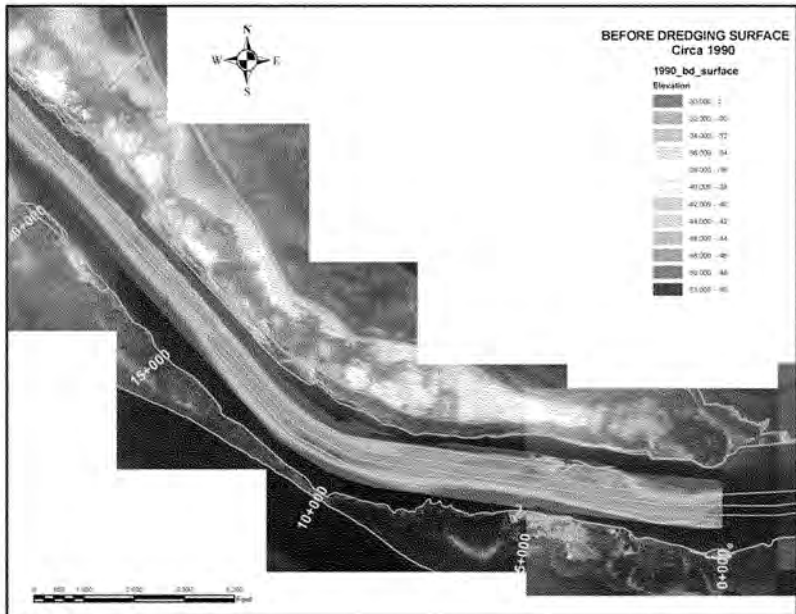


Figure 7-32 Before Dredging Surface Circa 1990 Stations 0+000 to 20+000.

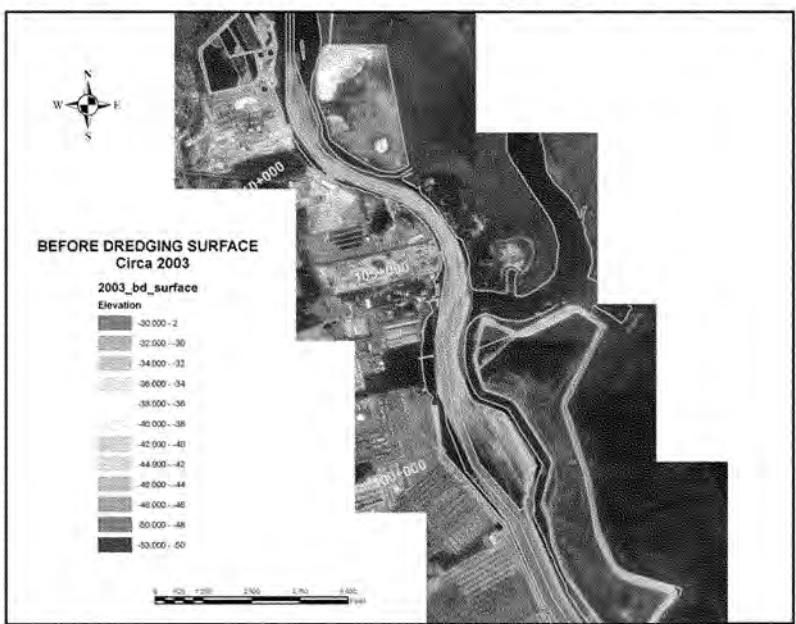


Figure 7-33 Before Dredging Surface Circa 2003 Stations 100+000 to 110+000.

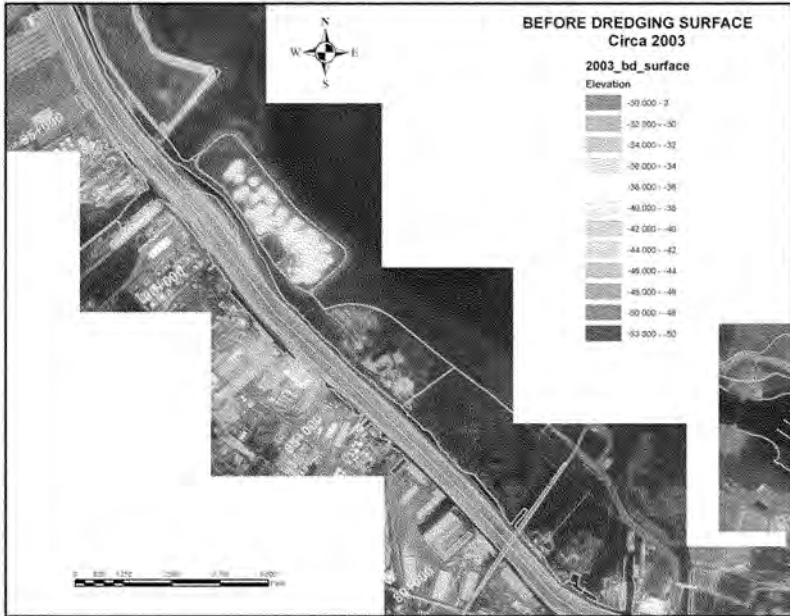


Figure 7-34 Before Dredging Surface Circa 2003 Stations 80+000 to 95+000.

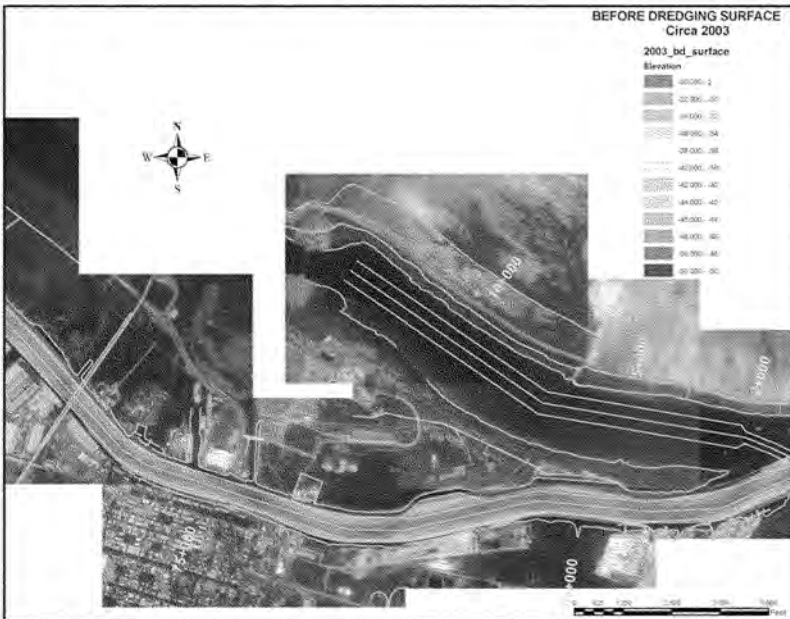
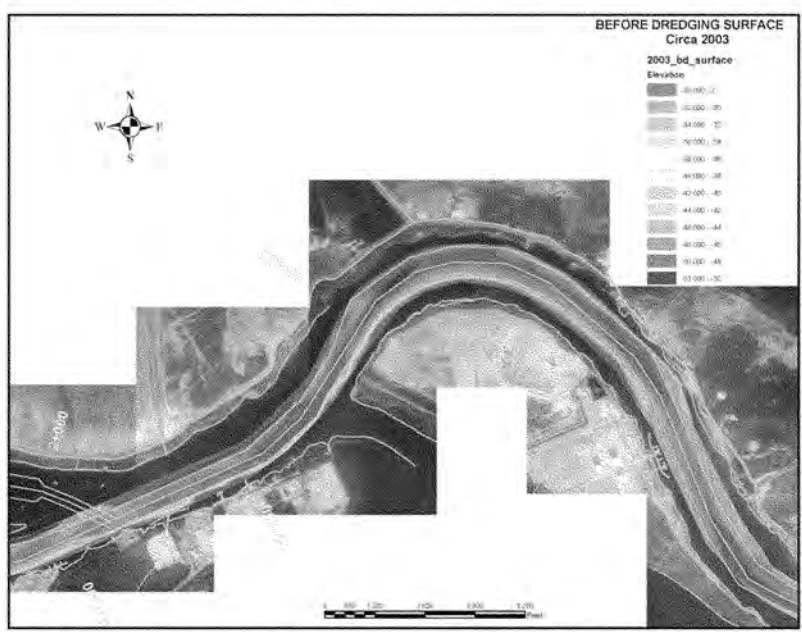


Figure 7-35 Before Dredging Surface Circa 2003 Stations 65+000 to 75+000.



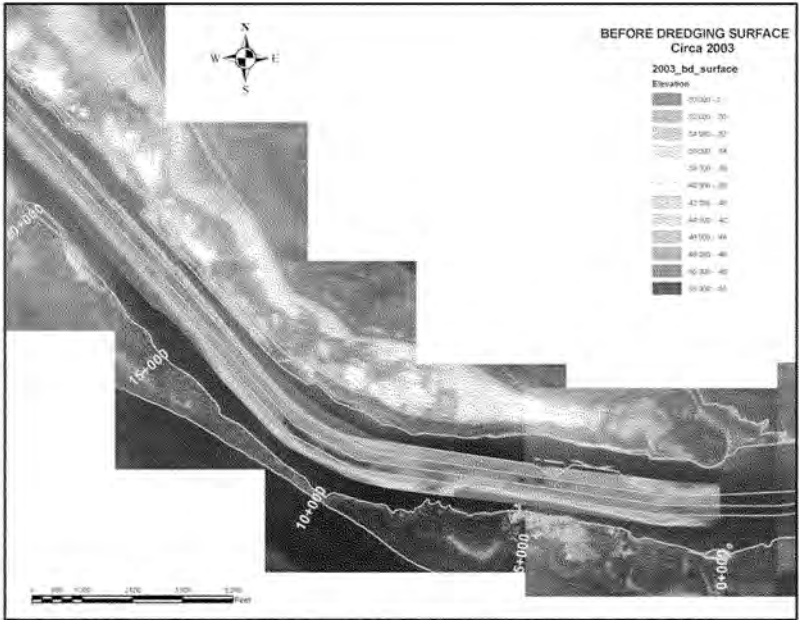


Figure 7-38 Before Dredging Surface Circa 2003 Stations 0+000 to 20+000.



Figure 7-39 Before Dredging Surface Changes Circa 1990 to 2003 Stations 100+000 to 110+000.

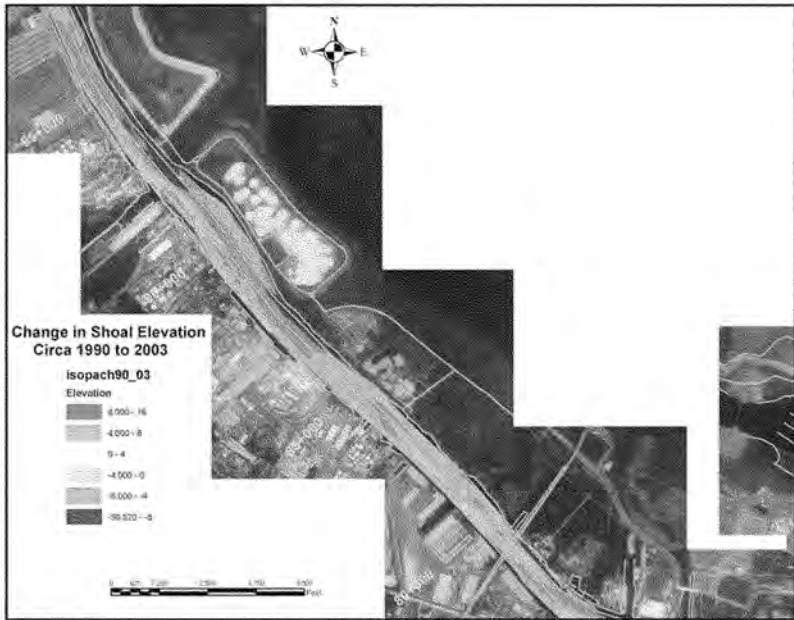


Figure 7-40 Before Dredging Surface Changes Circa 1990 to 2003 Stations 80+000 to 95+000.

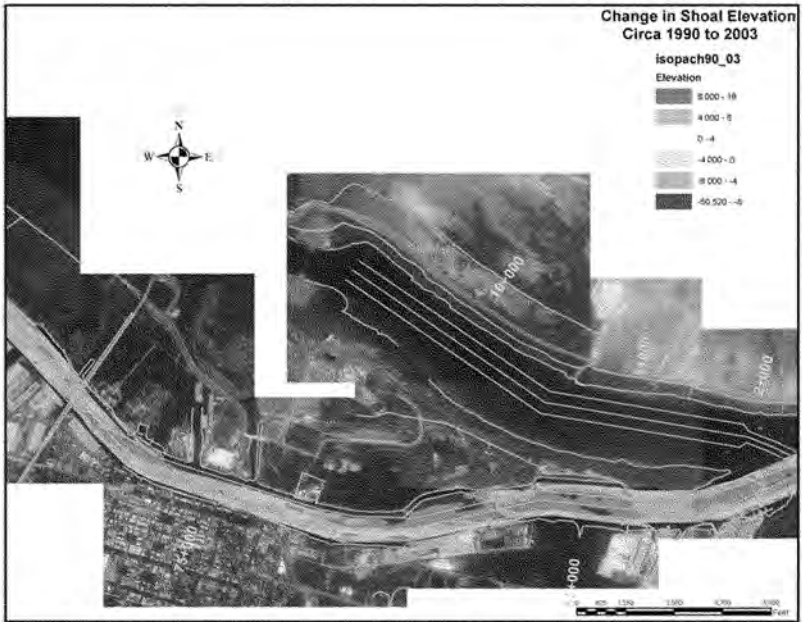


Figure 7-41 Before Dredging Surface Changes Circa 1990 to 2003 Stations 65+000 to 75+000.

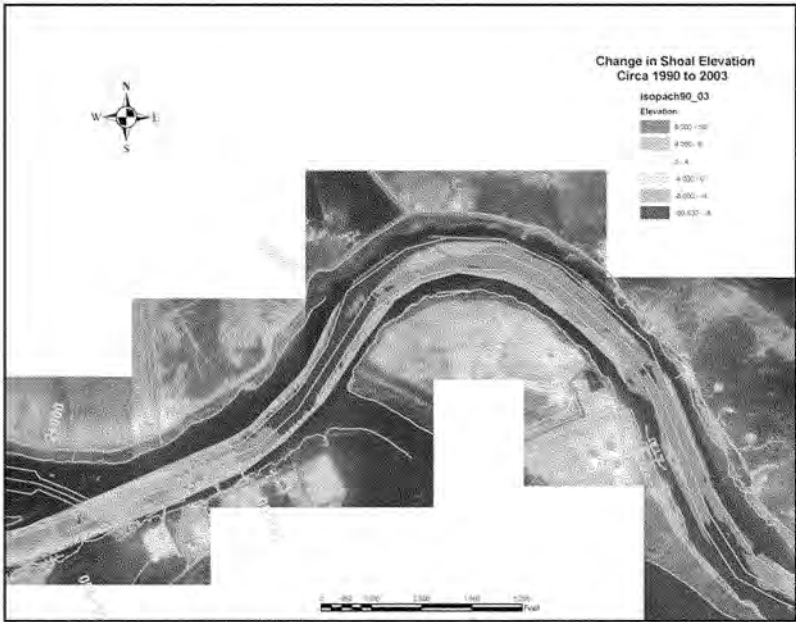


Figure 7-42 Before Dredging Surface Changes Circa 1990 to 2003 Stations 40+000 to 60+000.

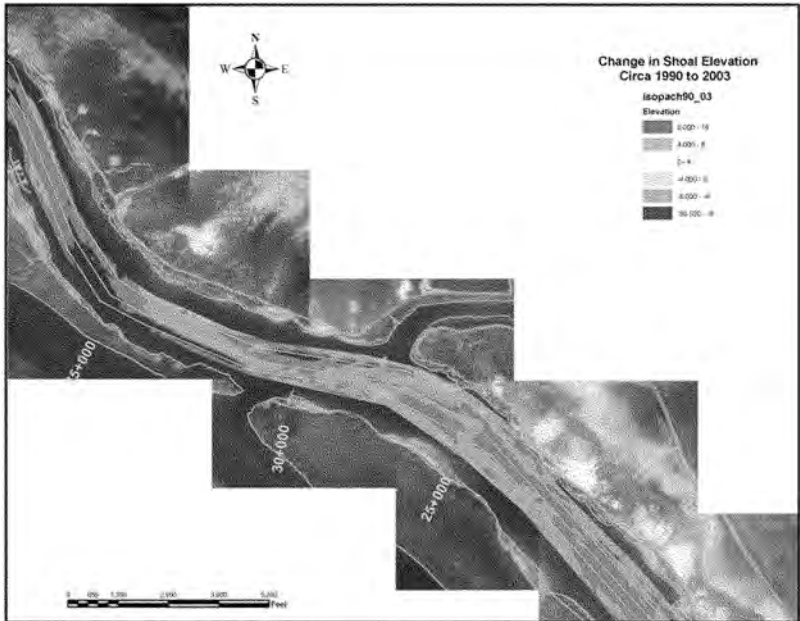


Figure 7-43 Before Dredging Surface Changes Circa 1990 to 2003 Stations 25+000 to 35+000.

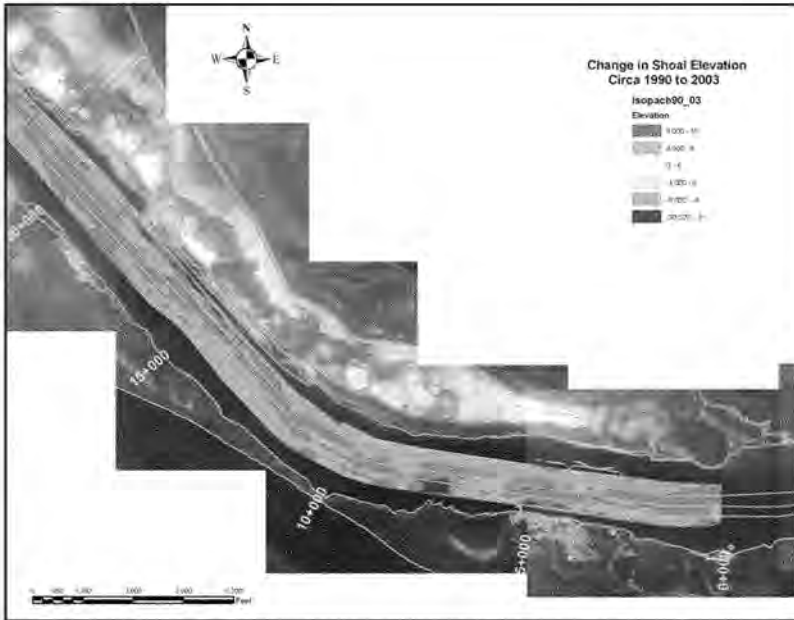


Figure 7-44 Before Dredging Surface Changes Circa 1990 to 2003 Stations 00+000 to 20+000.

The volume dredged in the in the mid-river reach, 787,000 cubic yards, decreased by 1,057,000 cubic yards from the period 1981-1985 to 1997-2004. Of this mid-river dredging decrease, 126,000 cubic yards can be attributed to an average annual dredging increase at the SLNG turning basin. The remainder of the decrease in annual volume dredged can be attributed to the location of zero net bottom flow moving from the mid-river reach to the upper river reach and the continued operation of the sediment trap. The area from station 28+000 to 34+000 was unchanged or had small increases. This area is at the confluence of the inner harbor channel with both Elba Island and Fields Cuts. The shoaling at this location is controlled by the converging flows from the side channels. The area immediately upstream was shown to respond atypically to the changes from 1970-1975 to 1981-1985 and the sediment samples taken in this area were not consistent with the along channel trend. (See Table 7-2 and Figure 7-2.)

The volume dredged in the lower river reach, 298,000 cubic yards, had a decrease of 233,000 cubic yards from the period 1981-1985 to 1997-2004.

The volume dredged in the Sediment Basin, 1,555,000 cubic yards, was a decrease of 1,242,000 cubic yards. The decrease in volume dredged is likely due to increases in the ebb flow current as a result of the removal of the tide gates and to the location of zero net bottom flow moving from the mid-river reach

to the upper river reach. This change will be discussed in greater detail in the Sediment Basin section 7.2.4 Sediment Basin Efficiency.

The average annual volumes dredged by period and reaches are shown in Figure 7-45 and Table 7-9. In order to account for changes in the volume dredged due to river discharge the linear regression equation from Figure 7-16 was applied to an average discharge of 10,159 cfs for the period 1981-1985 and an average discharge 9,921 cfs for the period 1997-2004. The ratio of the calculated volume dredged for the period to the calculated volume dredged for the average river discharge was multiplied by the actual volume dredged for the period to produce normalized volumes dredged. The normalized values are presented in Table 7-10.

Using the values in Table 7-10, the shift in shoaling from the mid-river reach and Sediment Basin to the upper river reach more than accounts for the 1,738,000 cubic yard increase in the volume dredged in the upper reach. This shift in shoaling to the upper river reach is due to the shift of the location of zero net bottom flow from the mid-river reach to the upper river reach. While the zero net bottom flow was in the mid-river reach the Sediment Basin was able to filter out the re-circulating sediment. The shift of the net zero bottom flow location out of the mid-river reach would have taken with it the sediment that was shoaling in the channel and the Sediment Basin. Of the 1,344,000 cubic yard reduction in the Sediment Basin, 578,000 cubic yards shifted to the upper river reach and 126,000 cubic yards were dredged out of the SLNG turning basin. The remaining 640,000 cubic yards are unaccounted for. The volume of material that is unaccounted was either deposited outside of the navigation channel or can be attributed in small part to the uncertainty in the river discharge correction to the shoaling volume.

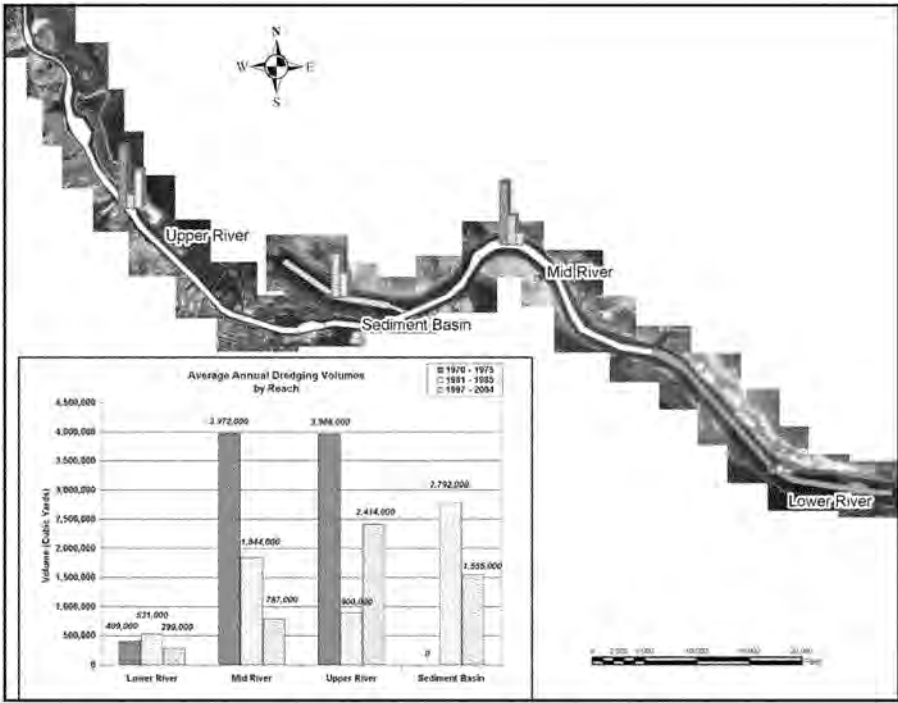


Figure 7-45 Average Annual Volume Dredged by Reach 1970 to 2004.

Reach	Average Annual Cubic Yards Dredged 1981 to 1985	Average Annual Cubic Yards Dredged 1997 to 2004	Difference
Lower River	531,000	298,000	-233,000
Mid-river	1,844,000	787,000	-1,057,000
Upper River	900,000	2,414,000	1,514,000
Sediment Basin	2,792,000	1,555,000	-1,237,000
Total	6,067,000	5,054,000	-1,013,000

Table 7-9 Average Annual Volumes Dredged From the Period 1981-1985 to the Period 1997-2004 by Reach.

Reach	Average Annual Cubic Yards Dredged 1981 to 1985	Average Annual Cubic Yards Dredged 1997 to 2004	Difference
Lower River	591,000	338,000	-253,000
Mid-river	2,053,000	893,000	-1,160,000
Upper River	1,002,000	2,740,000	1,738,000

Sediment Basin	3,109,000	1,765,000	-1,344,000
Total	6,755,000	5,736,000	-1,019,000

Table 7-10 Discharge Adjusted Average Annual Volumes Dredged From the Period 1981-1985 to the Period 1997-2004 by Reach.

7.2.3.1.5 Predicted Inner Harbor Shoaling Response to Proposed Changes.

To determine the changes to the amount and distribution of the inner harbor dredging volumes due to potential channel depth increases, the changes due to the 4-foot depth increase in 1994 were used as a predictor. In addition to the shoaling response to past changes, the velocities as predicted by the three-dimensional hydrodynamic model Environmental Fluid Dynamics Code (EFDC) were used to check for potential shifts in shoaling distribution due to potential depth increases. With the small exception of the passing lane extending into an existing shoal, no changes to the shoaling volume or distribution are predicted for the three inner harbor reaches.

The most significant statistic in examining the changes from the period 1981-1985 to 1997-2004 is that the total average annual volume dredged decreased by approximately 1,000,000 cubic yards, Tables 7-8 and 7-9.

A comparison between the inner harbor dredging volume distributions between the periods 1970-1975 and 1997-2004, Figure 7-46, does not indicate any shoaling changes that can be attributed to a depth increase. There were multiple construction related changes between the two time periods. The construction related changes reflected in the distributions are inner harbor depth increase from -38 feet to -42 feet between Stations 0+000 and 103+000, the widening of the channel from 400 feet to 500 feet from station 70+000 to station 100+000, the enlargement of the Kings Island Turning Basin from 900 x 1,000 feet to 1,500 x 1,600 feet and the operation of the Sediment Basin. The Tide Gate and New Cut were not operational during either the 1970-1975 or the 1997-2004 time periods.

Starting at the downstream end, the changes to note between the two distributions are:

1. Around station 5+000 there is an increase in dredging due to Oyster Bed Island Turning basin being incorporated into the Federal Project.
2. There is a small increase around station 35+000. This is an atypical area upstream from the confluence of the inner harbor channel with Elba and Fields Cuts. The sediments in this area have higher components of silt and clay than the sediments at stations upstream and downstream. The localized changes in this area are related to the complex converging flows and are not directly related to channel deepening.

3. There is a large reduction in the volume dredged from station 40+000 to station 66+000. The continued O&M dredging of the Sediment Basin has resulted in a reduced dredging volume in the inner harbor channel, Section **7.2.3.1.4.1**.

4. At the Fig Island Turning Basin there is a spreading out of the volume dredged due to the diminution of two scour areas upstream of the Fig Island Turning Basin. The scour areas are caused by the oscillating channel flow impinging on the side of the channel, which causes a localized increase in velocity. The channel widening caused the flow to spread out and reduce the velocity increase. A small part of the reduction from station 67+000 to 69+000 may be due to the Sediment Basin but the quantity is difficult to determine since the effects of the Sediment Basin ends in this area.

5. The last significant change is at the Kings Island Turning Basin. The increase here is due to the size of the Turning Basin being increased from 900 x 1,000 feet to 1,500 x 1,600 feet, which more than doubled its size.

There are no changes to the total volume dredged or to the shoaling distribution that can be attributed to the 1994 channel deepening and widening.

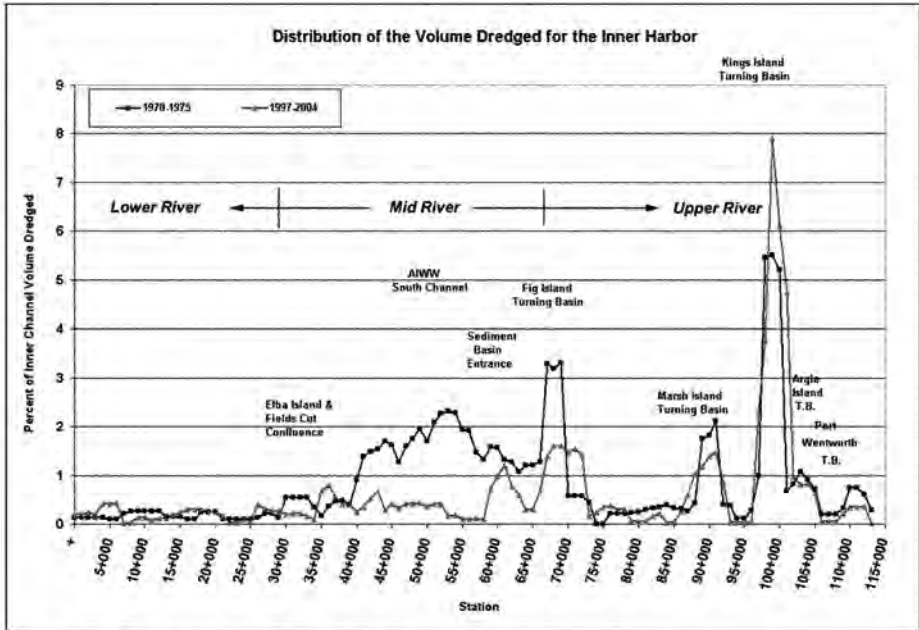


Figure 7-46 Distribution of the Volume Dredged for the Inner Harbor.

To determine if proposed depth increase would change the shoaling pattern in the river, the three-dimensional hydrodynamic model, EFDC, was run for low, average and high flow conditions with existing project depths, a 3-foot depth increase and a 6-foot depth increase. The low flow runs used historic river discharges starting on April 1, 1999 and was run for 214 days. The average flow runs used historic river discharges starting on August 1, 1997 and was run for 91 days. The high flow runs used historic river discharges starting on July 1, 1998. The EFDC cells are plotted in Figure 7-47 and the inner harbor river stations associated with the cells are listed in Table 7-11. The maximum current speeds for the existing project geometry, the plan geometry, and the difference between the maximum current speeds for the existing and plan geometry are plotted in Figures 7-48 through 7-59. There are specific locations where velocity changes occur. The velocity changes due to a 6-foot deepening with average flow conditions best represents the locations where changes occur and is plotted with the percent of volume dredged distributions for the 1970-1975 and 1997-2004 time periods in Figure 7-60. Velocity changes are predicted at locations where there is high shoaling already occurring and no shift in shoaling pattern is predicted with two possible exceptions. The first exception is a small shoal at station 35+000. Based on the predicted ebb velocity changes this shoal may shift toward station 31+000. The second exception is the spreading out of the Marsh Island Turning Basin shoal based on predicted flood velocity changes. If these exceptions did occur they may cause small changes in the shoaling

distribution but the response of the volume-dredged distribution to the last deepening in 1994, Figure 7-24, indicates that this changes will not occur and the total volume-dredged would likely not change.

Another indication that there will not be major flow induced changes due to potential channel deepening is that the past depth increases have improved the conveyance of the channel to the point where a full tidal range is presently moving up the channel to the upstream end of the harbor. The mean tidal range at the entrance to Savannah Harbor, Fort Pulaski, is 6.9 feet and the mean tidal range at the upstream end of the harbor is 7.0 feet, Port Wentworth. Additional deepening would not be expected to significantly affect the tidal flow or salinity related shoaling that is associated with the location of no net bottom flow.

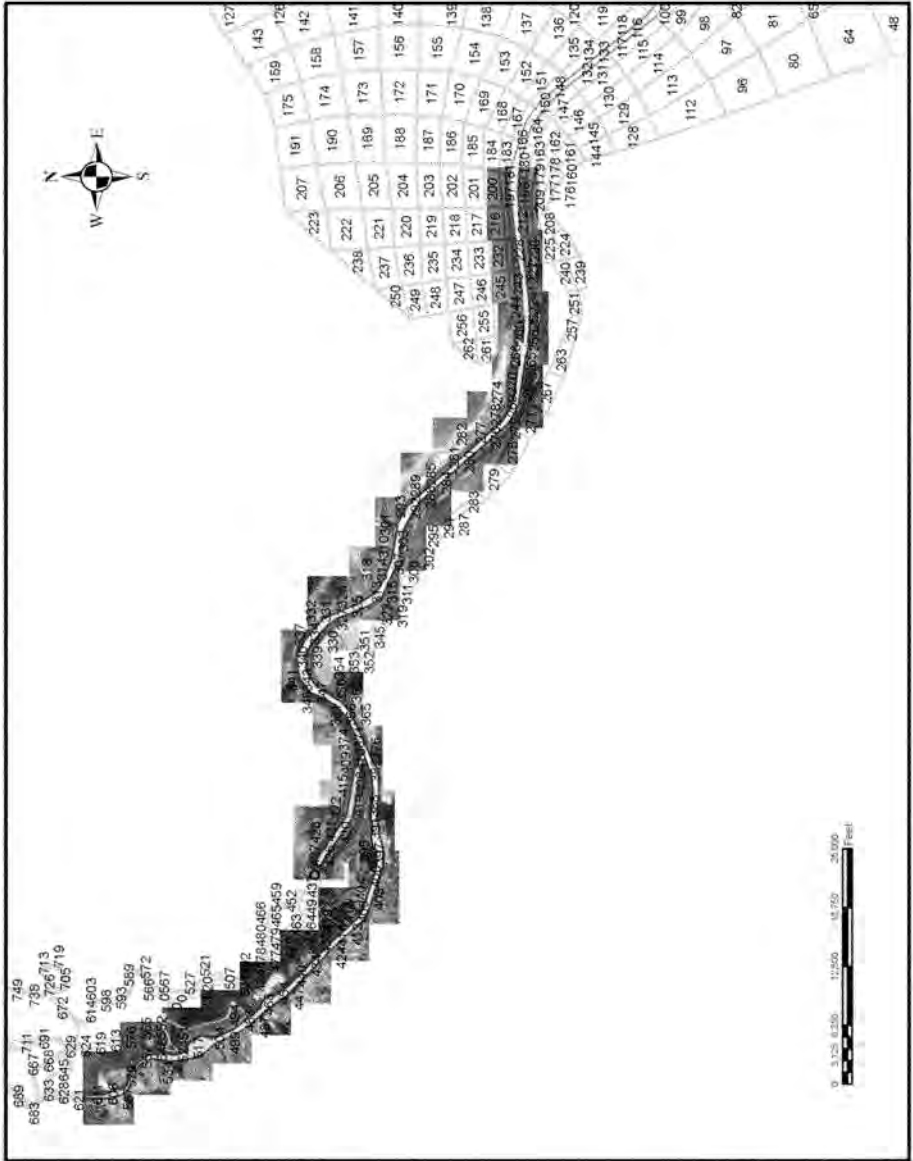


Figure 7-47 EFDC Inner Harbor Cells.

Cell #	Start Station	End Station	Cell #	Start Station	End Station	Cell #	Start Station	End Station
259	0+500	3+000	361	53+000	54+250	488	92+500	94+000
265	3+000	5+500	366	54+250	56+250	494	94+000	95+250
269	5+500	9+000	371	56+250	58+250	499	95+250	96+250
273	9+000	11+500	376	58+250	60+000	504	96+250	97+500
277	11+500	15+500	382	60+000	62+000	509	97+500	98+750
281	15+500	19+000	385	62+000	63+500	516	98+750	100+000
285	19+000	22+000	388	63+500	66+250	523	100+000	101+250
289	22+000	23+750	391	66+250	68+000	530	101+250	102+000
293	23+750	25+750	394	68+000	69+750	535	102+000	102+750
297	25+750	27+000	397	69+750	71+500	540	102+750	103+500
300	27+000	28+500	400	71+500	73+500	545	103+500	104+250
304	28+500	30+000	403	73+500	75+500	557	104+250	105+000
309	30+000	32+000	406	75+500	77+500	563	105+000	105+750
313	32+000	33+750	412	77+500	79+000	569	105+750	106+750
317	33+750	35+000	418	79+000	80+750	574	106+750	107+250
321	35+000	36+750	424	80+750	82+250	579	107+500	108+500
325	36+750	38+750	430	82+250	83+750	583	108+500	109+250
328	38+750	40+500	434	83+750	85+250	587	109+250	110+000
331	40+500	42+250	440	85+250	86+750	591	110+000	110+250
334	42+250	44+000	447	86+750	88+000	595	110+250	110+750
337	44+000	45+750	454	88+000	89+250	600	110+750	111+250
340	45+750	47+750	461	89+250	90+000	605	111+250	112+250
343	47+750	49+750	468	90+000	91+250	610	112+250	113+000
347	49+750	51+750	475	91+250	91+750	616	113+000	114+000
357	51+750	53+000	482	91+750	92+500			

Table 7-11 EFDC Cell Inner Harbor Station Numbers.

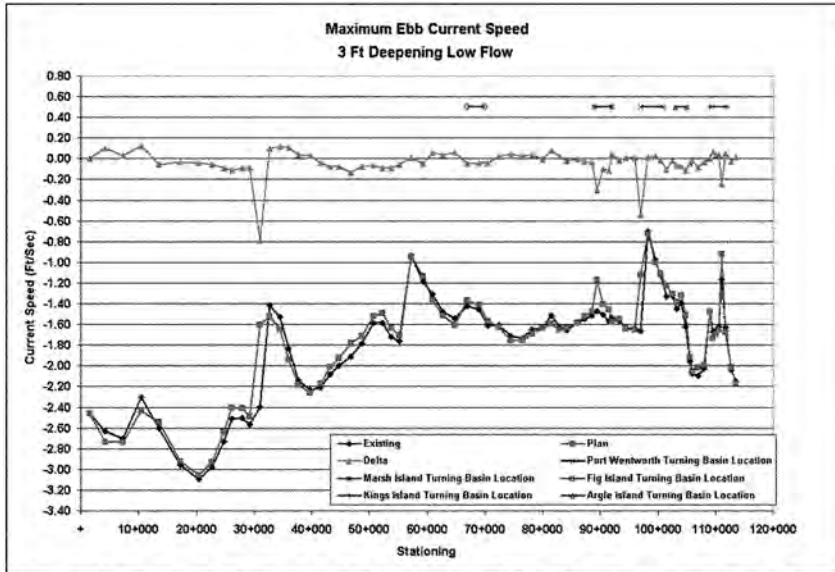


Figure 7-48 Maximum Ebb Current Speeds for a 3-Foot Depth Increase During Low Flow Conditions.

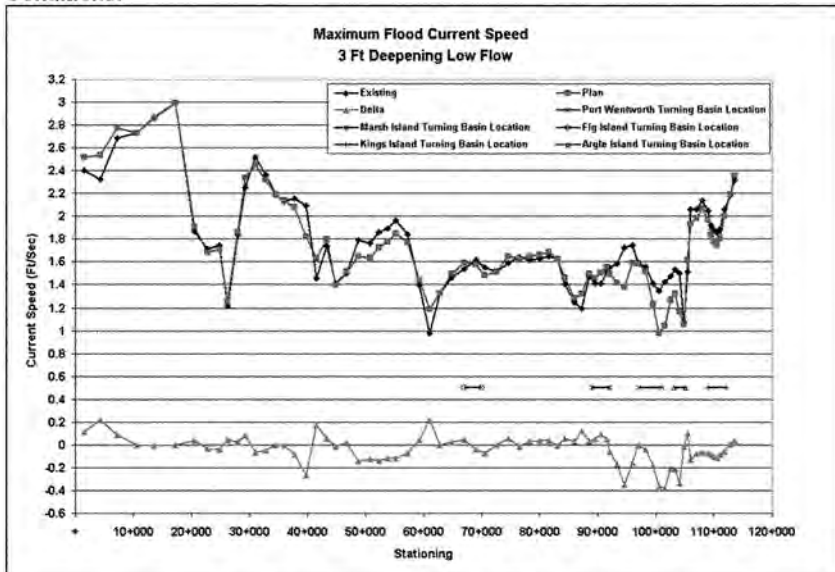


Figure 7-49 Maximum Flood Current Speeds for a 3-Foot Depth Increase During Low Flow Conditions.

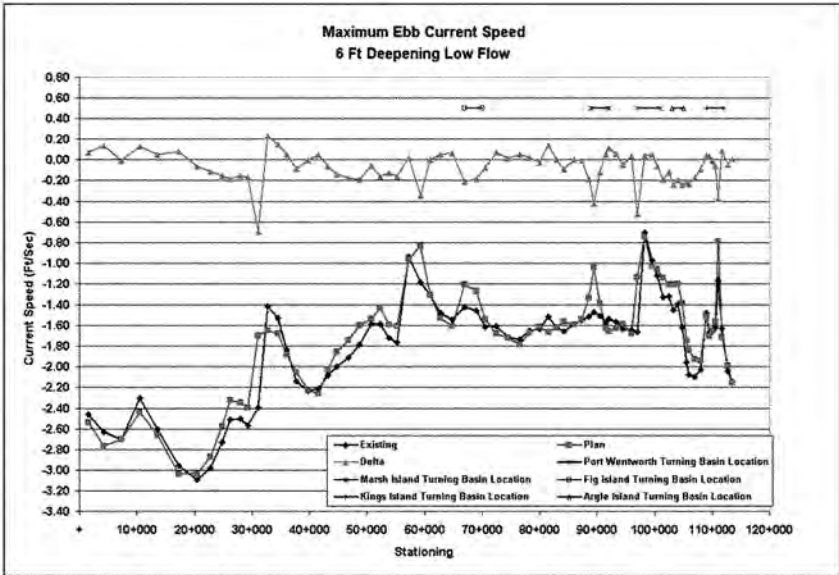


Figure 7-50 Maximum Ebb Current Speeds for a 6-Foot Depth Increase During Low Flow Conditions.

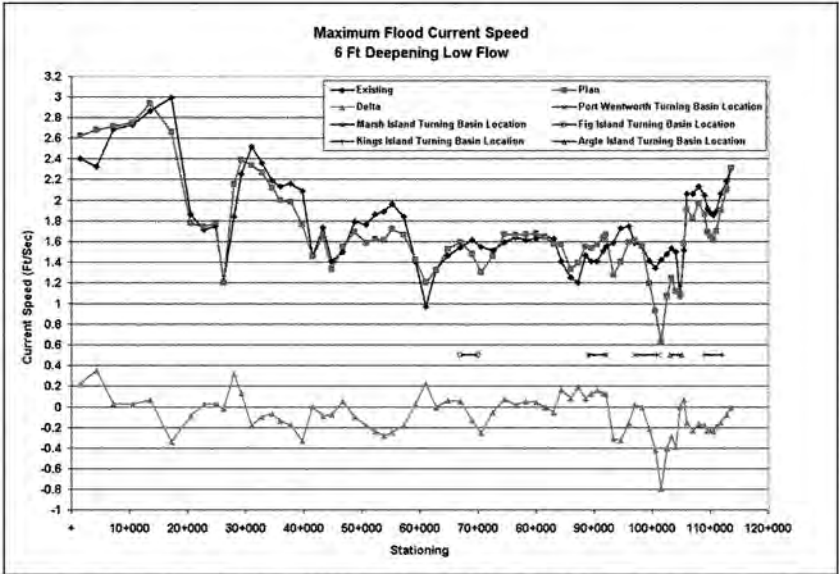


Figure 7-51 Maximum Flood Current Speeds for a 6-Foot Depth Increase During Low Flow Conditions.

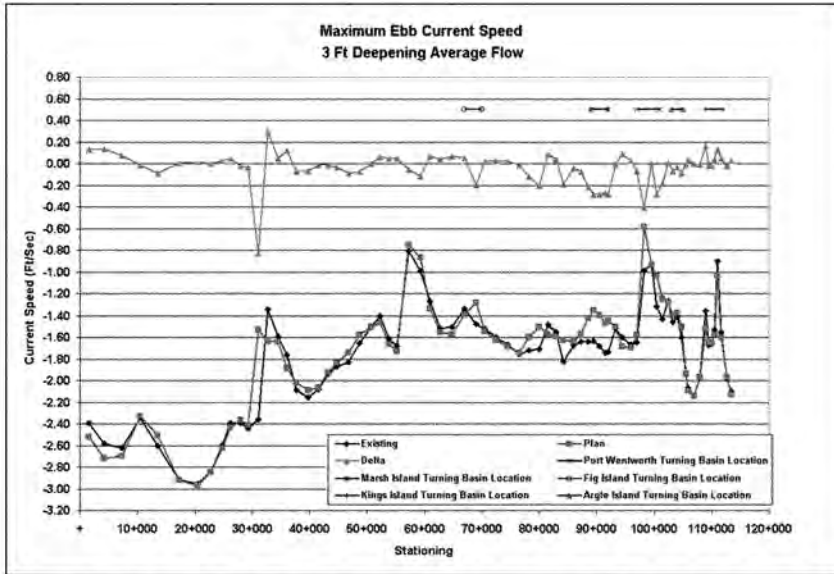


Figure 7-52 Maximum Ebb Current Speeds for a 3-Foot Depth Increase During Average Flow Conditions.

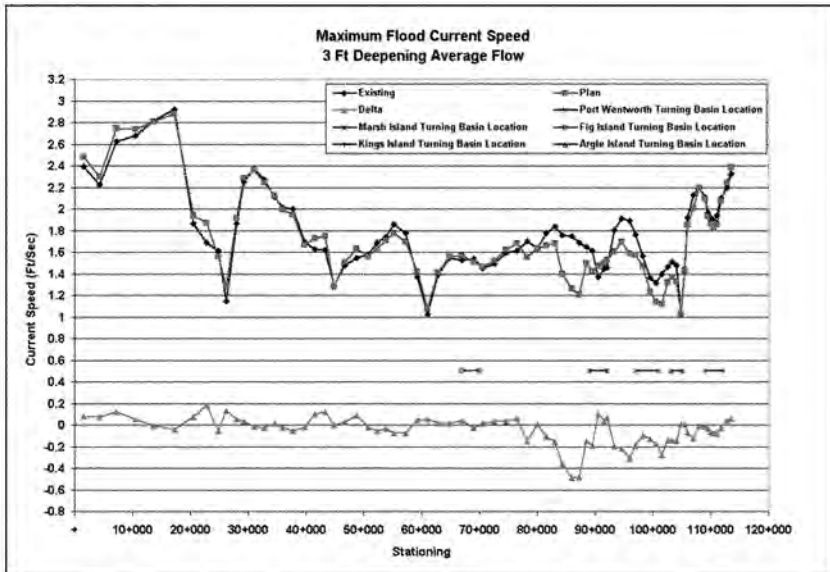


Figure 7-53 Maximum Flood Current Speeds for a 3-Foot Depth Increase During Average Flow Conditions.

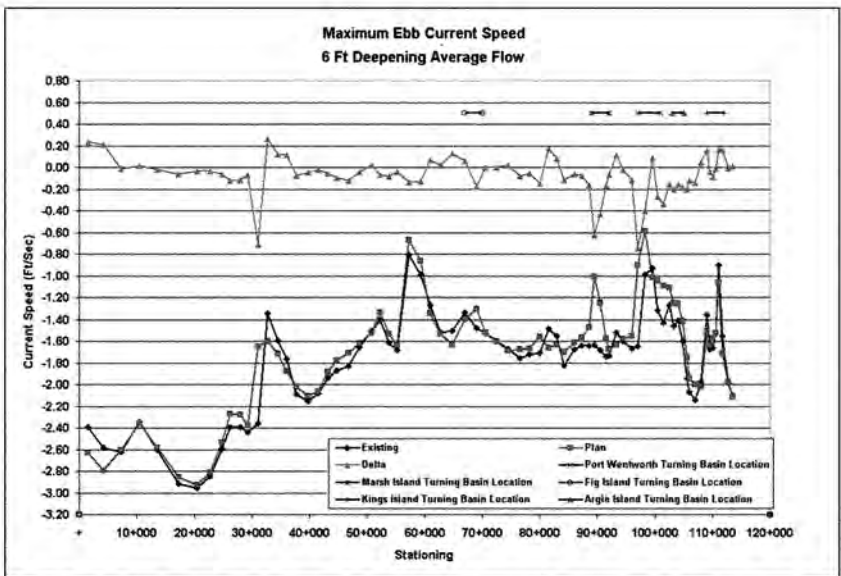


Figure 7-54 Maximum Ebb Current Speeds for a 6-Foot Depth Increase During Average Flow Conditions.

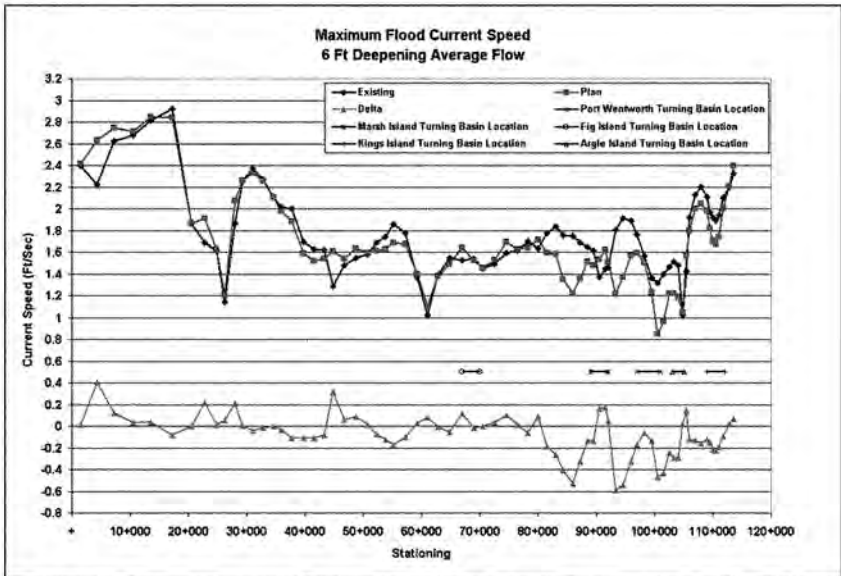


Figure 7-55 Maximum Flood Current Speeds for a 6-Foot Depth Increase During Average Flow Conditions.

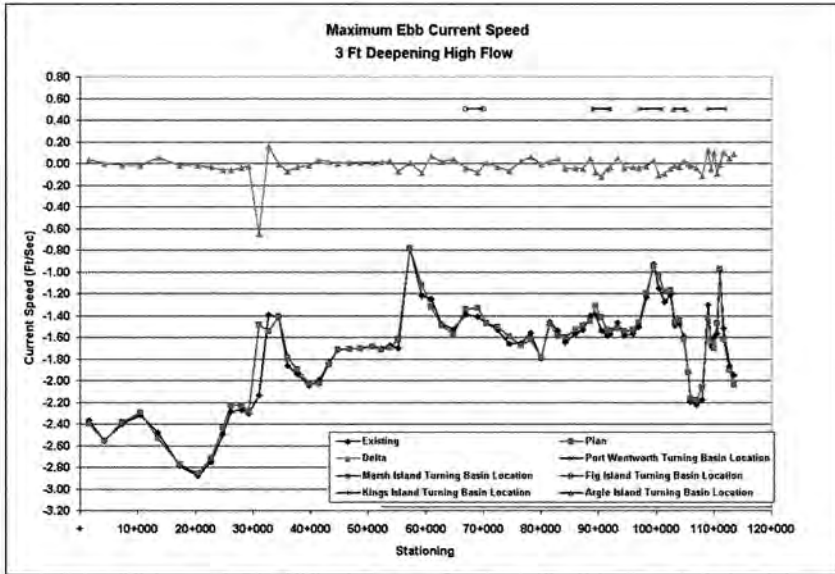


Figure 7-56 Maximum Ebb Current Speeds for a 3-Foot Depth Increase During High Flow Conditions.

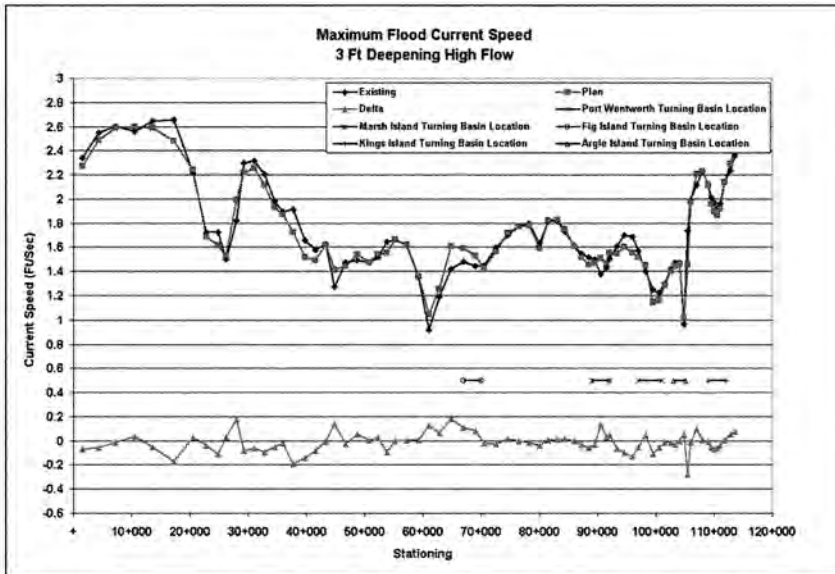


Figure 7-57 Maximum Flood Current Speeds for a 3-Foot Depth Increase During High Flow Conditions.

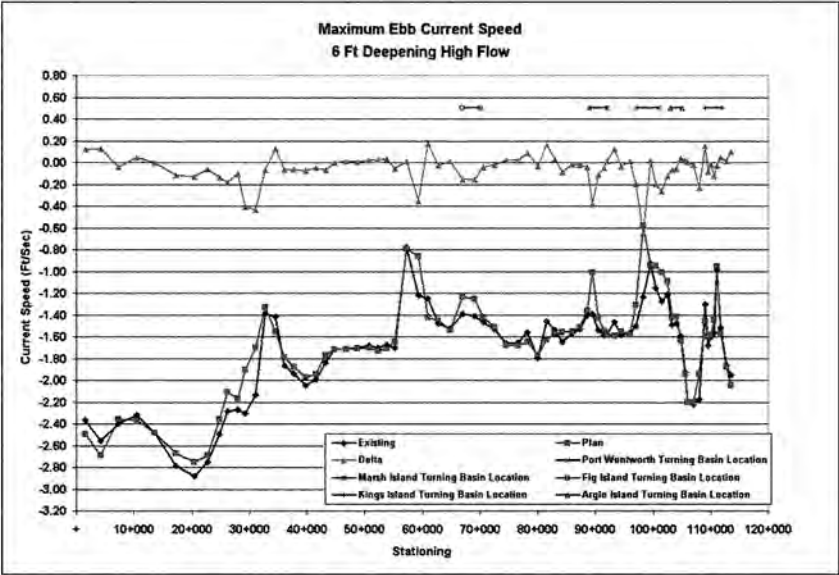


Figure 7-58 Maximum Ebb Current Speeds for a 6-Foot Depth Increase During High Flow Conditions.

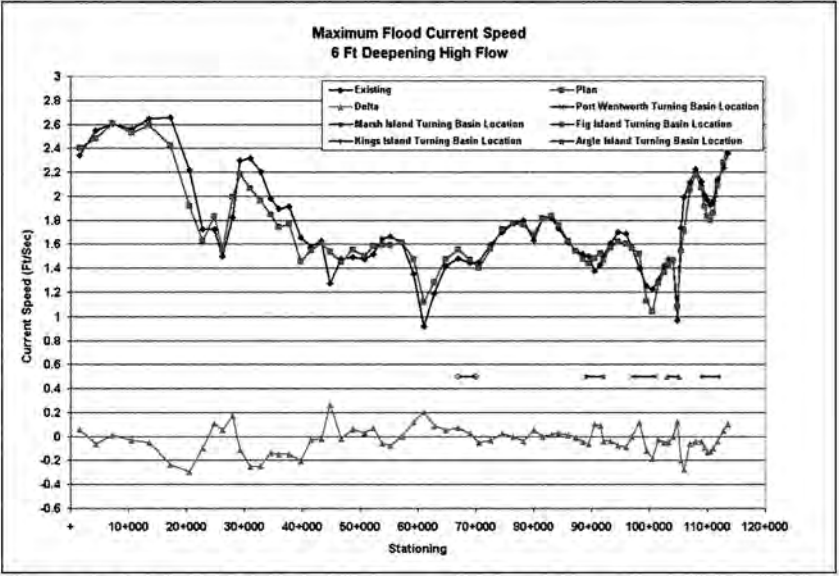


Figure 7-59 Maximum Flood Current Speeds for a 6-Foot Depth Increase During High Flow Conditions.

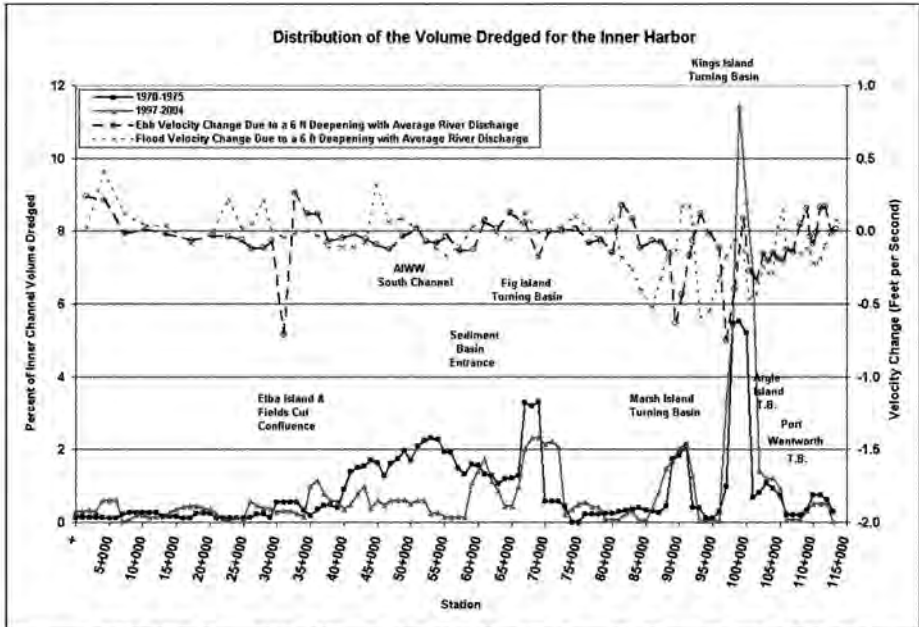


Figure 7-60 Distribution of the Volume Dredged for the Inner Harbor with Plan Velocity Changes.

Since 1) there were no changes to the shoaling volume or distribution attributed to the last channel deepening, 2) essentially all of the shoaling material from upstream sources is being trapped within the system, Section 7.2.3.1.1, and 3) the future depth increases will extend down along the existing channel side slopes which will decrease the bottom width of the channel, no major changes to shoaling volume or distribution is predicted.

The long-term average annual volume dredged from the inner harbor and the Sediment Basin from 1970 to 2004 is 6,194,000 cubic yards, Table 7-13. The average annual volume dredged for the period 1997 to 2004 is 5,054,000, Table 7-9. The ratio of long-term average to the 1997-2004 average is 1.226. This ratio was used to adjust the volume-dredged distribution for the period 1997 to 2004 from Table 7-9 to a long-term average that represents the present shoaling distribution and the result is presented in Table 7-14. To determine the shoaling volume for the various depth increases, the volumes in Table 7-12 should be multiplied by 1.226 and product distributed between stations 59+000 and 60+000 in Table 7-14. The total predicted volume for the inner harbor is 6,194,000 cubic yards plus the adjusted volume increase from Table 7-12.

The average volume dredged in the Sediment Basin during the period 1997-2004 was 1,555,000 cubic yards. The adjusted long-term average for the present shoaling distribution is 1,906,000 cubic yards.

Year	Volume	Year	Volume	Year	Volume
1970	8,922,658	1983	5,012,204	1996	-
1971	9,225,271	1984	8,115,635	1997	6,360,202
1972	7,196,706	1985	4,944,118	1998	4,366,081
1973	6,220,269	1986	4,569,268	1999	6,537,177
1974	11,754,058	1987	5,022,490	2000	8,051,883
1975	6,762,687	1988	2,083,541	2001	3,409,743
1976	9,362,727	1989	3,157,696	2002	1,508,184
1977	11,269,682	1990	3,500,328	2003	6,639,202
1978	5,130,898	1991	8,814,338	2004	3,565,498
1979	12,294,584	1992	3,529,807		
1980	6,100,646	1993	2,528,830	Average	6,194,000
1981	5,864,877	1994	-		
1982	6,397,966	1995	-		

Table 7-12 Inner Harbor and Sediment Basin Dredging Volume by Year.

Station	Long-Term Average Annual Volume Dredged	Station	Long-Term Average Annual Volume Dredged	Station	Long-Term Average Annual Volume Dredged
0	11,866	38000	24,392	76000	23,825
1000	11,866	39000	24,867	77000	18,418
2000	13,946	40000	15,157	78000	18,418
3000	12,266	41000	21,054	79000	3,746
4000	25,921	42000	32,835	80000	2,959
5000	25,921	43000	42,262	81000	2,959
6000	26,184	44000	17,155	82000	9,995
7000	1,026	45000	25,345	83000	13,606
8000	2,445	46000	20,211	84000	1,586

9000	8,337	47000	25,524	85000	1,586
10000	8,160	48000	25,158	86000	16,780
11000	5,337	49000	26,665	87000	36,899
12000	6,781	50000	22,060	88000	63,586
13000	6,888	51000	25,242	89000	72,272
14000	11,533	52000	25,242	90000	86,497
15000	14,790	53000	10,667	91000	91,420
16000	18,308	54000	11,369	92000	54,434
17000	18,756	55000	6,245	93000	2,050
18000	18,764	56000	5,751	94000	2,050
19000	15,669	57000	6,683	95000	2,050
20000	15,186	58000	6,011	96000	1,693
21000	9,740	59000	46,565	97000	142,429
22000	2,516	60000	60,347	98000	232,556
23000	1,858	61000	74,865	99000	489,662
24000	6,023	62000	47,994	100000	378,601
25000	4,572	63000	37,084	101000	293,983
26000	24,413	64000	18,925	102000	60,257
27000	19,840	65000	18,679	103000	50,618
28000	16,054	66000	42,012	104000	51,599
29000	16,521	67000	85,725	105000	40,057
30000	12,758	68000	99,524	106000	2,684
31000	13,158	69000	99,524	107000	2,684
32000	13,158	70000	91,460	108000	2,684
33000	10,511	71000	95,409	109000	13,305
34000	6,595	72000	87,680	110000	21,336
35000	42,128	73000	9,810	111000	21,336
36000	49,315	74000	14,794	112000	22,334
37000	34,386	75000	21,570	113000	0

Table 7-13 Long-Term Average Annual Volume Dredged.

7.2.3.1.6 Sediment Basin Efficiency.

The Sediment Basin is maintained to a depth of 40 feet. It was not deepened to 42 feet when the inner harbor channel was deepened in 1994 and is therefore at a higher elevation than the navigation channel. Two questions concerning the depth of the Sediment Basin have been raised. First, does the depth difference between the navigation channel and, second, the Sediment Basin reduce its efficiency and second, at what depth should the Sediment Basin be maintained to?

To determine if the increase in channel depth decreased the shoaling capacity of the Sediment Basin, the response of the shoaling in the Sediment Basin to the channel depth increase and cessation of the Tide Gate operation was analyzed. During the period 1981-1985, an average annual volume of 2,792,000 cubic was

dredged in the Sediment Basin. The average depth in the Sediment Basin in 1990 before dredging was 24.0 feet. During the 1997-2004 period, the average annual volume dredged in the Sediment Basin was 1,555,000 cubic yards and the average depth before dredging was 32.5 feet. Figures 7-63 to 7-65 contain surface plots of the Sediment Basin depths for the before dredging conditions in 1990, 2003 and the difference between the 1990 and 2003 before dredging surfaces. Figure 7-66a contains cross section plots at station 10+000 in the Sediment Basin for the before dredging conditions in 1990 and 2003. During both periods, the depth to which the Sediment Basin shoals is at least 10 feet above the channel depth. The shoaling in the Sediment Basin to an elevation 10 feet above the channel depth indicates that the sediment shoaling in the basin is suspended sediment and the depth difference between the channel and the basin is not the controlling factor for Sediment Basin shoaling. The change in shoaling conditions between the periods 1981-1985 to 1997-2004 was due to an increase in ebb flow velocities which controls the depth to which the basin shoals. Based on current measurements with and without the Tide Gate operating it was reported in Reference 2.4 that the maximum ebb tide velocities in the Sediment Basin are reduced from about 3 feet per second to less than 1 foot per second when the tide gates are operating. The depth to which the Sediment Basin shoals is not controlled by the depth difference between the basin and the inner harbor channel but by the ebb flow velocities in the basin.

To calculate the present efficiency of the Sediment Basin without the Tide Gate operating, the volume dredged distributions in Figure 7-46 were used to calculate the percent change in the volume dredged from stations 40+000 to 66+000, - 73%, and this change is attributed to the operation of the Sediment Basin, Section 7.2.3.1.4.1. The volume dredged between stations 40+000 to 66+000 during the period 1997 to 2004, 572,800 cubic yards, should be 27% of the volume that would have shoaled between stations 40+000 and 66+000 without the Sediment Basin or the SLNG turning basin, 2,121,500 cubic yards. The 73% reduction of the 2,121,500 cubic yards that would have shoaled between stations 40+000 and 66+000 is 1,548,700 cubic yards, which is 76% of the volume dredged in the Sediment Basin, 1,555,400 cubic yards, and the SLNG turning basin, 487,1000 cubic yards. The 76% is the percentage of sediment that shoals in the Sediment Basin and SLNG turning basin that would have shoaled in the navigation channel. The physical modeling tests for the Sediment Basin design predicted a reduction in channel shoaling of 86%, Figure 7-13. The 86% reduction in channel shoaling was based on ability of the Sediment Basin to filter a model shoaling material over a 119 tidal cycles. The reduction predicted by the model is used as the maximum reduction since it is based on the long term filtering capacity of the Sediment Basin and it is a very high efficiency. It would be unreasonable to assume that the Sediment Basin could eliminate all of the shoaling between stations 40+000 to 66+000. To calculate how much would have to be removed from the Sediment Basin to achieve a 86% reduction in channel shoaling, the 86% was applied to the 2,121,500 cubic yards that would shoal between stations 40+000 to 66+000 to get 1,824,500 cubic yards. The

shoaling between stations 40+000 to 66+000 would have to be reduced by an additional 269,100 cubic yards. Because the Sediment Basin traps channel sediment at a 76% efficiency the capacity the Sediment Basin needs to increase in volume by 354,000 cubic yards. Using the ratio 1.23, developed in the preceding section, to adjust this increase to the present long-term average gives a volume of 425,400 cubic yards. The Sediment Basin volume increases versus 1-foot depth increases are contained in Table 7-15. Using the 425,400 cubic yard volume and Table 7-15, the Sediment Basin would need to be deepened by 2.0 feet to achieve maximum efficiency.

Increasing the depth of the Sediment Basin by 1-foot would trap an additional 244,444 cubic yards and prevent 185,800 cubic yards from settling in the navigation channel. Increasing the depth of the Sediment Basin by 2 feet would trap slightly more than the additional 425,400 cubic yards required to achieve 354,000 cubic yards reduction of shoaling in the navigation channel. Based on the results of the physical model test, additional depth increases beyond 2 feet would not trap additional sediment from that which would have settled in the navigation channel.

Sediment Basin Depth Increase (Feet)	Sediment Basin Volume Increase (Cubic Yards)
1	244,444
2	488,889
3	733,333
4	977,778
5	1,222,222

Table 7-14 Sediment Basin Depth Increase Versus Volume Increase.

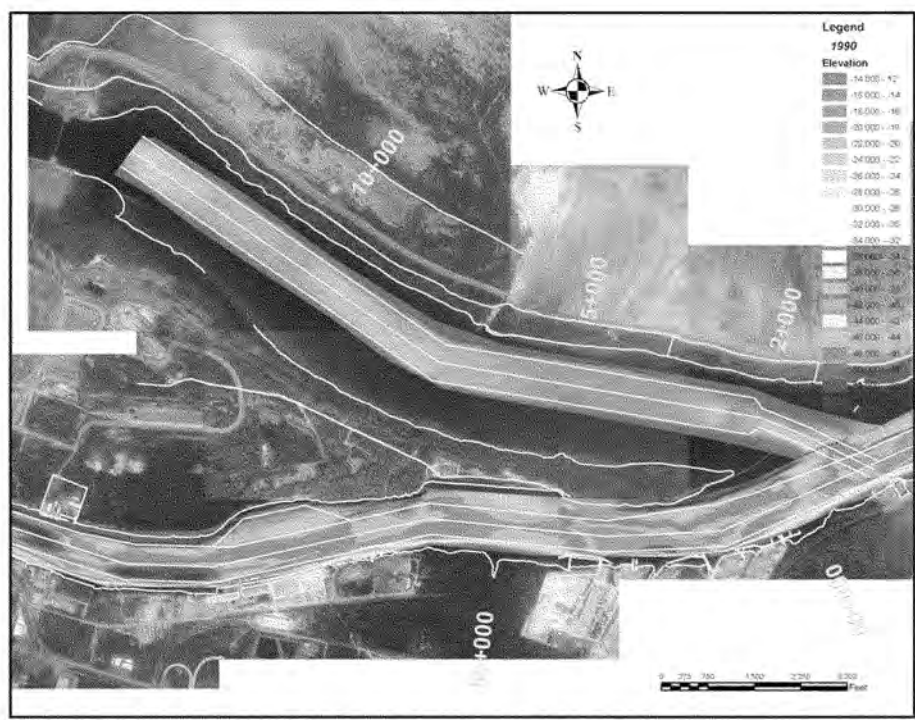


Figure 7-61 Sediment Basin 1990 Before Dredging Surface.



Figure 7-62 Sediment Basin 2003 Before Dredging Surface.

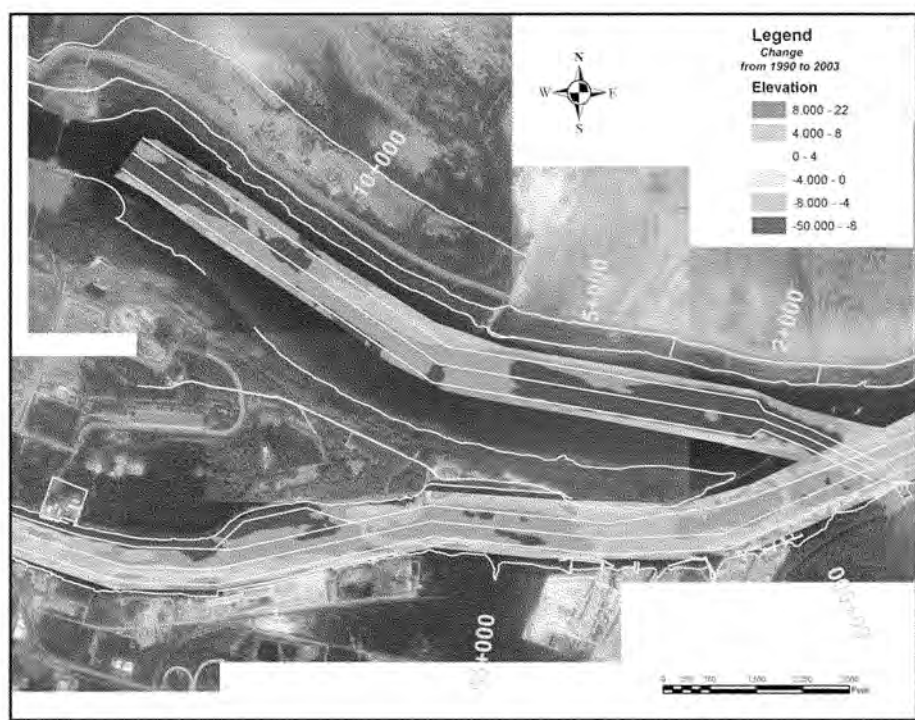


Figure 7-63 Sediment Basin Change from 1990 Before Dredging to 2003 Before Dredging Surface.

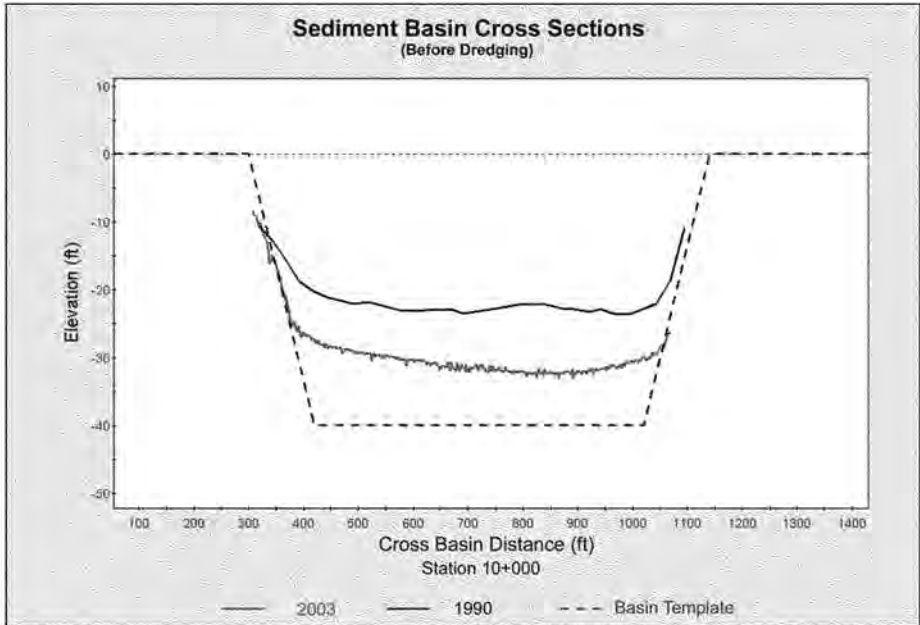


Figure 7-64a Sediment Basin Before Dredging Cross Sections.

7.2.3.1.7 Discontinued Use of the Sediment Basin

A mitigation feature under consideration is to discontinue dredging the sediment basin which will reduce the amount of salinity moving up back river. If the use of the sediment basin is discontinued, the sediment that is annually trapped in the sediment basin will begin to settle in the river channel in a pattern similar to that which occurred before the construction of the sediment basin. The river channel shoaling distributions, before and after construction of the sediment basin, are plotted in Figure 7-66b. After construction of the sediment basin, the river channel shoaling volume between stations 40+000 and 70+000 was reduced by 2,050,000 cubic yards. The 1,906,000 cubic yards that shoaled in the sediment basin, which is adjacent to the reach of river between stations 40+000 to 70+000, was responsible for the majority of the shoaling reduction in the river channel. The remainder of shoaling reduction, between stations 40+000 and 70+000, is account for in the enlarged turning basins upstream. If the sediment basin is not maintained, the sediment that would have settled in the sediment basin will now be deposited in the river channel between stations 40+000 and 70+000. The distribution would be similar to the without sediment basin distribution in Figure 7-66b. A tabular form of the predicted without and with sediment basin distributions are contained in Table 15a.

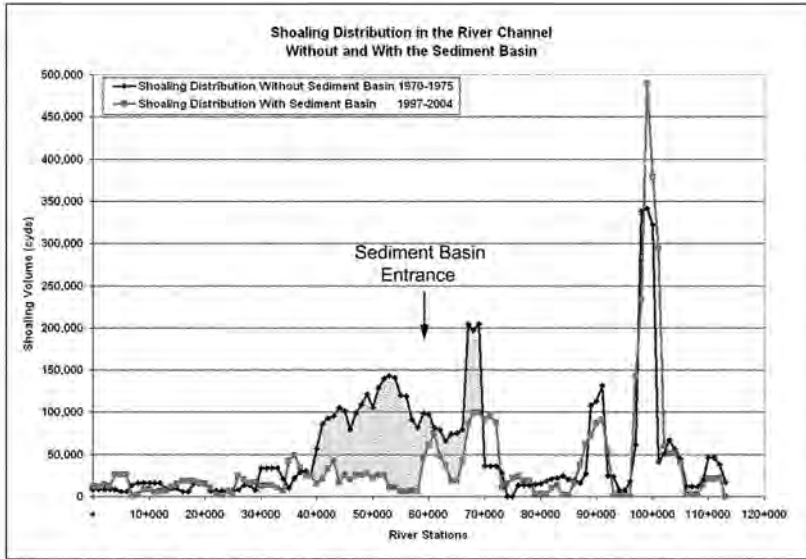


Figure 7-64b Shoaling Distribution Without and With the Sediment Basin.

Station	Long Term Shoaling Average CYDS Existing Conditions	Long Term Shoaling Average CYDS Without Sediment Basin	Station	Long Term Shoaling Average CYDS Existing Conditions	Long Term Shoaling Average CYDS Without Sediment Basin	Station	Long Term Shoaling Average CYDS Existing Conditions	Long Term Shoaling Average CYDS Without Sediment Basin
0	11,866	11,866	38+000	24,392	24,392	76+000	23,825	23,825
1+000	11,866	11,866	39+000	24,867	24,867	77+000	18,418	18,418
2+000	13,946	13,946	40+000	15,157	50,776	78+000	18,418	18,418
3+000	12,266	12,266	41+000	21,054	78,654	79+000	3,746	3,746
4+000	25,921	25,921	42+000	32,835	79,121	80+000	2,959	2,959
5+000	25,921	25,921	43+000	42,262	77,469	81+000	2,959	2,959
6+000	26,184	26,184	44+000	17,155	100,139	82+000	9,995	9,995
7+000	1,026	1,026	45+000	25,345	91,506	83+000	13,606	13,606
8+000	2,445	2,445	46+000	20,211	71,338	84+000	1,586	1,586
9+000	8,337	8,337	47+000	25,524	89,525	85+000	1,586	1,586
10+000	8,160	8,160	48+000	25,158	99,451	86+000	16,780	16,780
11+000	5,337	5,337	49+000	26,665	111,788	87+000	36,899	36,899
12+000	6,781	6,781	50+000	22,060	97,610	88+000	63,586	63,586
13+000	6,888	6,888	51+000	25,242	120,877	89+000	72,272	72,272
14+000	11,533	11,533	52+000	25,242	131,767	90+000	86,497	86,497
15+000	14,790	14,790	53+000	10,667	142,640	91+000	91,420	91,420

16+000	18,308	18,308	54+000	11,369	139,781	92+000	54,434	54,434
17+000	18,756	18,756	55+000	6,245	119,986	93+000	2,050	2,050
18+000	18,764	18,764	56+000	5,751	119,605	94+000	2,050	2,050
19+000	15,669	15,669	57+000	6,683	90,569	95+000	2,050	2,050
20+000	15,186	15,186	58+000	6,011	81,041	96+000	1,693	1,693
21+000	9,740	9,740	59+000	46,565	79,048	97+000	142,429	142,429
22+000	2,516	2,516	60+000	60,347	70,804	98+000	232,556	232,556
23+000	1,858	1,858	61+000	74,865	74,865	99+000	489,662	489,662
24+000	6,023	6,023	62+000	47,994	57,927	100+000	378,601	378,601
25+000	4,572	4,572	63+000	37,084	49,992	101+000	293,983	293,983
26+000	24,413	24,413	64+000	18,925	67,354	102+000	60,257	60,257
27+000	19,840	19,840	65+000	18,679	68,045	103+000	50,618	50,618
28+000	16,054	16,054	66+000	42,012	60,960	104+000	51,599	51,599
29+000	16,521	16,521	67+000	85,725	168,061	105+000	40,057	40,057
30+000	12,758	12,758	68+000	99,524	154,911	106+000	2,684	2,684
31+000	13,158	13,158	69+000	99,524	162,270	107+000	2,684	2,684
32+000	13,158	13,158	70+000	91,460	91,460	108+000	2,684	2,684
33+000	10,511	10,511	71+000	95,409	95,409	109+000	13,305	13,305
34+000	6,595	6,595	72+000	87,680	87,680	110+000	21,336	21,336
35+000	42,128	42,128	73+000	9,810	9,810	111+000	21,336	21,336
36+000	49,315	49,315	74+000	14,794	14,794	112+000	22,334	22,334
37+000	34,386	34,386	75+000	21,570	21,570			

Table 7-14a Tabular Shoaling Distribution Without and With the Sediment Basin.

7.2.3.1.7.1 The Effect of Mitigation Plan 6a on the Shoaling Distribution.

The features of mitigation plan 6a are described in Figure 7-66c. To predict if

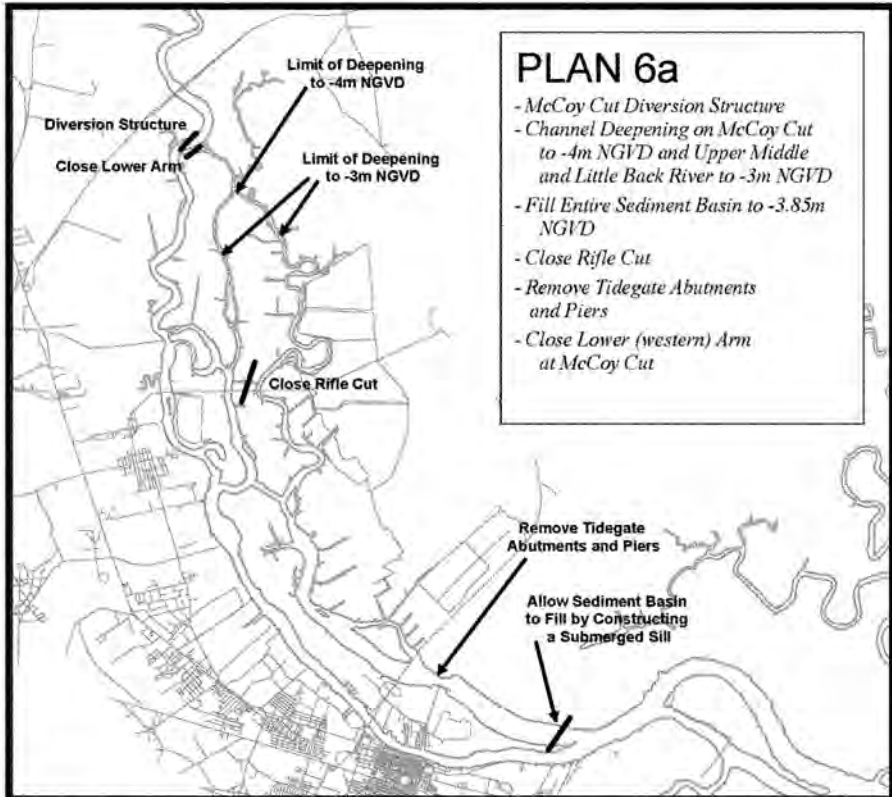


Figure 7-64c Mitigation Plan 6a.

there will be a shift of the shoaling distribution due to the implementation of plan 6a, the numerically modeled shift of the salinity distribution associated with the implementation of the mitigation plan 6a was compared to the measured shift of the salinity distribution and the corresponding shoaling shift in a physical model of a deepened Savannah River. The use of a shift in the salinity distribution as an indicator of a shift in the shoaling distribution is valid since not only is the shoaling process sensitive to salinity concentrations but the hydrodynamics that affect the shoaling distribution also affect the salinity concentration. (See Section 7.2.3.1.2)

A physical model of the Savannah River was constructed at the U. S. Army Engineer Waterways Experiment Station in 1955 to investigate the effects of increasing the navigation channel dimensions (Reference 2.5). Figure 7-66d contains the plan for Test 1 from Reference 2.5. Test 1 is a 2 foot deepening of the navigation channel. The shift in the salinity distribution for normal flow conditions is displayed in Figure 7-66e. The average of the shift at high and low slack water for location of 10,000 part per million (10 parts per thousand) is approximately 10,000 feet. For this shift in salinity distribution, the shoaling distribution did not change significantly, as shown in Figure 7-66f.

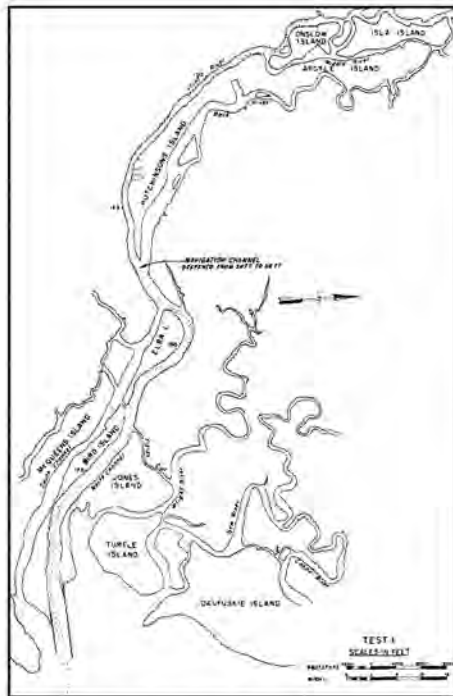


Figure 7-64d Test 1 Plan. Deepen Base Condition Channel by 2 feet.

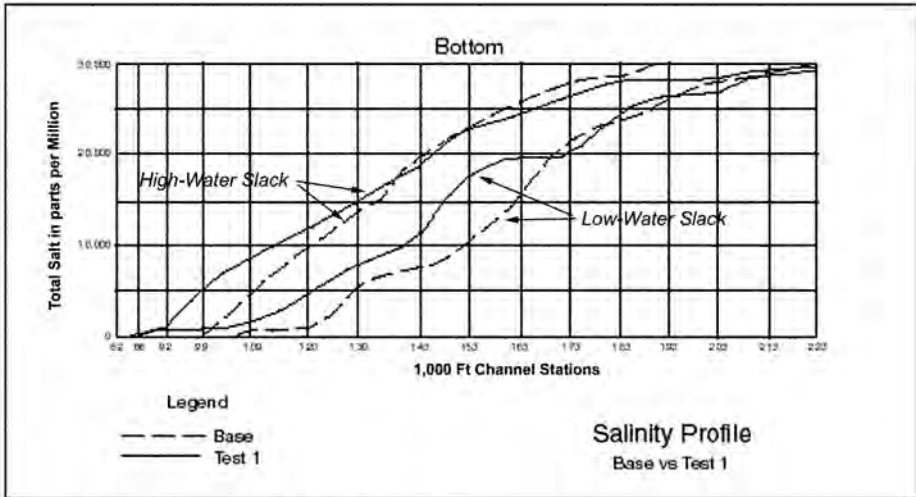


Figure 7-64e Test 1 Shift in Salinity Profile.

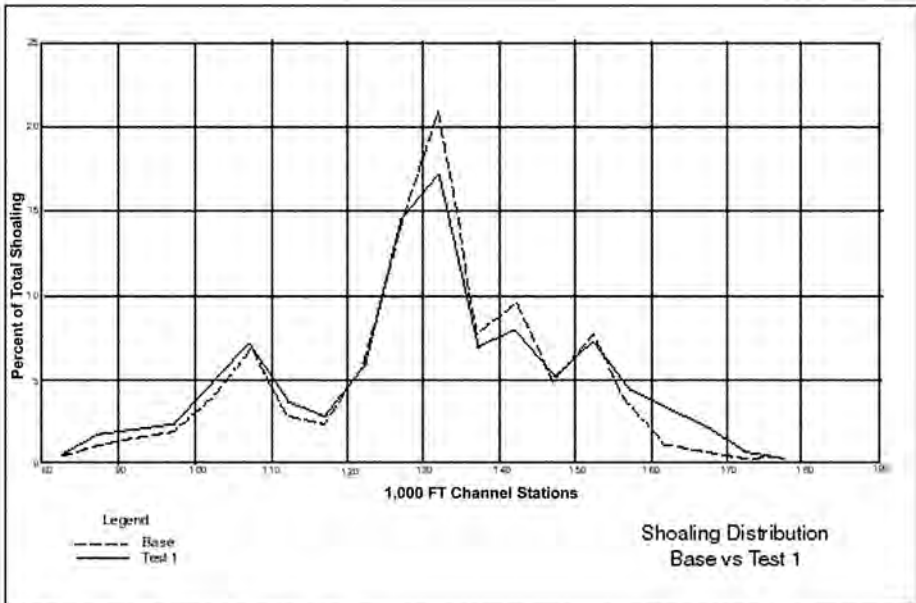


Figure 7-64f Test 1 Shoaling Distribution.

The salinity distributions as predicted by the three-dimensional hydrodynamic model Environmental Fluid Dynamics Code (EFDC) is shown in Figure 7-66g for

the 6 foot deepening plan 6 and the 6 foot deepening plan with mitigation plan 6a implemented. The average shift in the 10 parts per thousand concentration is on the order of 500 ft, Figure 7-66g. The predicted salinity shift for plan 6a is much less than the modeled salinity shift for Test 1 which did not produce a significant change in the shoaling distribution. Based on the small predicted change in the salinity distribution for plan 6a, implementation of plan 6a will not change the shoaling distribution from the 6 foot deepening plan 6. The predicted salinity changes for the other deepening alternatives are less than for plan 6a and therefore they also will not affect the without mitigation shoaling distribution.

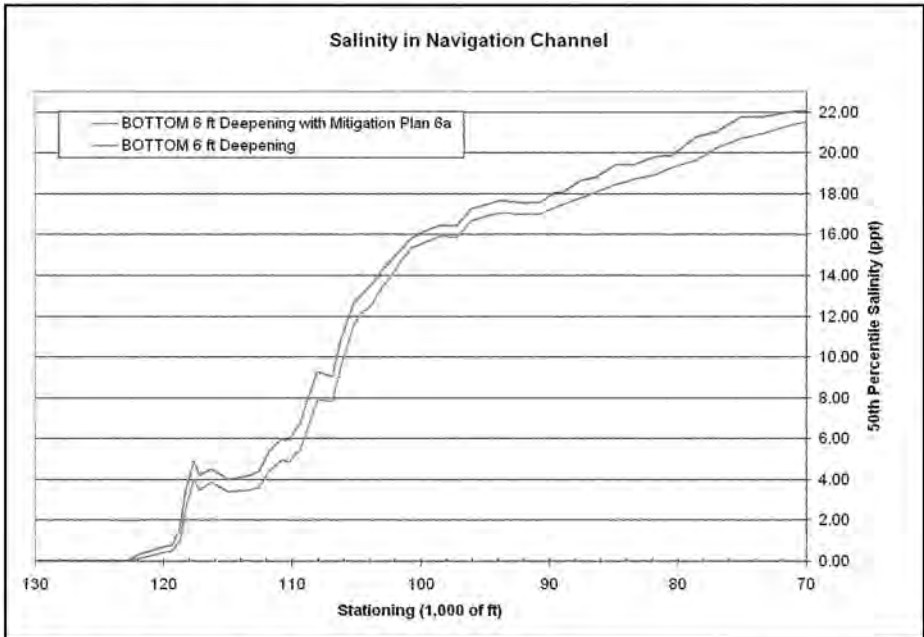


Figure 7-64g. Shift in Salinity Profile Due to Mitigation Plan 6a.

7.2.3.1.8 Berth Maintenance

The berths in Savannah Harbor are maintained by agitation dredging. Table 7-16 lists the agitation dredging permit holders and their approximate location. Records of the agitation volumes dredged go back to 1995. The total volume dredged by agitation is plotted in Figure 7-66 for the period 1995 to 2004.

Permit Holders	Approximate Channel Station
S.T. Services	60+500
Conoco Phillips	61+000
S.T. Services Dock 2	62+300
G P Gypsum	63+600
East Coast Term.	68+450
Ga. Ports Auth. O.T.	78+000-82+000
Colonial Oil (Plant 1)	83 + 424
Gobal Ship Systems	84+000
Colonial Oil (Plant 2)	85 + 594
International Paper	88+500
Citgo	90+000
Colonial Ga. Kaolin	91+000
Conbulk Mar. Term. (S. Bulk)	91+872
Ga. Ports Auth. G.C.	92+000-102+000
Savannah Sugar	104+100
G.P.A. Berth 7	109+000

Table 7-15 Agitation Dredging Permit Holders.

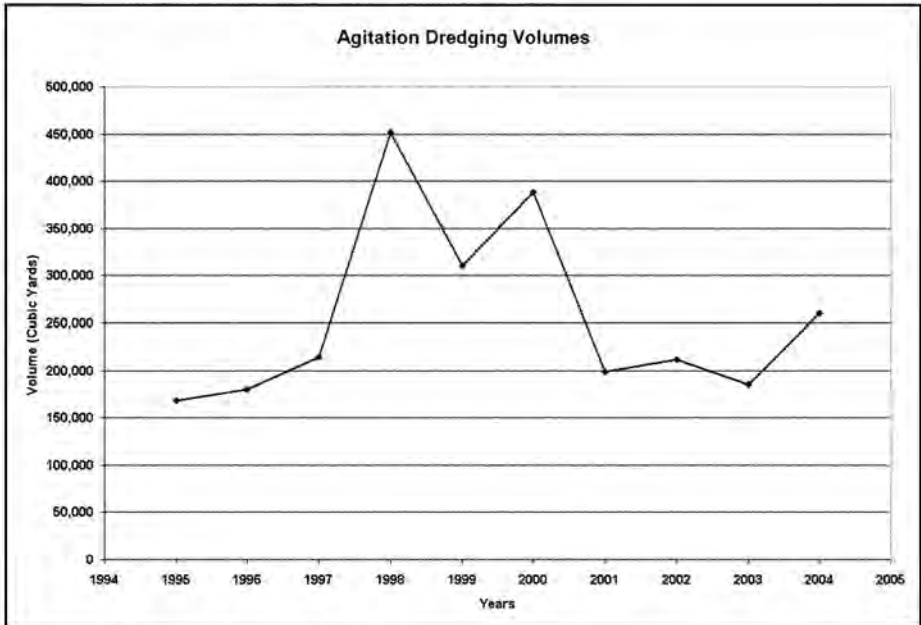


Figure 7-64 Agitation Dredging Volumes.

The existing shoaling pattern is not predicted to change with project depth increase and therefore the agitation volumes dredged are not predicted to change due to a project depth increase.

7.2.3.2 Entrance Channel

7.2.3.2.1 Entrance Channel Shoaling Response to Depth Increases

At the present project depth of 44 feet mllw, the entrance channel is a sediment sink, which is a total interdiction of the littoral transport. Increases in depth will not increase the channel ability to capture sediment. The average annual shoaling volume record did show an apparent increase in shoaling after the last deepening but this was due to the short post-deepening record not including both a high and low shoaling period as did the pre-deepening record. A small volume increase is predicted based on an increase in channel length.

The location of the entrance channel is shown in Figure 7-67. The entrance channel is 42 feet deep (mllw) and is 500 feet wide from station 0+000 to -14+000. From station -14+000 to -60+000 the channel is 44 feet deep (mllw) and 600 feet wide. The entrance channel is a trap for all of the sediment that is transported to it. To substantiate that the entrance channel is sediment sink, the depth of closure, or the depth beyond which the bottom doesn't change with storms, was calculated. Hallermeier proposed the following equation to estimate the depth of closure, Reference 2.10.

$$h_c = 2 H + 11 \sigma_H$$

Where

h_c is the depth of closure.

H is the annual mean significant wave height.

σ_H is the standard deviation of significant wave height.

Using, in the above equation, an annual mean significant wave height of 3.28 feet and a standard deviation of 1.64 feet from station 368 of the Wave Information Study database, <http://frf.usace.army.mil/wis>, produces a depth of closure of 24.6 feet. As will be shown in the following section on advance maintenance, the shoals in the entrance change rarely rise above a depth of 40 feet. Sediment that is presently transported into the entrance channel remains there until it is dredged and an increase in depth will not make the entrance channel a more effective trap. The shoaling in the entrance channel is a function of the amount of sand transported to it, which is then trapped in it.

Another indication that the entrance channel is a total interdiction of the sediment entering the inlet environment is that the entrance channel completely cuts through the inlet's ocean bar. The ocean bar is the end product of the integrated effects of tidal currents, wave action and the associated sediment transport and deposition, Reference 2.11. Channel depths deeper than the depth at which the

seaward tip of the ocean bar meets the offshore sea bottom will cause the channel to be a total interdiction of the littoral drift. The color-coded depths in Figure 7-67 indicate that the bulbous shape of the ocean bar does not extend beyond the 30 to 35 foot depth band. This is in agreement with the shoaling distribution along the entrance channel, Figure 7-68, which has virtually no shoaling beyond entrance channel station 50+000.

Maintenance dredging records for the entrance channel were available for the period 1974 to 2005. Dredging volumes for the entrance channel were also available from annual reports for the period 1975 to 2002. Both sets of dredging data are shown in Figure 7-69. The data from the dredging records reflect the total volume dredged in a calendar year. The annual reports give the volume dredged that was paid for in a fiscal year. There is a general agreement between the two data sets but the dredging record data appears to be missing several years. Table 7-17 contains the average annual volumes dredged in the entrance channel for the period of record, the pre-1994 deepening period and the post 1994 deepening period. Both data sets show an increase in dredging of over 100,000 cubic yards from the pre to post 1994 deepening periods. The explanation for the apparent shoaling increase is due to the difference in length of records of the pre and post deepening periods. The pre-deepening period is 19 years long and contains a cycle of both high and low shoaling periods. The post-deepening period is 8 years and contains only a high shoaling period with shoaling magnitudes comparable to those of the pre deepening high shoaling period.

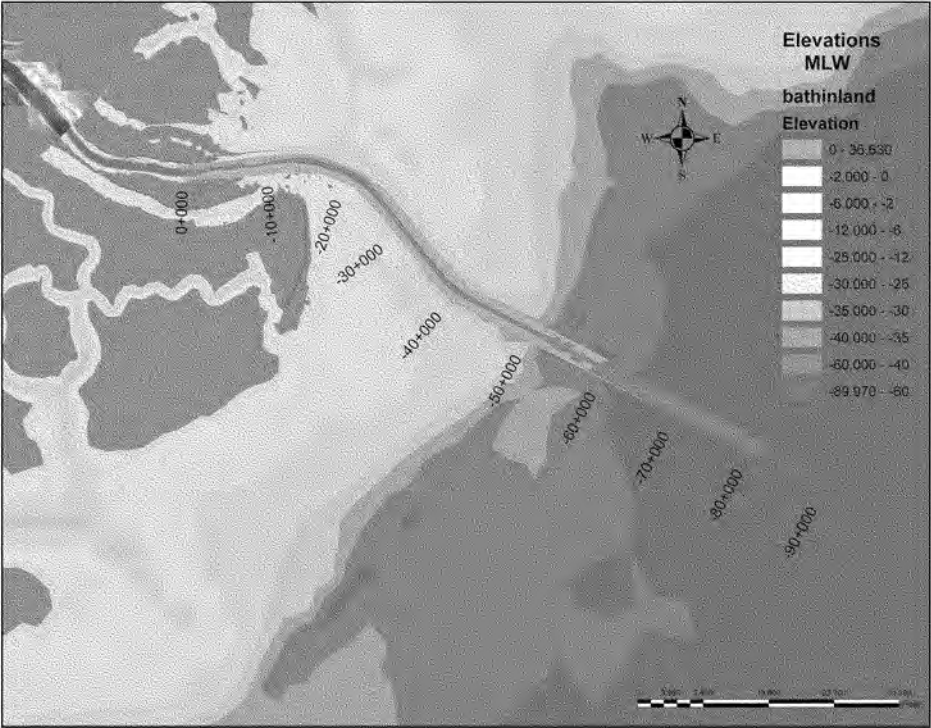


Figure 7-65 Entrance Channel.

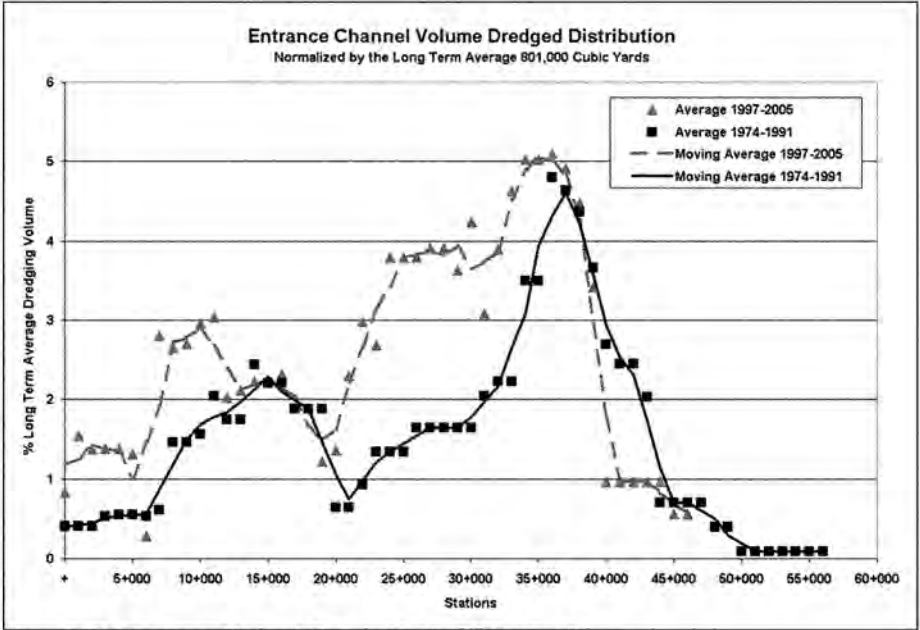


Figure 7-66 Entrance Channel Volume Dredged Distributions.

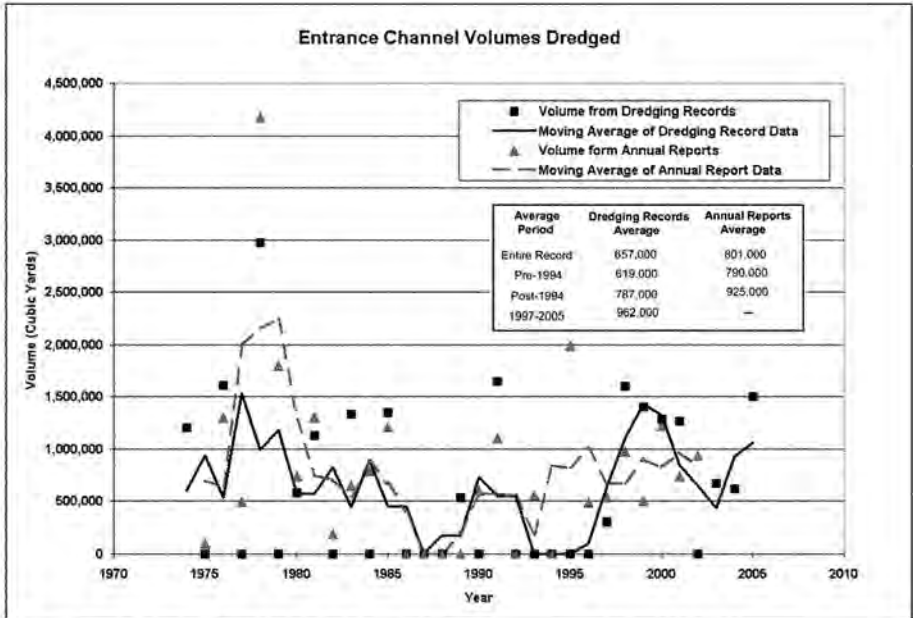


Figure 7-67 Entrance Channel Volumes Dredged.

Time	Period	Average Annual Volume	Average Annual Volume
Span		from Dredging Records	from Annual Reports
1974-2005	Period of Record	657,000	-
1975-2002	Period of Record	-	801,000
1974-1993	Pre-1994 Deepening	619,000	-
1975-1993	Pre-1994 Deepening	-	790,000
1995-2005	Post 1994 Deepening	787,000	-
1995-2002	Post 1994 Deepening	-	925,000
1997-2005	Post 1994 Deepening	962,000	-

Table 7-16 Entrance Channel Average Annual Volumes Dredged.

The first step in determining the physical cause of the short term shoaling increase was to identify where the shoaling increase occurred. The entrance channel dredging volume distributions are plotted in Figure 7-68 for the periods

1974-1991 and 1997-2005. There was an increase in the volume dredged from station 0+000 to 12+000 and another increase from station 20+000 to 36+000.

With the shoaling increase locations identified, the channel surveys were examined to further investigate the nature of the shoaling increase. Entrance channel cross sections from before dredging surveys in 1991 and 2003 are plotted in Figures 7-70 through 7-74. The shoal surface in 2003 is higher than 1991 at station 9+000, 15+000, and 25+000 even though the channel is 4 feet deeper. The reverse is true for station 37+500 and 40+000. Of special interest are the elevations outside of the channel. The elevations outside of the channel are higher in 2003 than in 1991 at stations 9+000, 15+000 and 25+000. This indicates that shoals adjacent to the channel are growing and more sediment is moving into the area and into the entrance channel. The channel stations which show increases in dredging volumes, after the 1994 deepening, line up with the shoals to the north of the entrance channel, Figure 7-75. The entrance channel reach from station 12+000 to 20+000, which didn't show an increase in shoaling, lines up with the outer end of a channel that bifurcates the shoals to the north of the entrance channel and is maintained by the flow coming out of Calibogue Sound. The entrance channel is trapping more material because of the increase in sediment transport and not because of the 4-foot depth increase in 1994. This is evidenced by the growth of the shoals in the channel exceeding the 4-foot depth increase and the growth of the shoals outside of the channel adjacent to areas where increased dredge volumes occurred.

At a project depth of 44 feet the channel is trapping all of the littoral transport and only a small increase in the volume dredged is expected for potential channel depth increases due to a corresponding increase in channel length.

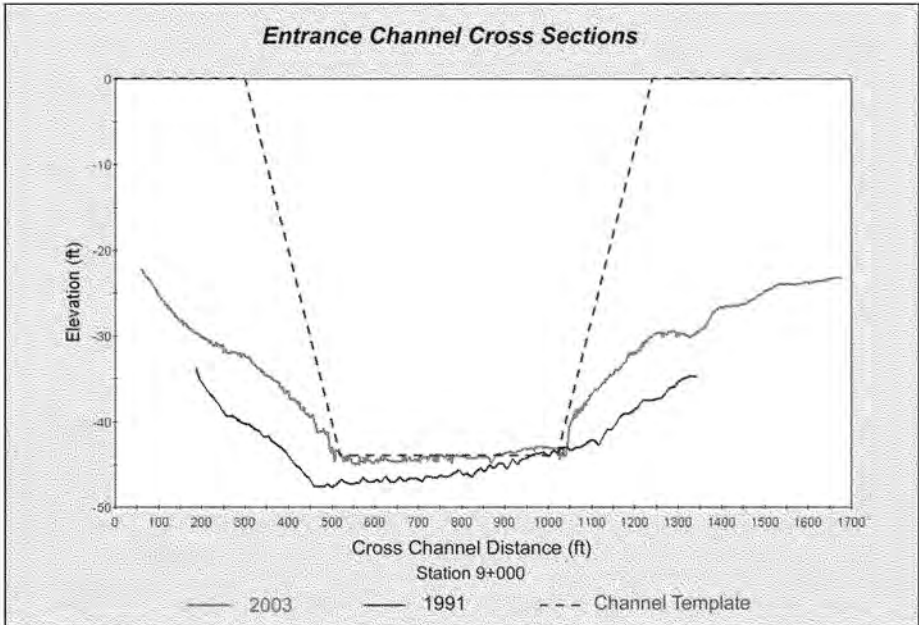


Figure 7-68 Before Dredging Cross Sections Entrance Channel Station 9+000.

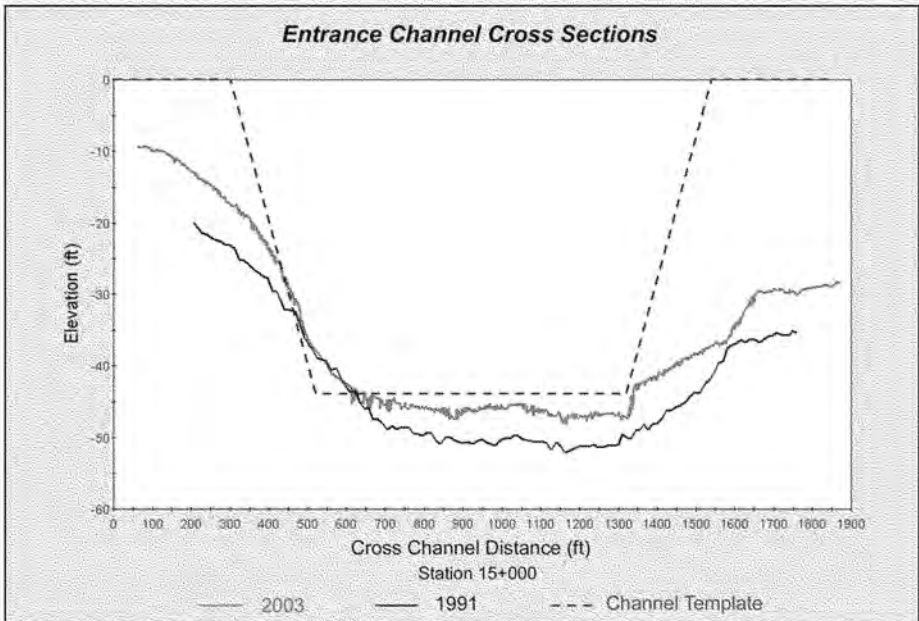


Figure 7-69 Before Dredging Cross Sections Entrance Channel Station 15+000.

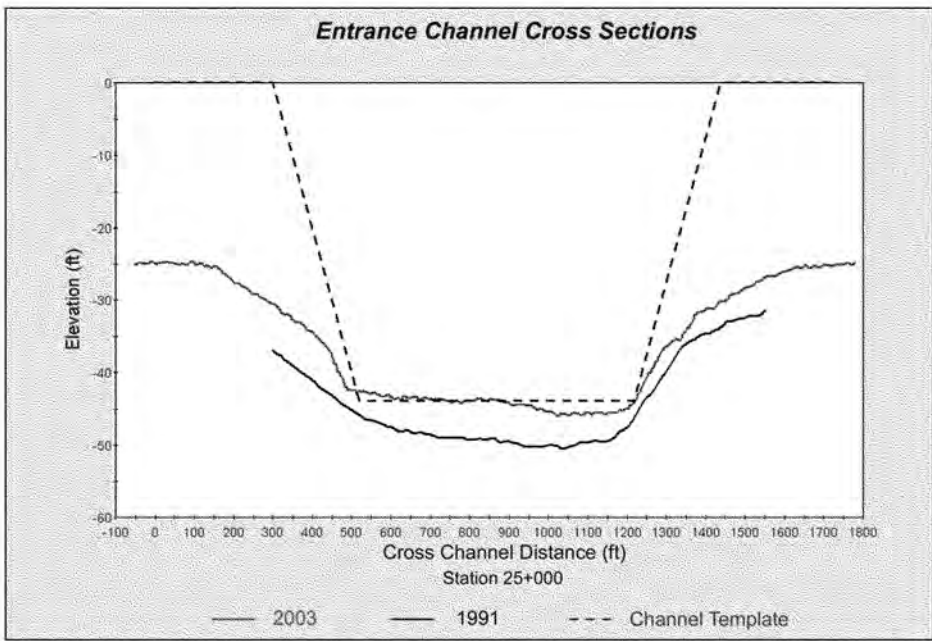


Figure 7-70 Before Dredging Cross Sections Entrance Channel Station 25+000.

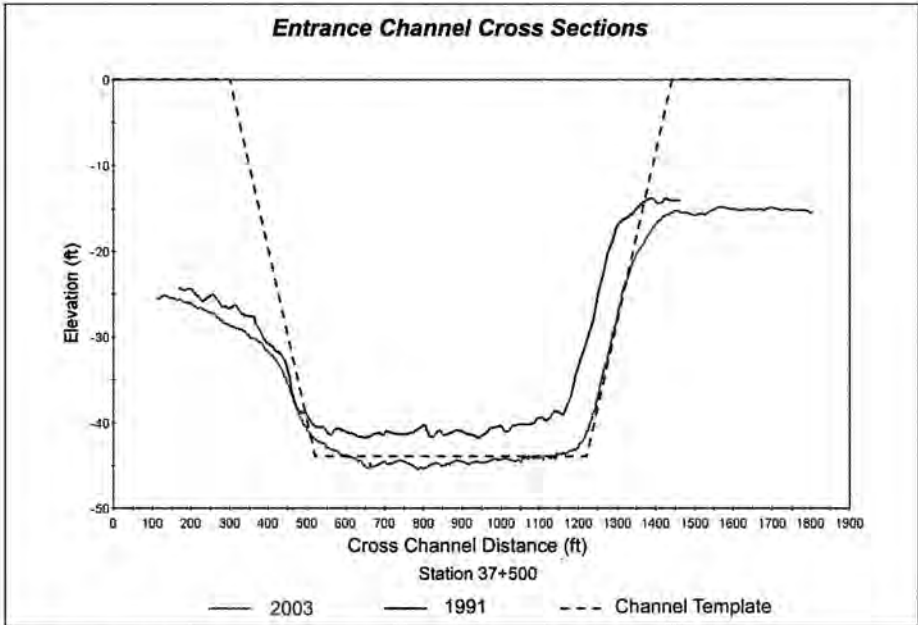


Figure 7-71 Before Dredging Cross Sections Entrance Channel Station 37+500.

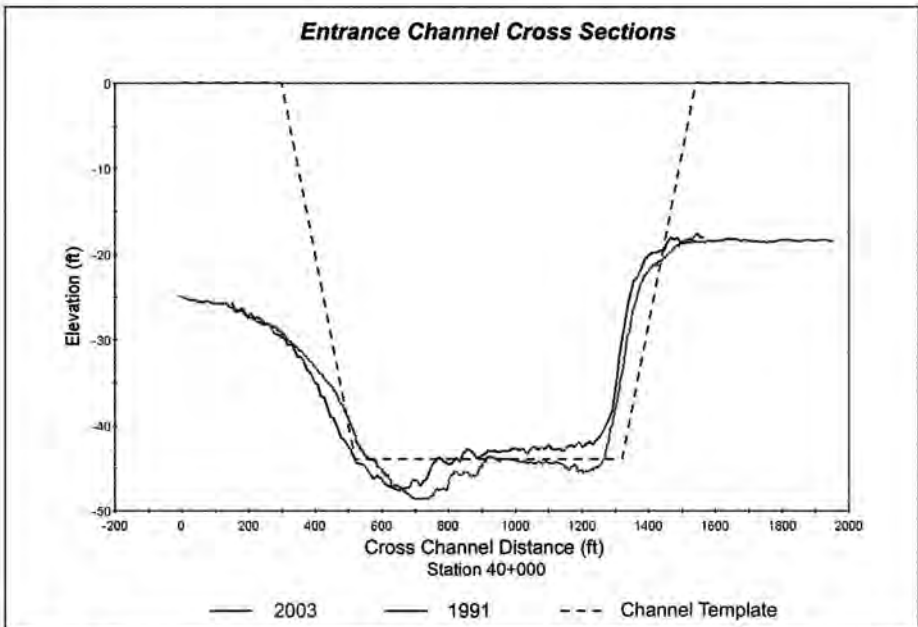


Figure 7-72 Before Dredging Cross Sections Entrance Channel Station 40+000.

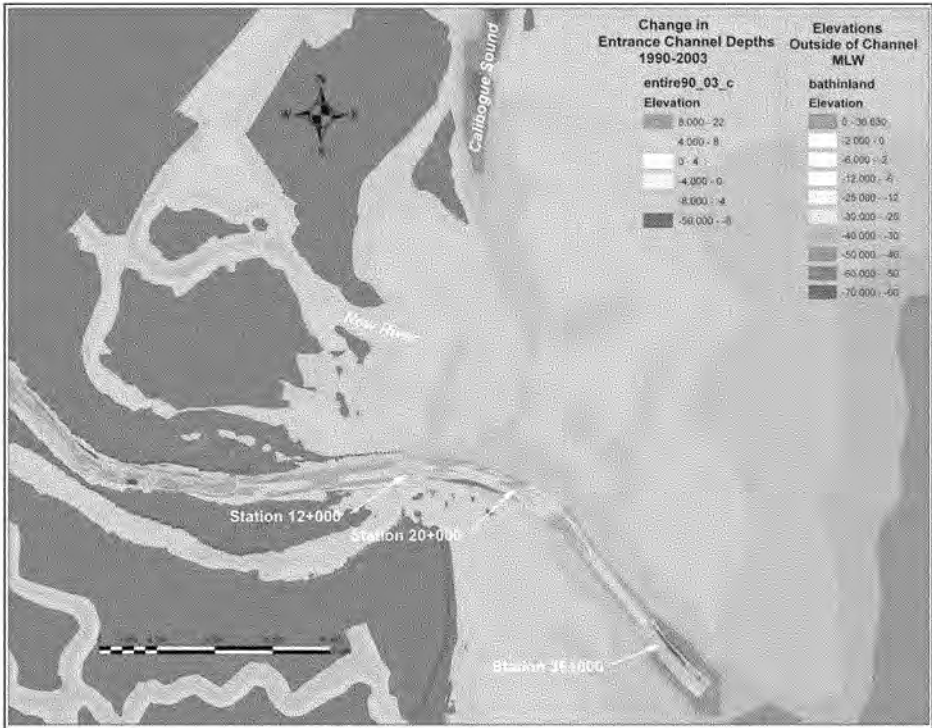


Figure 7-73 Shoals Adjacent to the Entrance Channel.

To determine channel length increases due to potential channel depth increases, the average entrance channel depths from station 0+000 to station 85+000 are shown in Figure 7-76. Based on the depths in Figure 7-76, the channel length increases beyond station 60+000 are shown in Table 7-18 for a range of channel depths.

The entrance channel between stations 50+000 and 60+000 was dredged twice between 1974 and 2005. A total of 92,000 cubic yards were removed during the two dredging operations. The average annual volume dredged from this reach was 300 cubic yards per 1,000 feet of channel. Applying this rate for the channel increases gives the volume increases, which are listed in Table 7-19 and plotted in Figure 7-77.

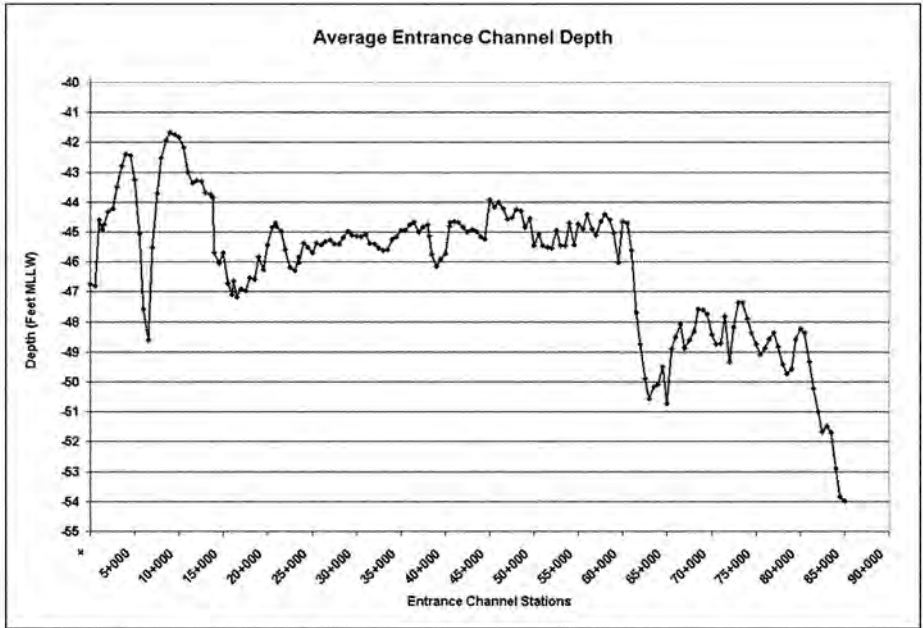


Figure 7-74 Average Entrance Channel Depths 1997.

Entrance Channel Depth	Channel Length Increase
45	1,000
46	1,250
47	1,500
48	14,000
49	21,000
50	21,500
51	22,000
52	23,500

Table 7-17 Entrance Channel Length Increases.

Entrance Channel Depth	Entrance Volume Dredged Increase
45	300
46	375
47	450
48	4,200
49	6,300
50	6,450
51	6,600
52	7,050

Table 7-18 Entrance Channel Volume Increases.

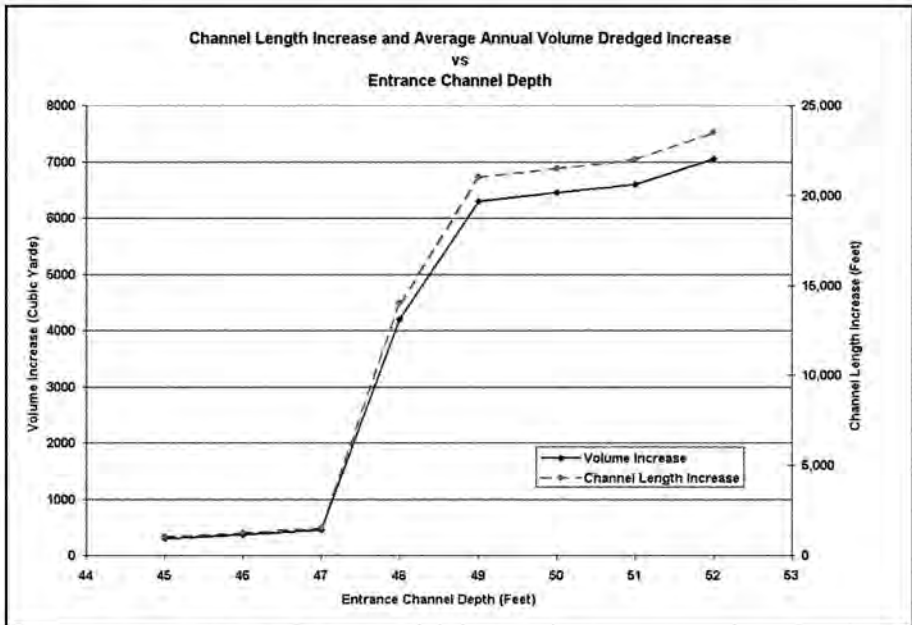


Figure 7-75 Channel Length and Volume Dredged Increases.

7.2.4 Advance Maintenance

7.2.4.1 Advance Maintenance After Deepening with Existing Operations.

Advance maintenance is authorized for Savannah Harbor to reduce the overall maintenance costs by decreasing the frequency of dredging. Dredging frequency is based on monthly project condition surveys. The condition surveys are taken along the four centerlines of the channel's quarters. When a shoal 2 feet or more above the project depth occurs at two adjacent quarters, a contractor is directed to remove the shoal. Figures 7-78 to 7-107 contain the

minimum depths along channel quarters from January 1997 to January 2005. Using the preceding dredging criteria, the existing advance maintenance areas, with the exception of Kings Island range, are providing acceptable navigation depths. The shoaling pattern is not predicted to change with future depth increases and the present advance maintenance areas do not need to be shifted due to future depth increases.

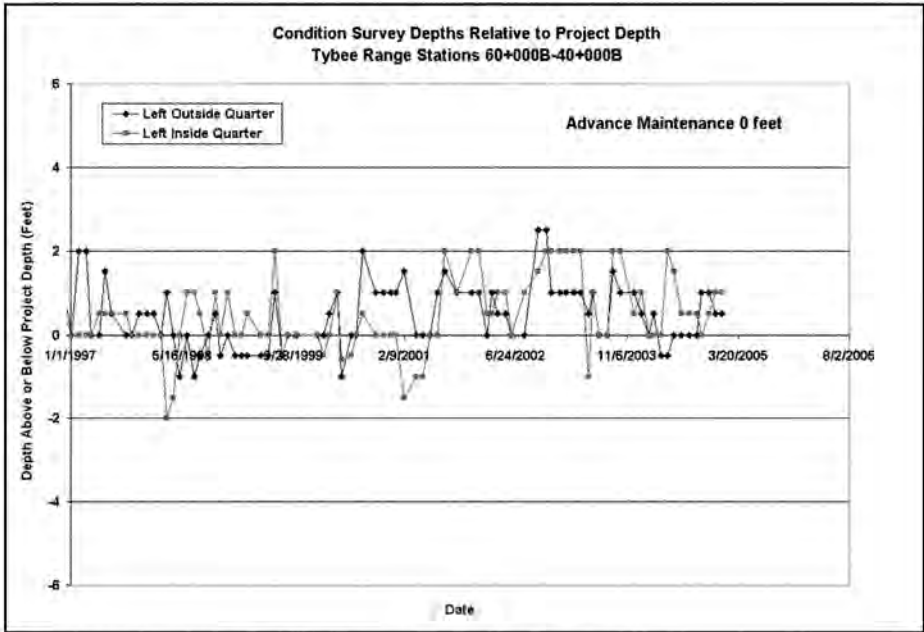


Figure 7-76 Condition Survey Left Quarter Depths, Tybee Range.

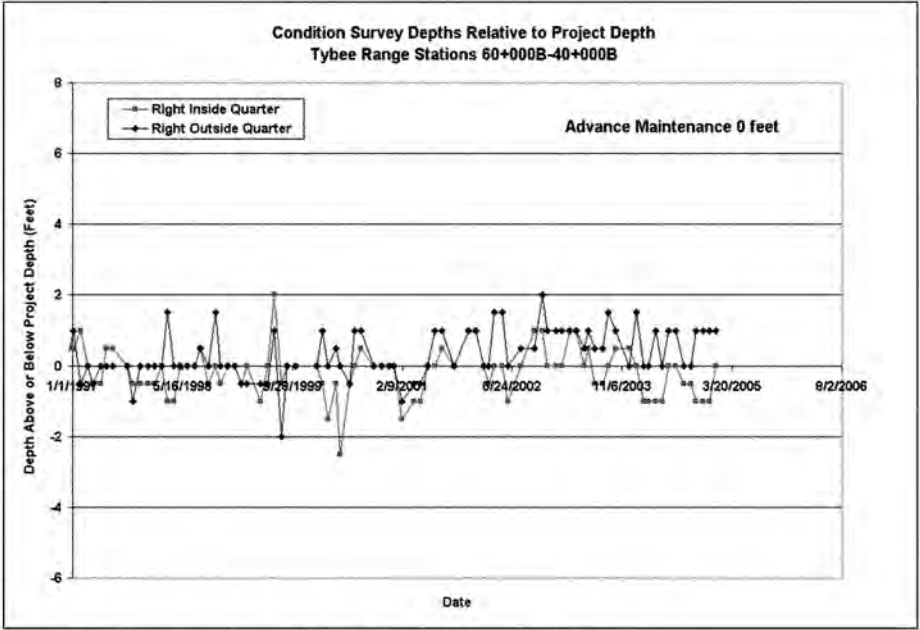


Figure 7-77 Condition Survey Right Quarter Depths, Tybee Range.

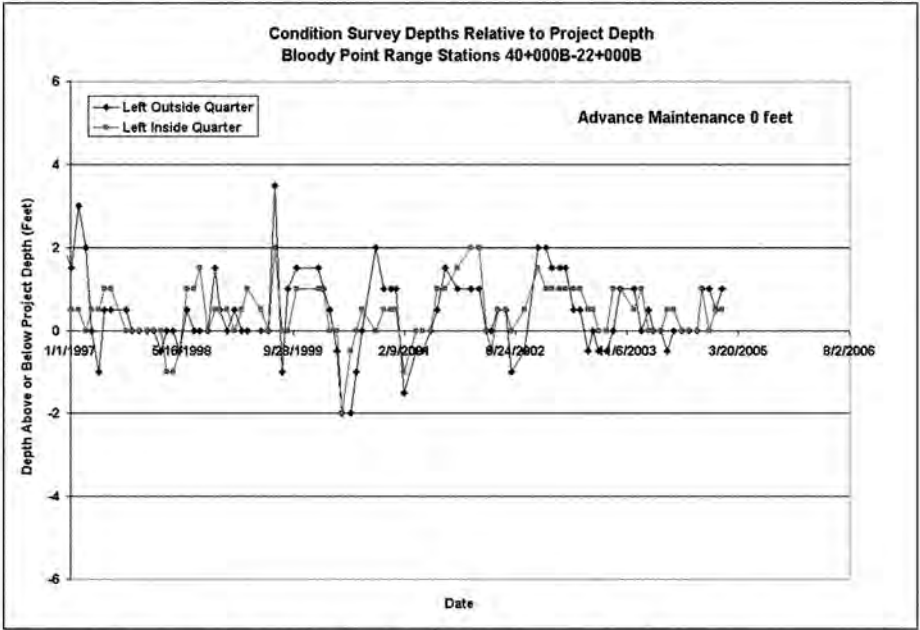


Figure 7-78 Condition Survey Left Quarter Depths, Bloody Point Range.

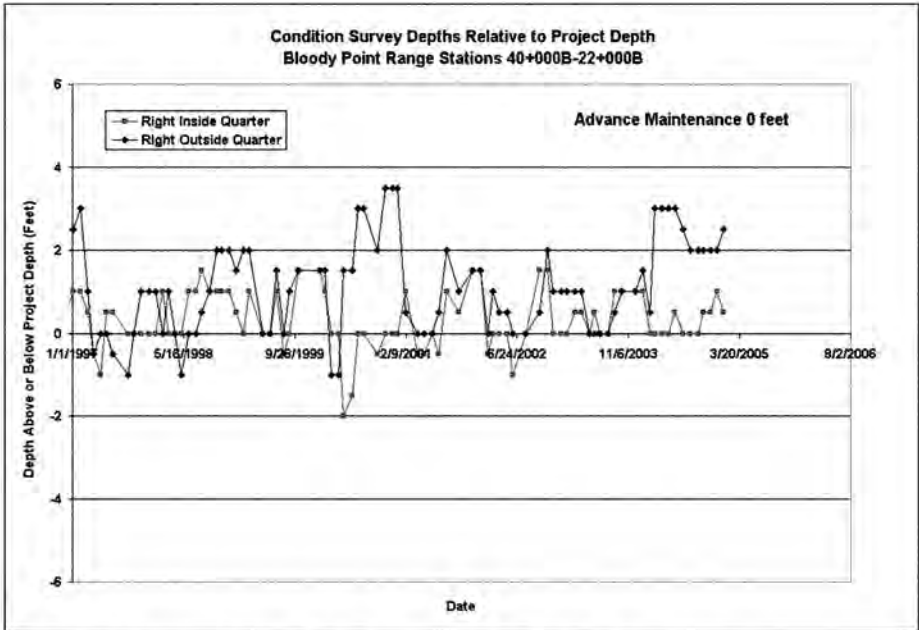


Figure 7-79 Condition Survey Right Quarter Depths, Bloody Point Range.

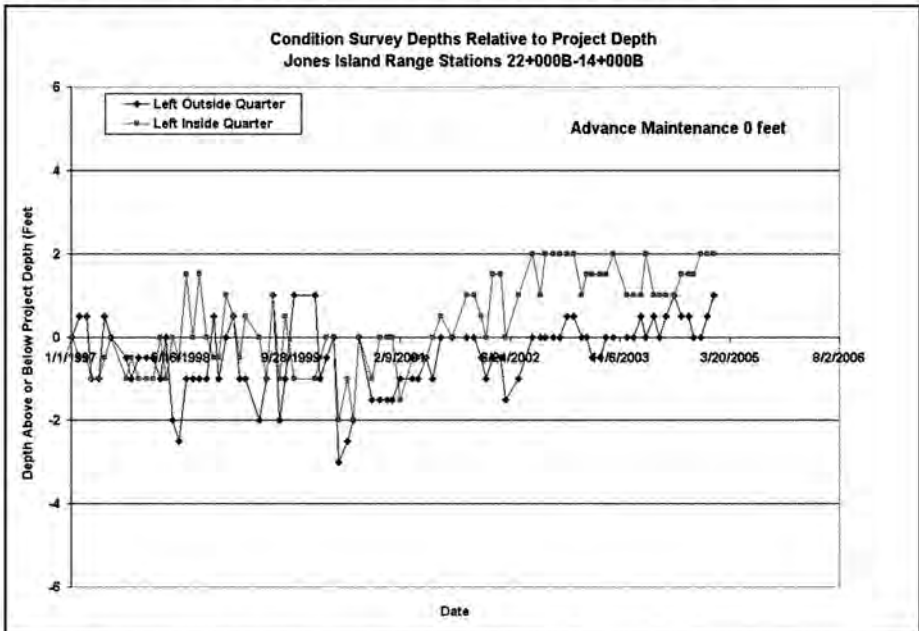


Figure 7-80 Condition Survey Left Quarter Depths, Jones Island Range.

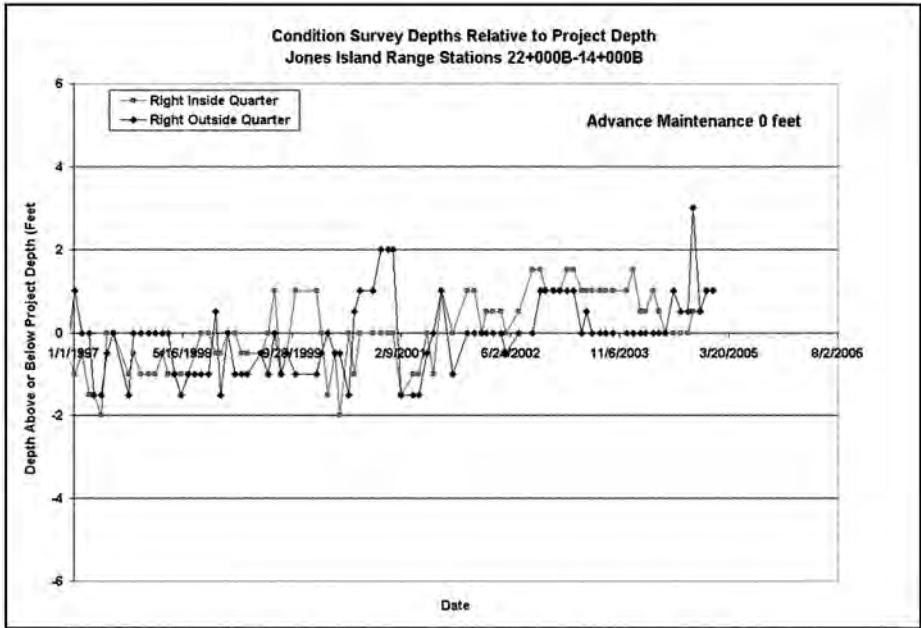


Figure 7-81 Condition Survey Right Quarter Depths, Jones Island Range.

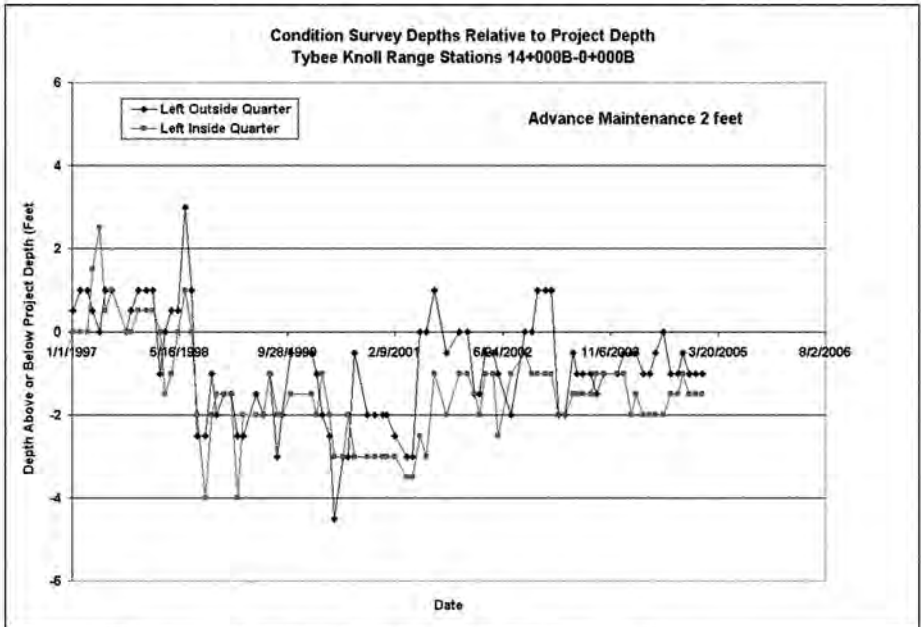


Figure 7-82 Condition Survey Left Quarter Depths, Tybee Knoll Range.

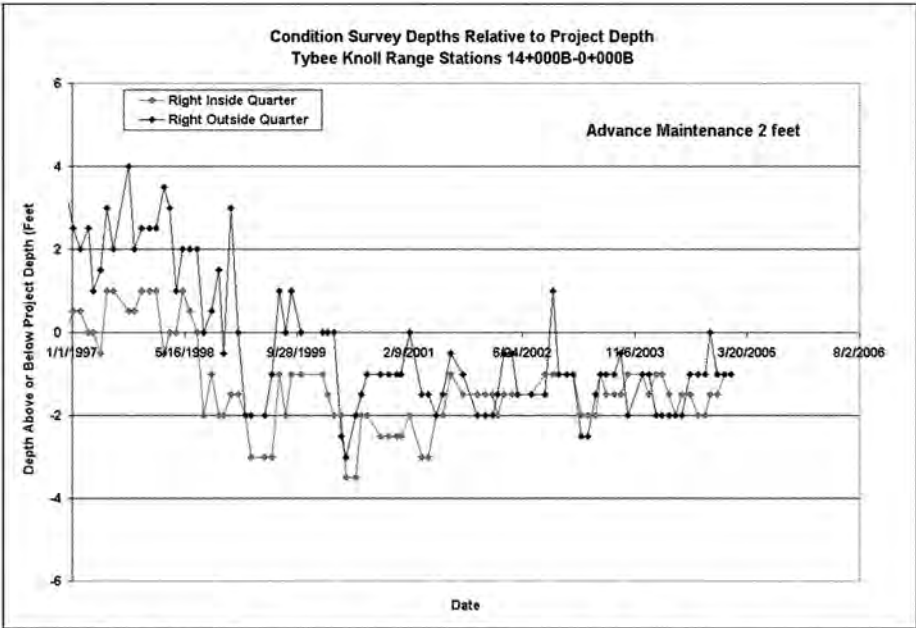


Figure 7-83 Condition Survey Right Quarter Depths, Tybee Knoll Range.

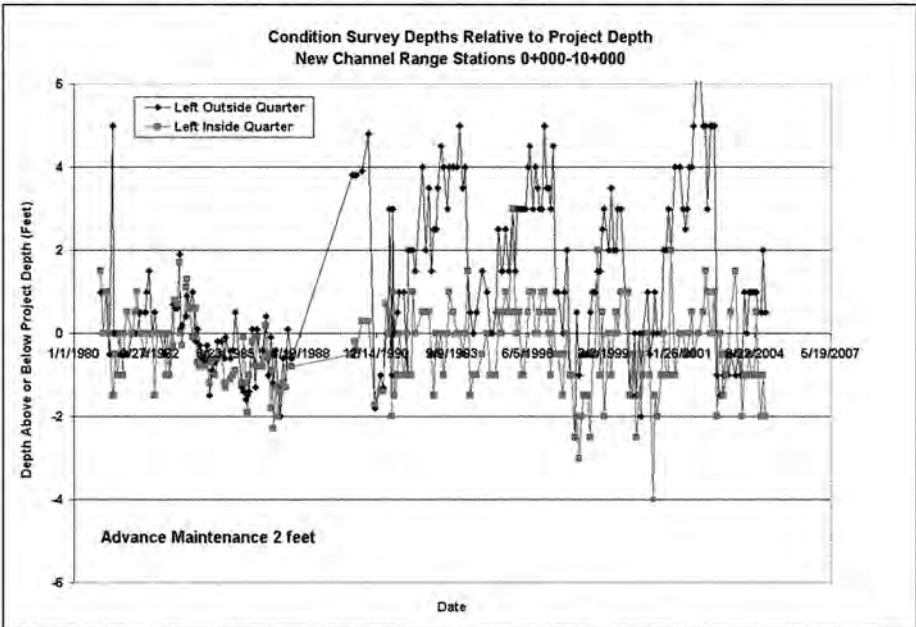


Figure 7-84 Condition Survey Left Quarter Depths, New Channel Range.

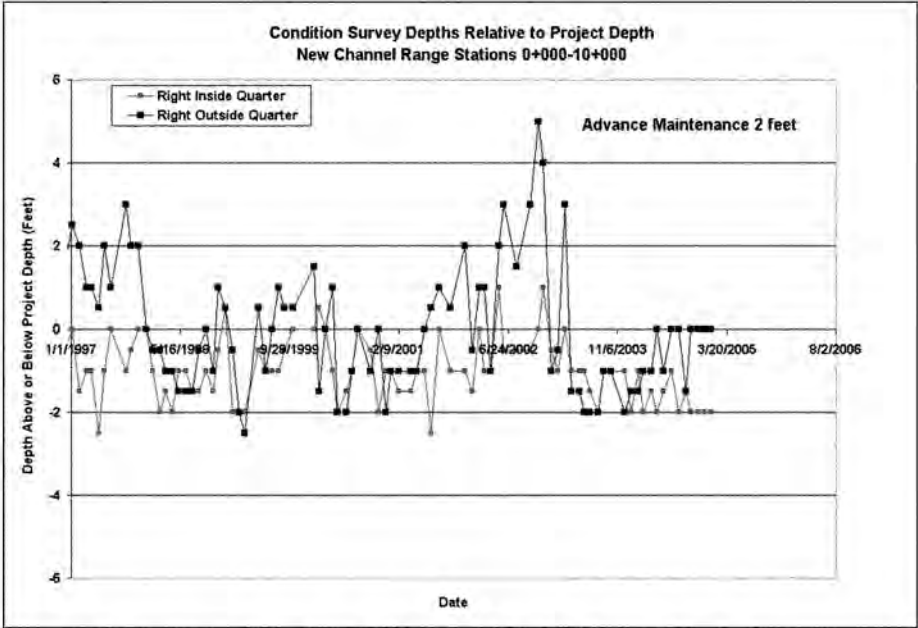


Figure 7-85 Condition Survey Right Quarter Depths, New Channel Range.

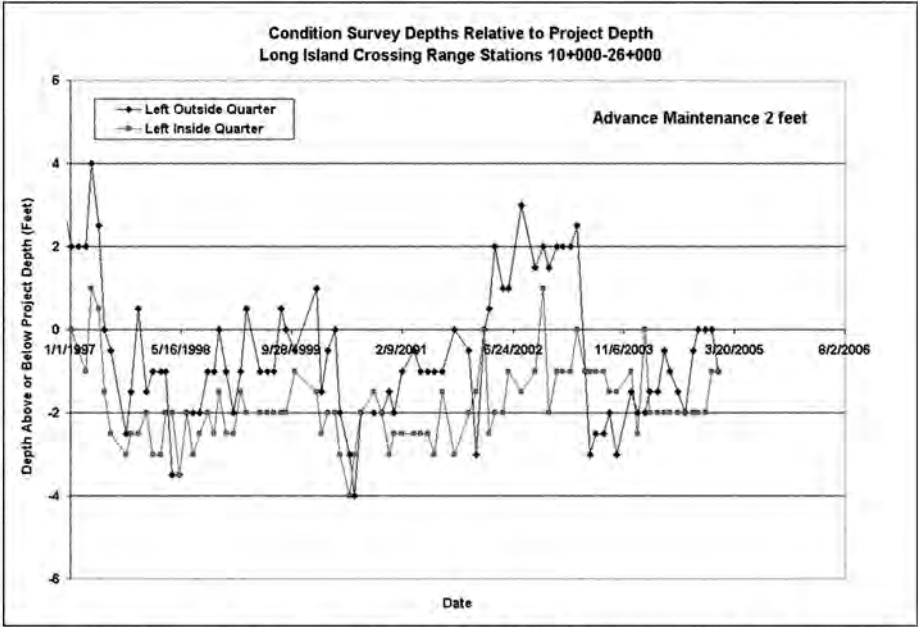


Figure 7-86 Condition Survey Left Quarter Depths, Long Island Crossing Range.

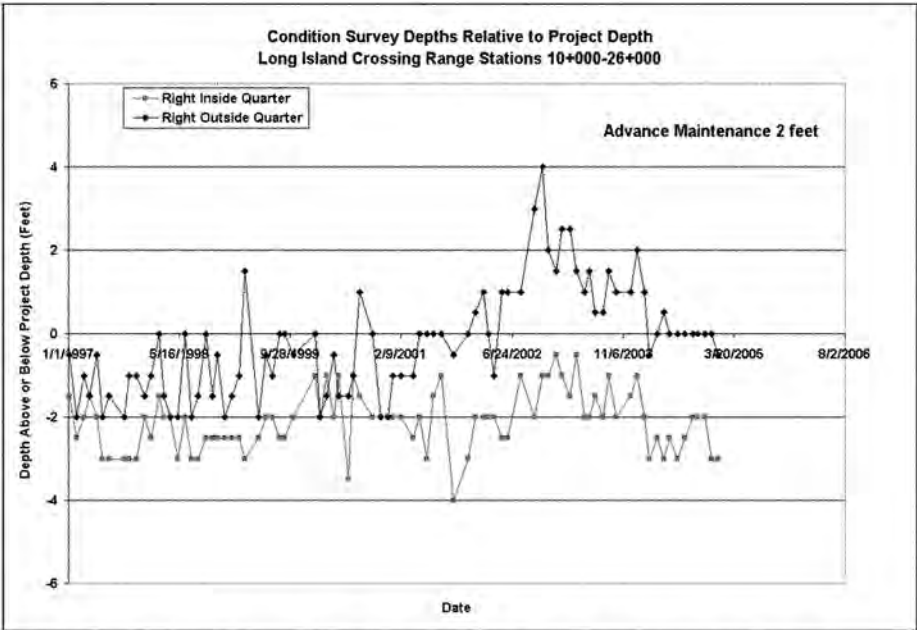


Figure 7-87 Condition Survey Right Quarter Depths, Long Island Crossing Range.

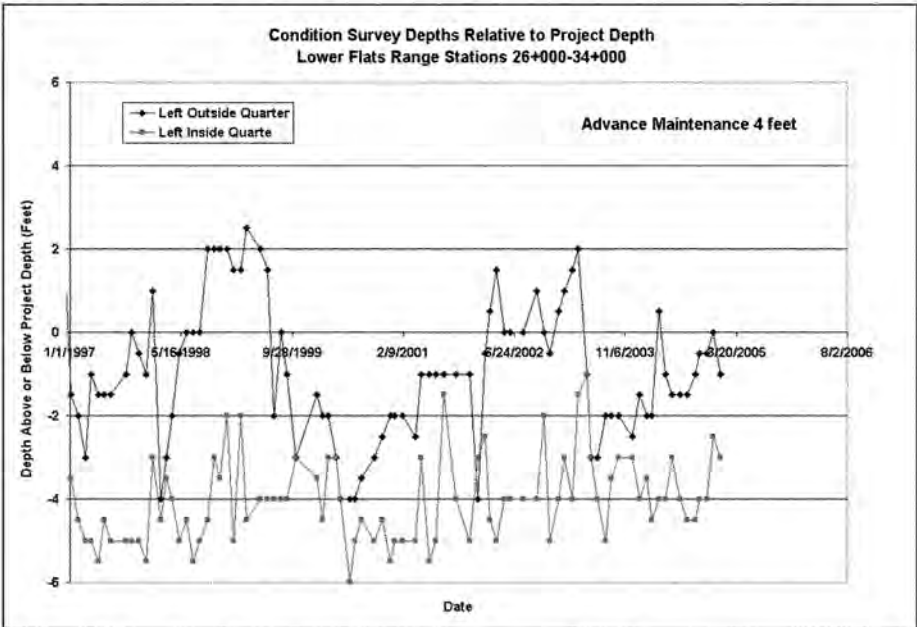


Figure 7-88 Condition Survey Left Quarter Depths, Lower Flats Range.

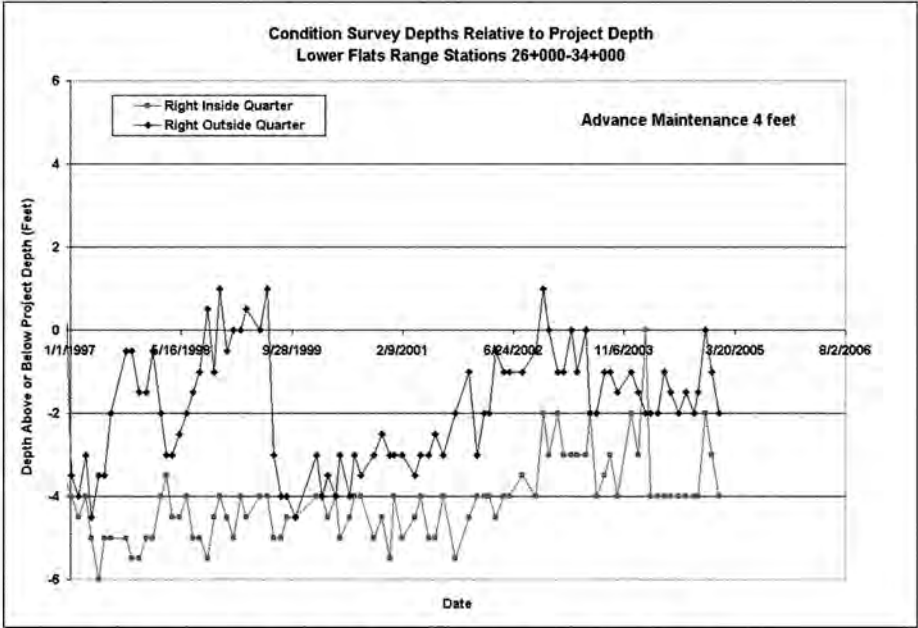


Figure 7-89 Condition Survey Right Quarter Depths, Lower Flats Range.

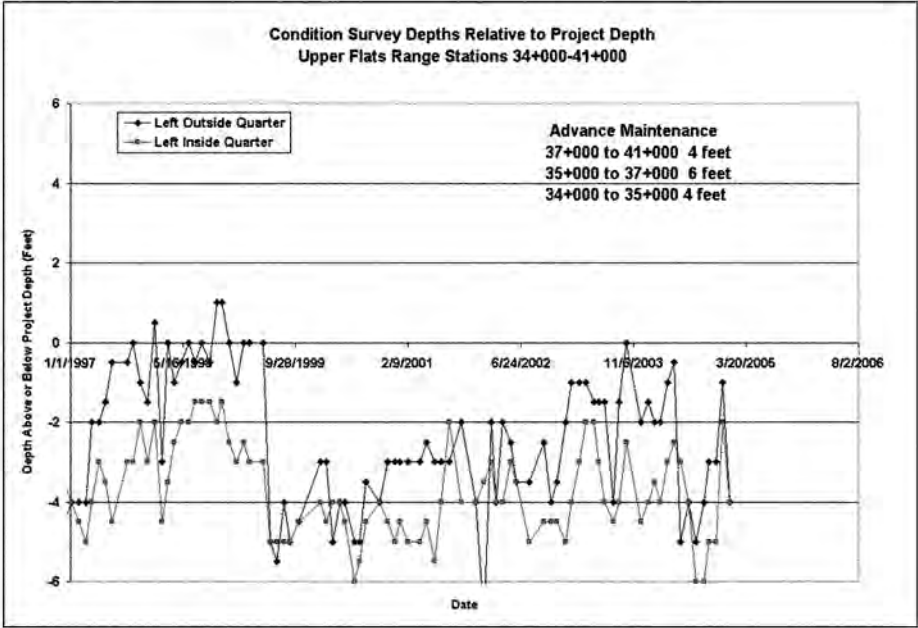


Figure 7-90 Condition Survey Left Quarter Depths, Upper Flats Range.

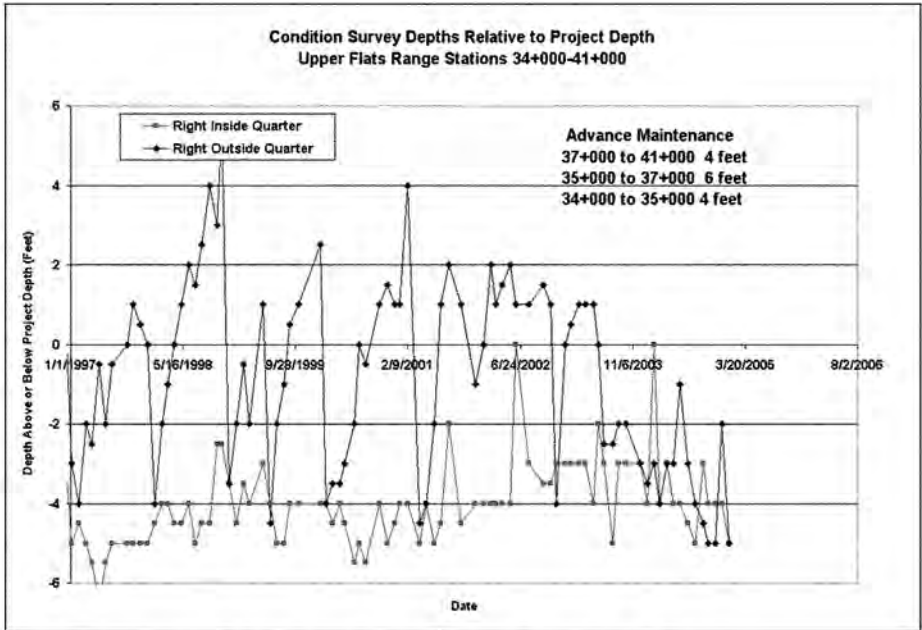


Figure 7-91 Condition Survey Right Quarter Depths, Upper Flats Range.

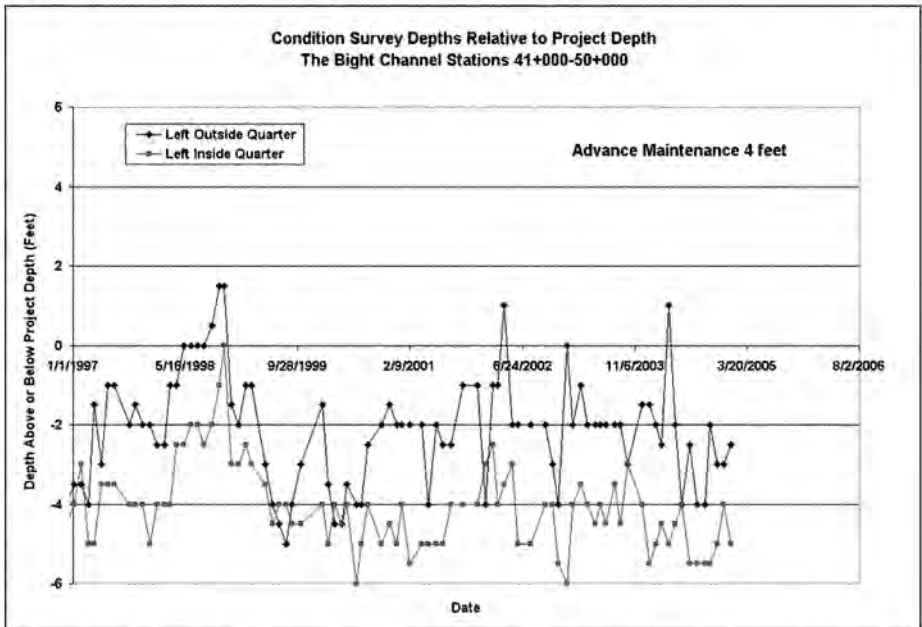


Figure 7-92 Condition Survey Left Quarter Depths, The Bight Channel.

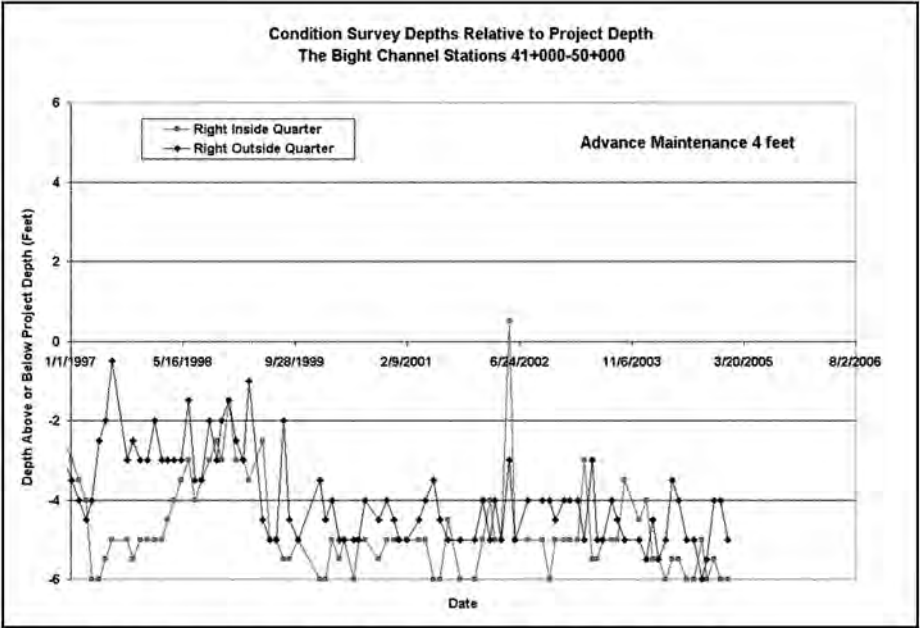


Figure 7-93 Condition Survey Right Quarter Depths, The Bight Channel.

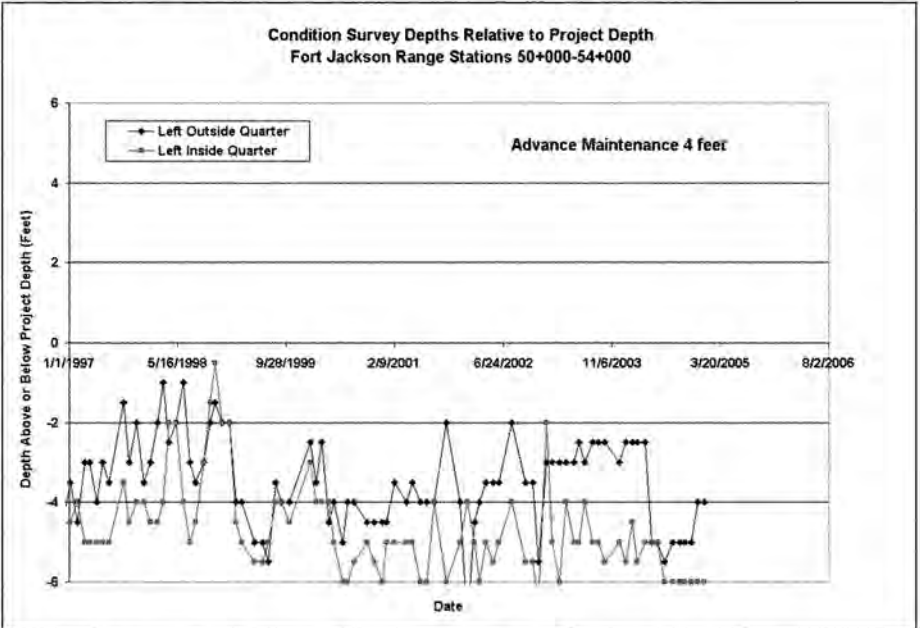


Figure 7-94 Condition Survey Left Quarter Depths, Fort Jackson Range.

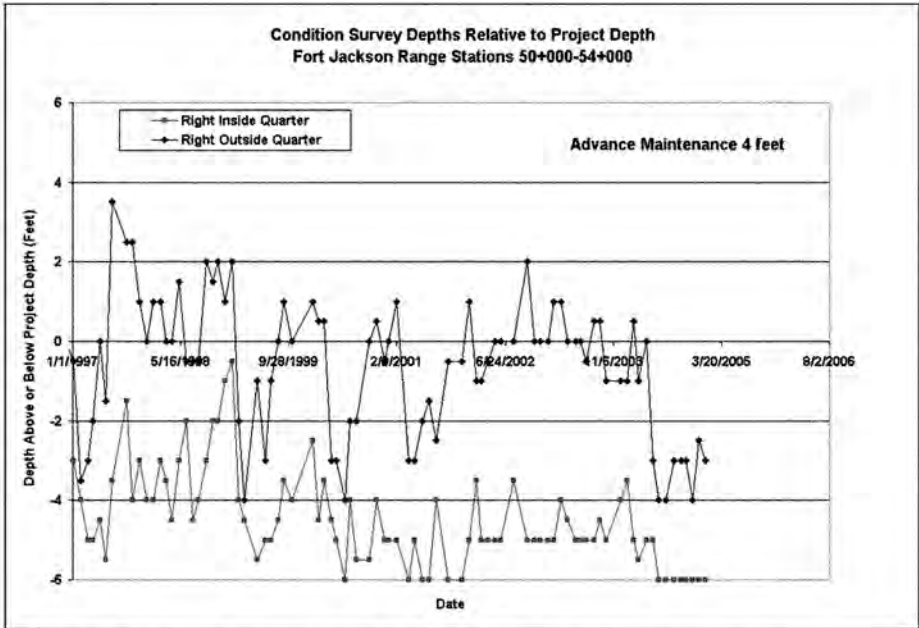


Figure 7-95 Condition Survey Right Quarter Depths, Fort Jackson Range.

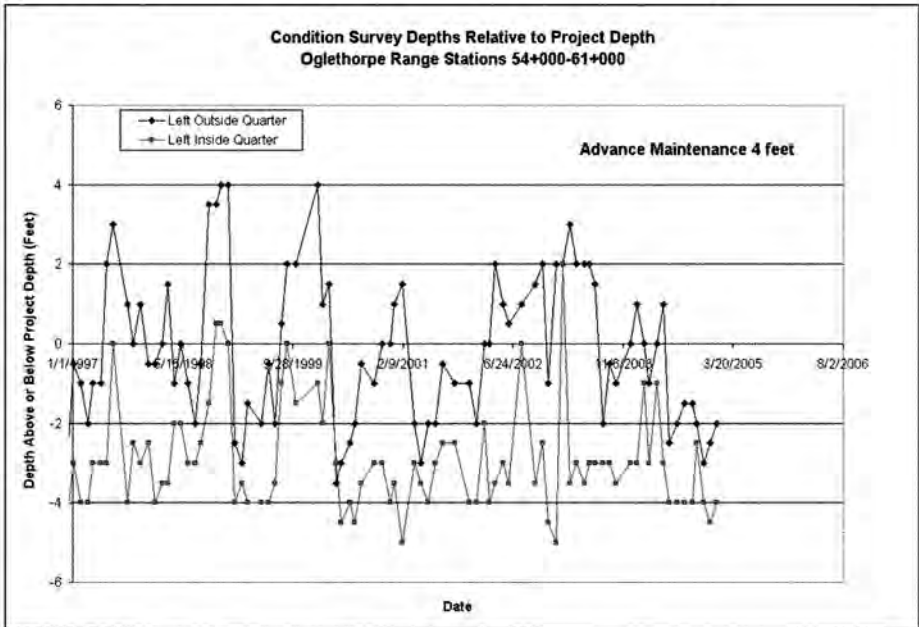


Figure 7-96 Condition Survey Left Quarter Depths, Oglethorpe Range.

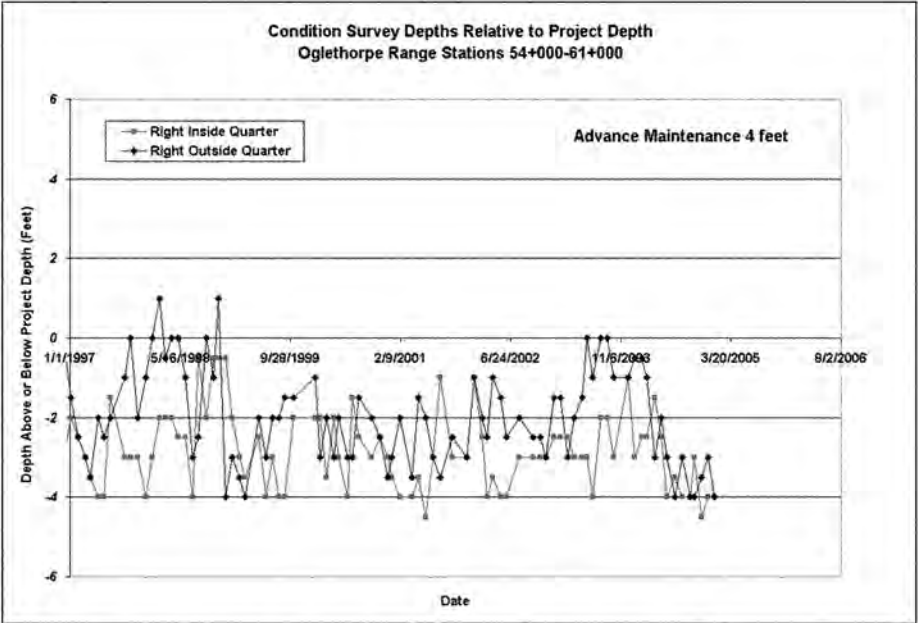


Figure 7-97 Condition Survey Right Quarter Depths, Oglethorpe Range.

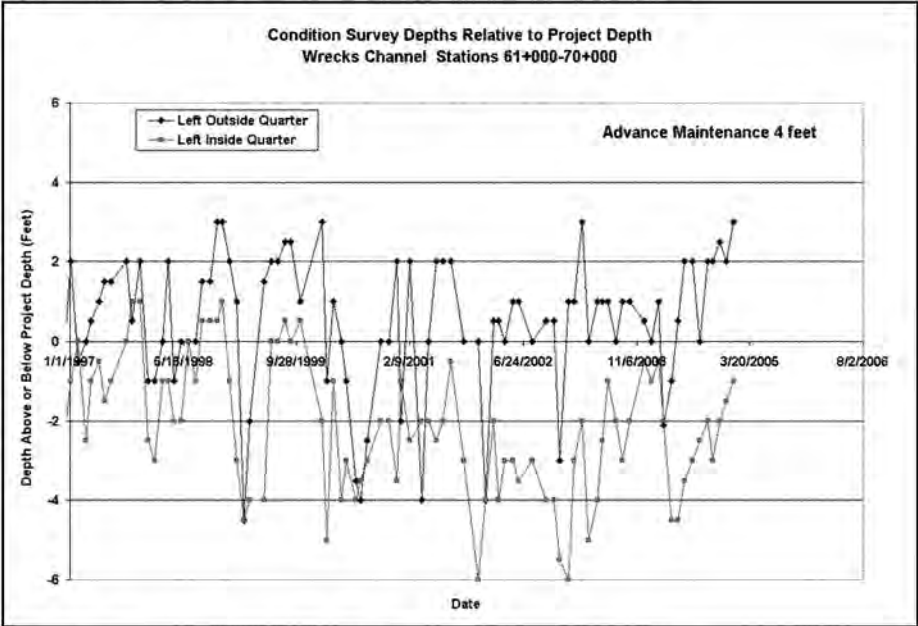


Figure 7-98 Condition Survey Left Quarter Depths, Wrecks Channel.

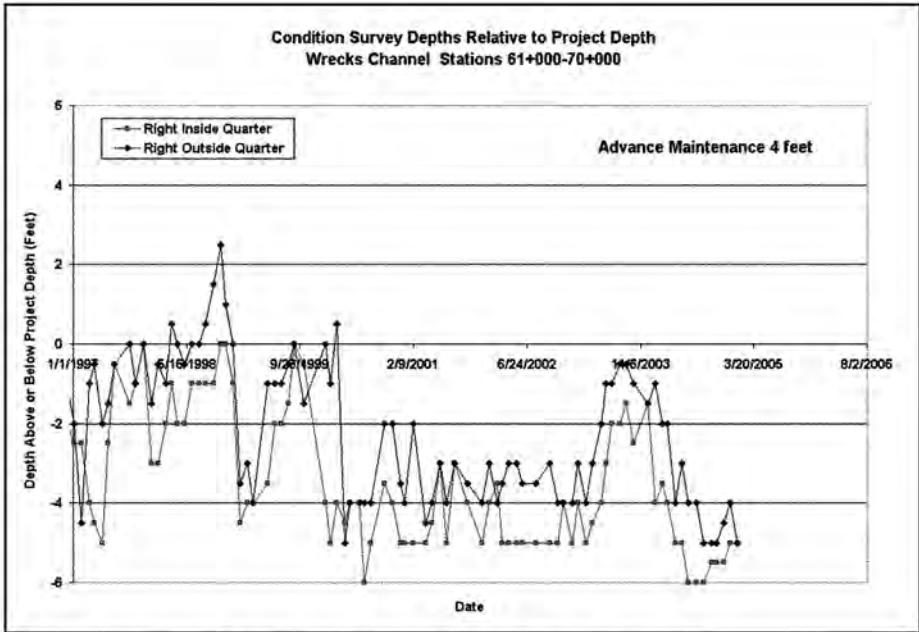


Figure 7-99 Condition Survey Right Quarter Depths, Wrecks Channel.

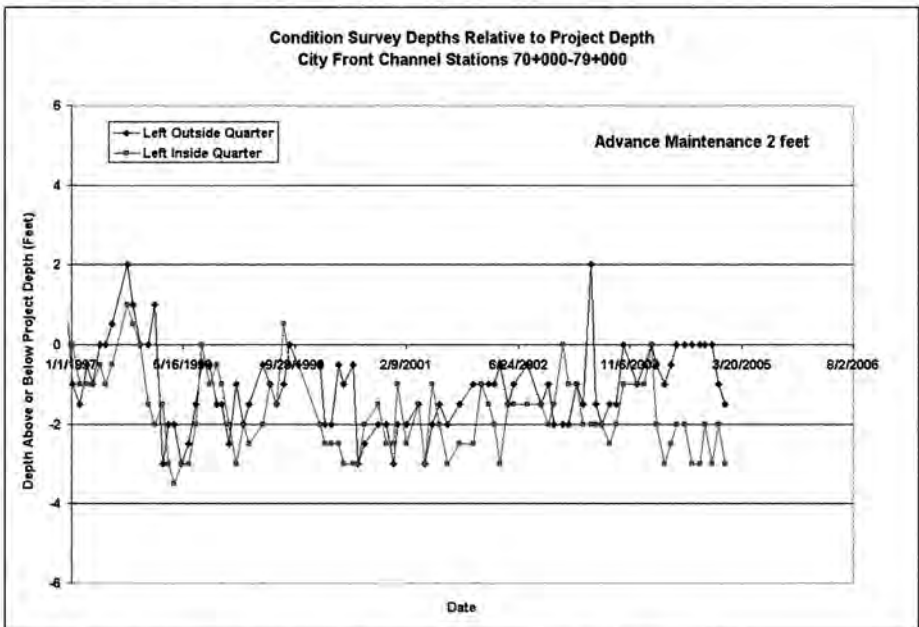


Figure 7-100 Condition Survey Left Quarter Depths, City Front Channel.

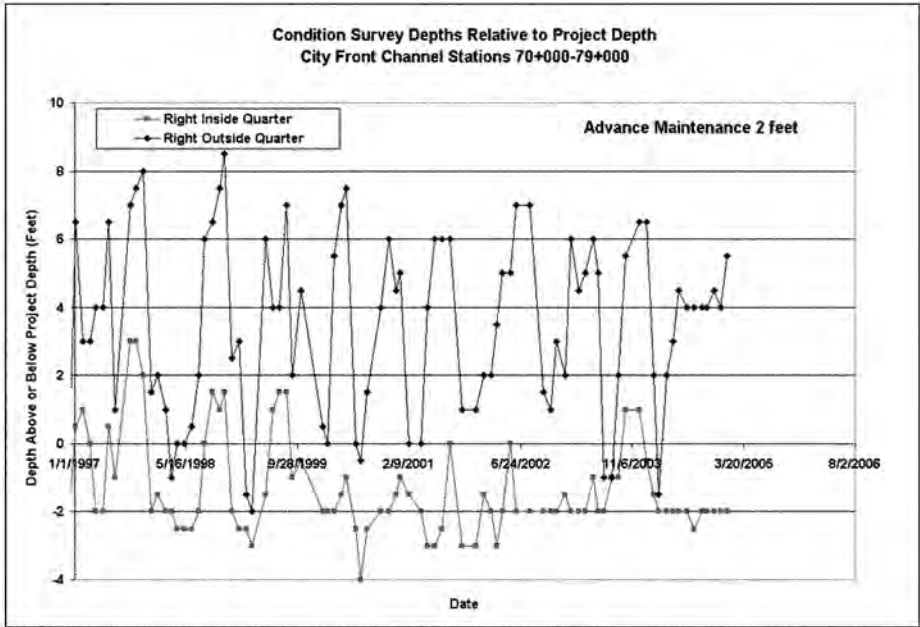


Figure 7-101 Condition Survey Right Quarter Depths, City Front Channel.

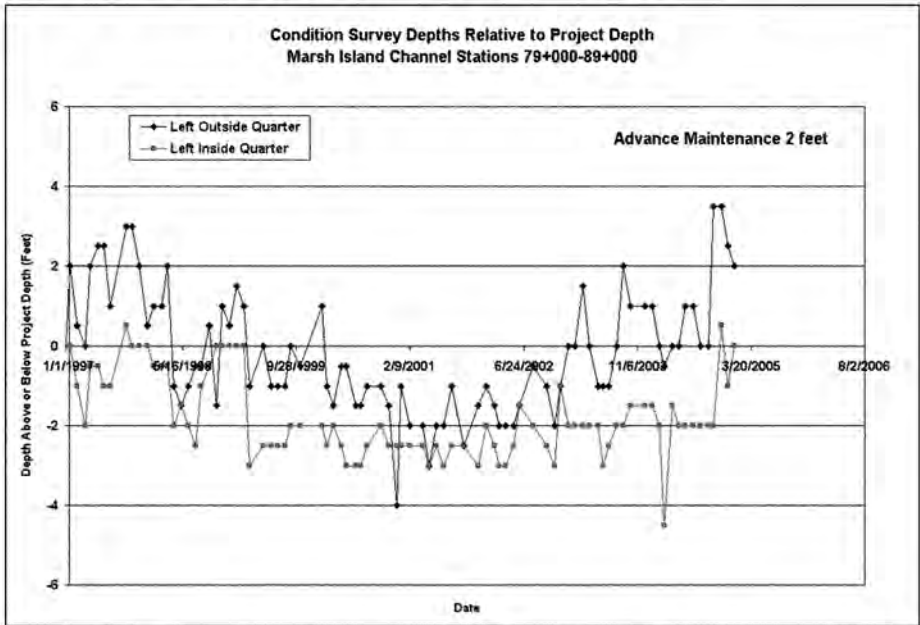


Figure 7-102 Condition Survey Left Quarter Depths, Marsh Island Channel.

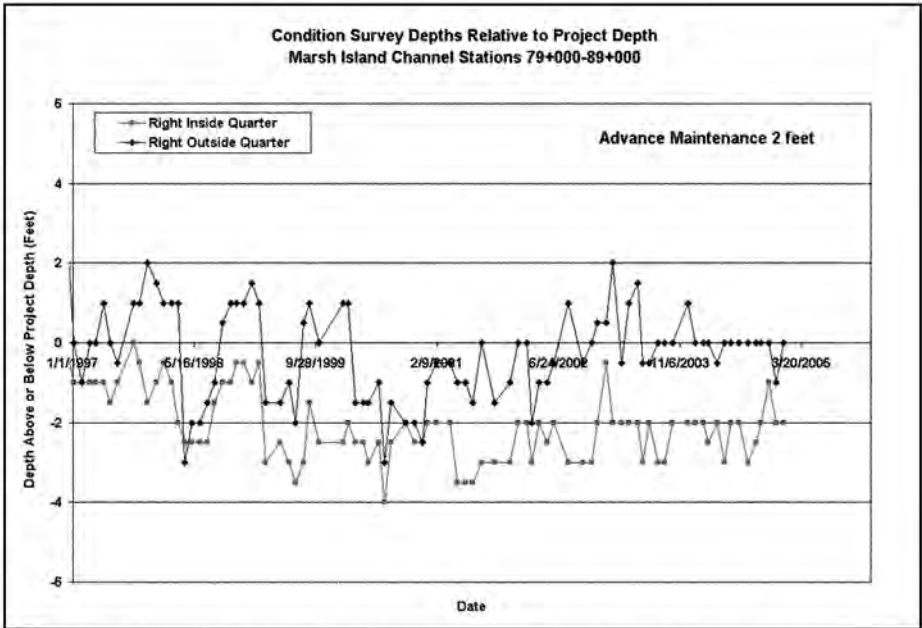


Figure 7-103 Condition Survey Right Quarter Depths, Marsh Island Channel.

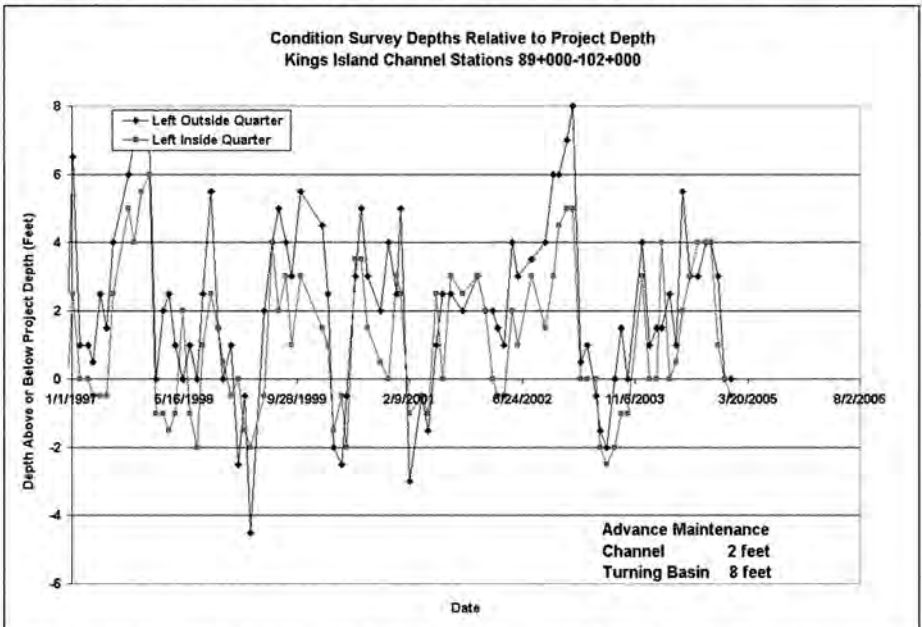


Figure 7-104 Condition Survey Left Quarter Depths, Kings Island Channel.

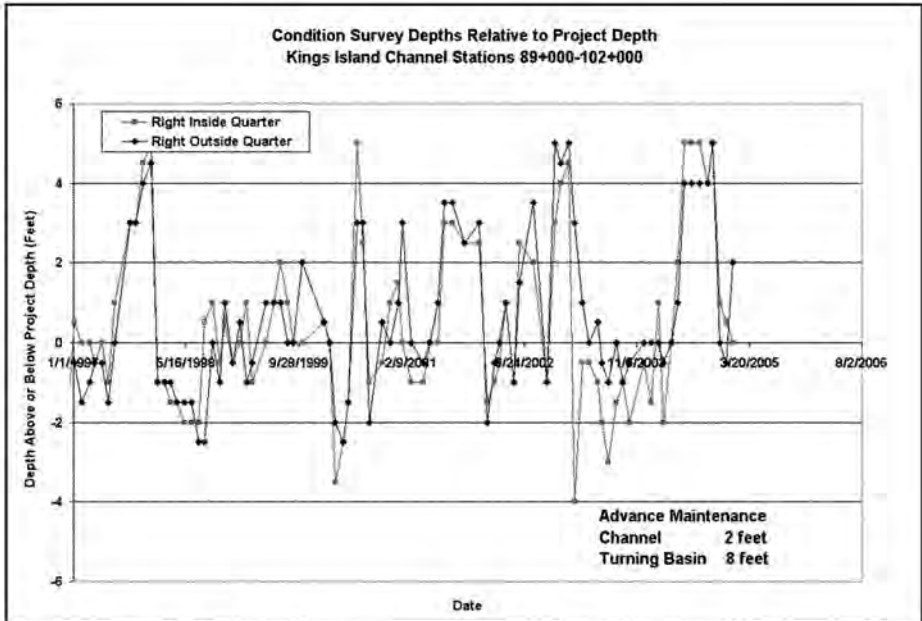


Figure 7-105 Condition Survey Right Quarter Depths, Kings Island Channel.

7.2.4.2 Advance Maintenance After Deepening Without Maintaining the Sediment Basin.

As discussed in 7.2.3.1.7 Discontinued Use of the Sediment Basin, a mitigation feature under consideration is to discontinue dredging the sediment basin which will reduce the amount of salinity moving up back river. If the use of the sediment basin is discontinued, the sediment that is annually trapped in the sediment basin will begin to settle in the river channel in a pattern similar to that which occurred before the construction of the sediment basin. The river channel shoaling distributions, before and after construction of the sediment basin, are plotted in Figure 7-66b. A tabular form of the predicted without and with sediment basin distributions, at 1,000 foot intervals, are contained in Table 15a. The shoaling increases in Table 15a are graphically displayed in Figure 7-108.

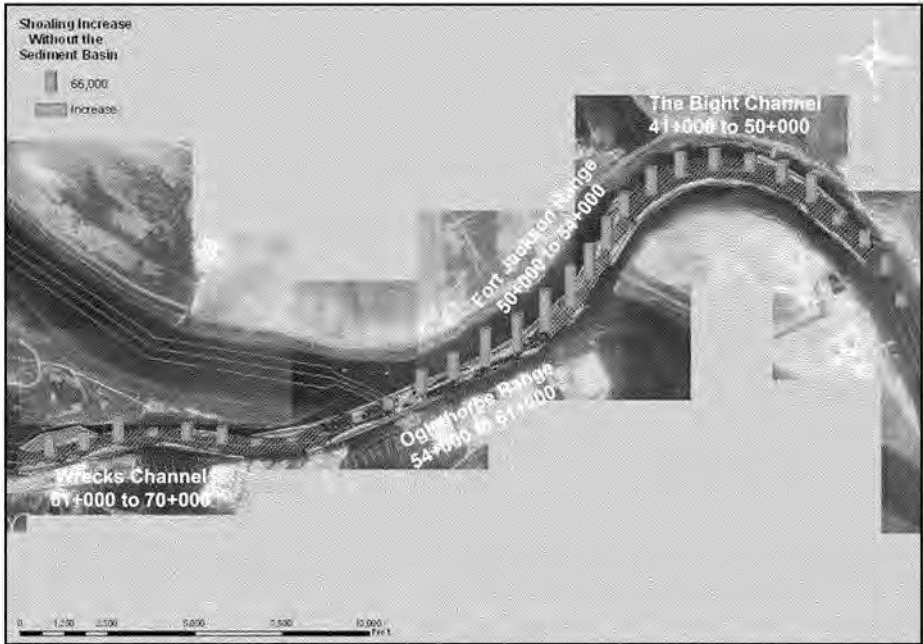


Figure 7-106 Channel Shoaling Increases Due to Discontinued Use of the Sediment Basin.

Two assumption made in this analysis are (1.) As stated in section 7.2.3.1.5, the shoaling volume and distribution is not predicted to change with the increase in channel depth. This analysis of advance maintenance requirements due to the discontinued use of the sediment basin is made relative to the project depth and applies to all the alternatives. (2.) The existing difference between advance maintenance depth and project depth will be maintained for the new project depth.

In order to evaluate the effect of the increased navigation channel shoaling on the existing advanced maintenance procedures, the shoaling volume increases need to be converted into shoal thickness. Before dredging shoal cross sections from the year 2003 were used as templates. (Examination of Figures 7-94 to 7-101 indicated that the year 2003 was not unusual.) The shoal thicknesses were non-uniformly increased. The shoal thickness increases were based on weighting factors determined by the existing shoal thickness. That is, the thicker part of the shoal was increased more than the thinner part of the shoal (Figure 7-109.) After the shoal thicknesses were increased, the volumes from the inflated cross sections were calculated. The volumes from the cross sections, which were 250 feet apart, were summed and compared to the predicted volumes for the 1,000 foot intervals from Table 7-15a. The shoal thicknesses were adjusted based on the volume comparisons. A trial and error procedure was performed

until the shoaling distribution calculated from the inflated shoals matched the predicted shoaling distribution to within 0.1 %. (Table 7-109.)

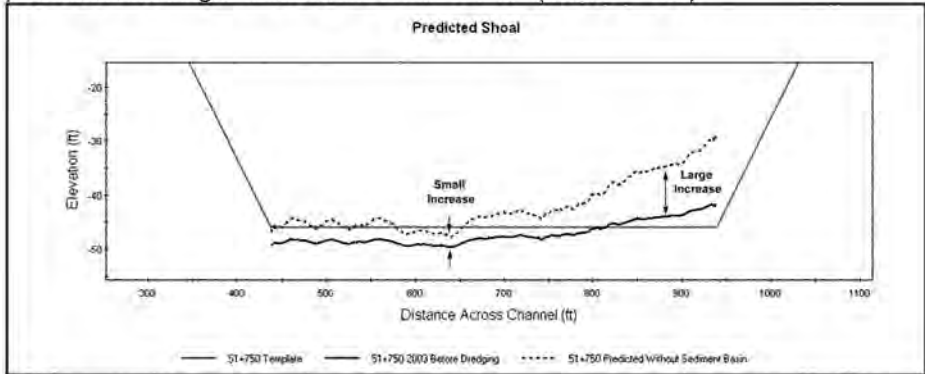


Figure 7-107 Shoal Inflation.

Station	Predicted Increase CYDs	Inflated Shoal Increase CYDs
40+000	35,619	35,619
41+000	57,600	57,600
42+000	46,286	46,286
43+000	35,207	35,173
44+000	82,984	83,026
45+000	66,161	66,147
46+000	51,127	51,127
47+000	64,001	64,001
48+000	74,293	74,293
49+000	85,123	85,123
50+000	75,550	75,550
51+000	95,635	95,635
52+000	106,525	106,525
53+000	131,973	131,973
54+000	128,412	128,412
55+000	113,741	113,741
56+000	113,854	113,854
57+000	83,886	83,886
58+000	75,030	75,030
59+000	32,483	32,483
60+000	10,457	10,457
61+000	0	1,929
62+000	9,933	9,934
63+000	12,908	12,902
64+000	48,429	48,438
65+000	49,366	49,491
66+000	18,948	18,326
67+000	82,336	80,778
68+000	55,387	56,707
69+000	62,746	62,746

Table 7-19 Inflated Shoal Volumes.

A surface of the predicted shoal increase above project depth is shown in Figures 7-110 to 7-113.

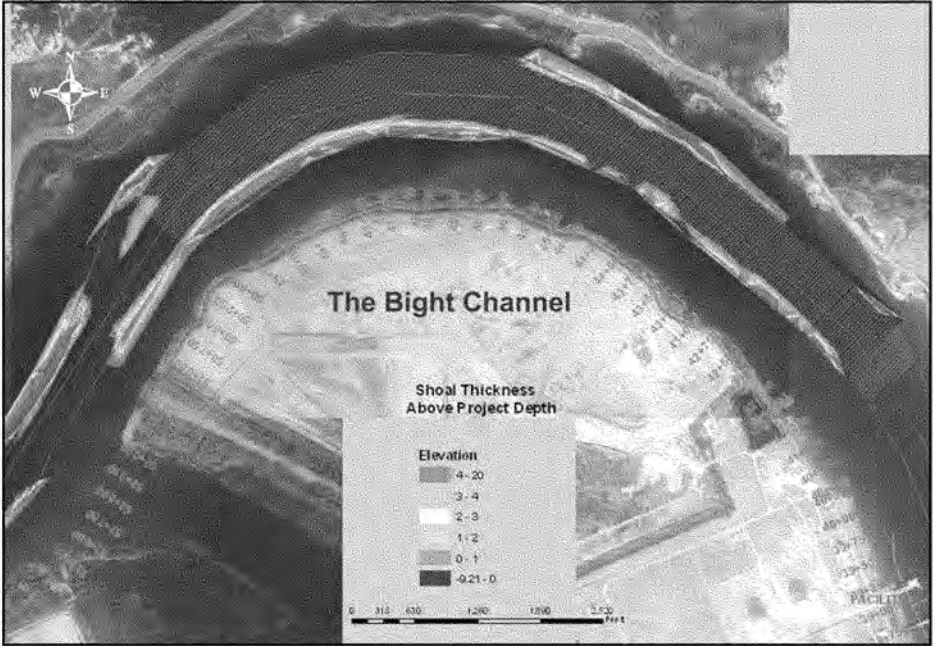


Figure 7-108 The Bight Channel Predicted Shoal Thickness Above Project Depth.

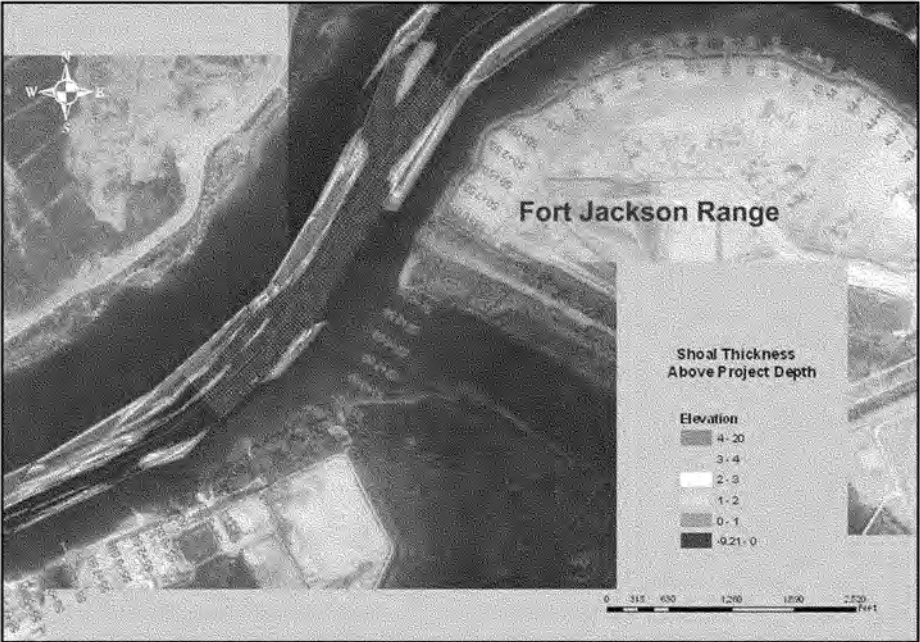


Figure 7-109 Fort Jackson Range Predicted Shoal Thickness Above Project Depth.



Figure 7-110 Oglethorpe Range Predicted Shoal Thickness Above Project Depth.

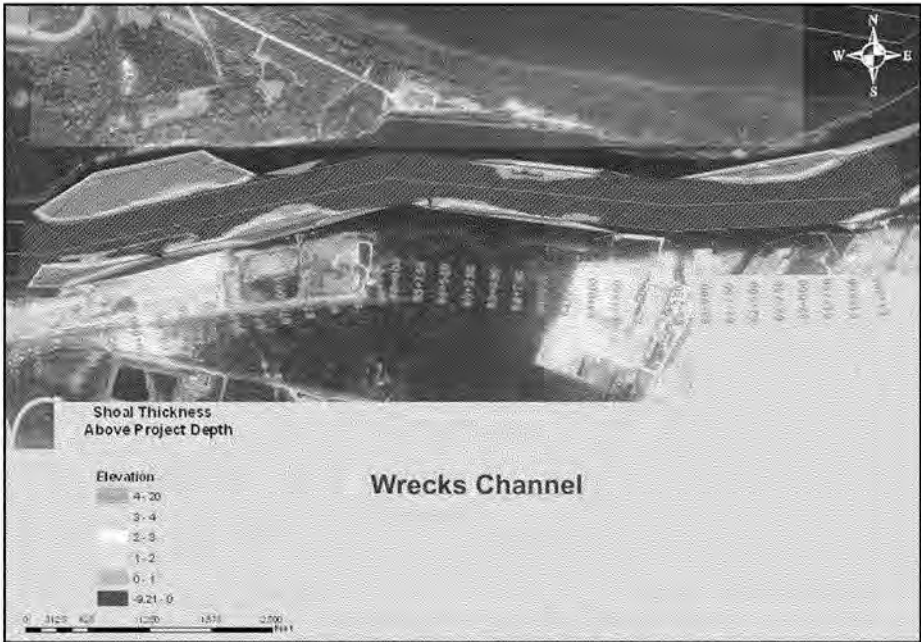


Figure 7-111 Wrecks Channel Predicted Shoal Thickness Above Project Depth.

Monthly channel condition reports identify the minimum depth along the centerline of the channel quadrants for all of the harbor’s ranges. The channel condition reports were used to generate Figures 7-78 to 7-108, which express the shoal thickness above project depth for each channel quadrant. The predicted shoal increases along the centerline of each of the channel quadrant for the stations in the ranges from the Bight Channel to Wrecks Channel was identified and listed in Table 7-21.

Station	Left Outside	Left Inside	Right Inside	Right Outside
40000	3.58	1.77	0.84	1.51
41693	3.24	1.46	1.81	2.14
41750	3.22	1.54	1.45	1.91
42000	3.49	1.24	1.29	1.62
42250	4.1	0.92	1.29	1.43
42500	3.83	0.71	1.28	1.46
42750	3.93	1.45	1.26	1.08
43000	1.55	0.72	0.42	0.53
43250	1.47	0.7	0.46	0.7
43500	1.36	0.79	0.28	0.83
43750	1.38	0.79	0.35	0.85
44000	4.61	3.07	1.27	3.28
44250	4.28	3	1.91	3.48
44500	3.29	2.72	2.16	4.23

44611	3.97	2.8	1.48	4.73
44750	3.97	2.2	1.68	4.36
45000	3.48	1.68	1.24	3.43
45250	3.96	2.21	1	1.86
45500	3.65	1.7	1.41	2.66
45750	3.41	2.5	1.41	3.55
45811	3.43	2.01	1.34	3.38
46000	2.19	1.22	0.78	1.99
46250	2.93	1.65	0.88	1.04
46500	2.98	1.58	0.99	0.94
46750	2.68	1.6	1.03	0.98
47000	3.61	1.96	0.75	1.5
47207	3.31	1.72	1.52	1.43
47250	3.37	1.73	1.54	1.4
47500	3.82	2.31	0.75	1.37
47750	4.02	2.42	0.97	1.36
48000	3.99	2.02	0.91	1.85
48222	3.78	1.46	1.13	1.84
48250	3.8	1.49	1.34	1.78
48500	4.04	2.4	1.22	1.73
48750	4.72	2.34	1.12	1.77
49000	5.41	2.6	1.12	1.91
49250	5.21	2.23	1.48	2.02
49489	4.58	1.19	2.29	2.57
49500	4.59	1.16	1.98	2.99
49750	3.2	0.97	3.63	3.41
50000	2.49	1.15	3.95	3.17
50250	3.33	1.35	4.35	2.16
50500	3.55	1.77	2.91	1.57
50750	3.91	1.64	2.26	2.37
51000	6.42	4.23	3.37	5.73
51250	4.09	4.49	3.18	8.46
51500	5.44	3.91	3.69	8.03
51750	3.53	2.28	4.46	9.12
52000	3.33	2.17	4.46	10.24
52250	3.44	2.44	5.04	9.8
52500	4.2	3.65	4.43	8.24
52750	4.86	5.06	3.17	5.79
53000	6.9	5.03	6.7	4.88
53127	5.79	3.94	7.51	6.1
53250	4.33	4.29	7.09	6.53
53500	4.78	3.56	4.27	9.89
53750	4.08	3.17	4.89	10.2
54000	3.27	3.71	6.05	9.04
54250	4.23	3.56	5.34	8.72
54481	6.92	3.63	5.94	7.67
54500	6.97	4.13	6.15	8.28
54750	7.28	3.03	6.19	6.75
55000	5.29	3.37	7.04	6.67
55250	4.84	2.98	6.6	7.21

55500	4.69	3.38	6.45	7.53
55750	4	3.09	6.01	8.45
56000	3.46	4.05	7.09	9.25
56250	4.36	4.87	7.81	8.76
56500	6.74	5.52	5.93	7.37
56750	3.22	6.09	5.96	9.36
57000	3.74	3.77	5.15	6.7
57250	3.5	3.83	5.94	5.99
57500	4.35	2.56	4.95	4.92
57750	3.77	2.64	4.47	5.54
58000	3.19	4.86	4.25	4.92
58130	5.96	3.8	3.07	4.13
58250	3.87	4.08	3.83	4.35
58500	3.48	3.35	5.05	5.72
58750	4.91	4.29	2.52	3.03
59000	2.26	1.45	2.19	1.95
59130	1.63	1.24	1.56	2.36
59250	2	1.21	1.41	2.15
59500	2.43	1.33	1.05	1.79
59750	2.47	1.29	1.25	2.73
60000	0.97	0.33	0.34	0.74
60250	1.15	0.46	0.57	0.24
60500	1.22	0.41	0.27	0.29
60750	1.24	0.3	0.36	0.42
61000	0	0	0	0
61250	0	0	0	0
61405	0	0	0	0
61500	0	0	0	0
61750	0	0	0	0
62000	0.22	0.15	0.42	1.03
62250	0.29	0.18	0.43	0.98
62500	0.2	0.23	0.39	1.07
62750	0.24	0.31	0.37	0.92
63000	0.26	0.22	0.38	0.55
63250	0.29	0.29	0.38	0.44
63277	0.29	0.29	0.38	0.45
63500	0.26	0.25	0.36	0.48
63750	0.35	0.3	0.29	0.36
64000	3.31	2.59	1.65	2.2
64250	2.85	2.04	1.35	2.97
64500	2.1	1.87	2.04	3.58
64750	2.57	1.9	1.93	2.43
65000	3.13	2.08	2.72	3.55
65250	4.52	2.46	2.76	2.38
65500	5.02	1.98	2.37	3.08
65750	4.59	2.99	2.34	2.23
66000	0.44	0.35	0.16	0.3
66136	0.36	0.32	0.17	0.33
66250	0.33	0.3	0.25	0.34
66500	0.46	0.28	0.23	0.19

66750	0.58	0.29	0.23	0.25
67000	7.23	3.79	3.53	2.09
67250	7.45	4.61	3.63	2.67
67500	8.41	3.99	2.47	2.72
67750	5.34	3	2.06	1.43
68000	1.17	0.49	0.62	0.72
68250	1.24	0.52	0.44	0.55
68500	1.41	0.45	0.79	1.02
68750	0.96	0.84	0.6	0.73
69000	1.62	1.28	0.81	1.34
69250	2.1	1.79	0.66	1.58
69500	3.45	2.25	0.8	1.87
69734	5.25	2.14	0.69	1.78
69750	5.4	2.23	0.68	1.79

Table 7-20 Predicted Shoaling Increase in Feet Along the Channel Quadrants.

The maximum shoal increases along the centerline of each quadrant for each reach was identified and are listed in Table 7-22.

	Left Outside Quadrant	Left Inside Quadrant	Right Inside Quadrant	Right Outside Quadrant
The Bight Channel 41+000 to 50+000	5.41	3.08	3.63	4.74
Ft Jackson Range 50+00 to 54+000	6.9	5.06	7.51	10.24
Oglethorpe Range 54+000 to 61+000	7.28	6.09	7.81	9.36
Wrecks Channel 61+000 to 70+000	8.41	4.61	3.63	3.58

Table 7-21 Maximum Shoal Increases in Feet along the Centerline of Each Channel Quadrant.

The historic monthly channel condition report data was increased by the maximum shoal increases in Table 7-22 and the results are contained in Figures 7-114 to 7-121.

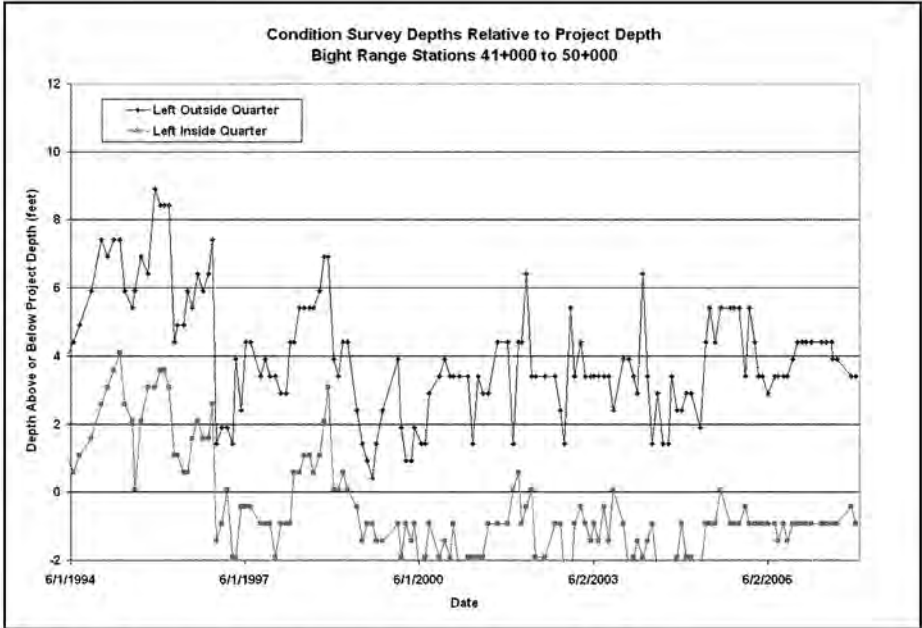


Figure 7-112 Predicted Channel Condition Depths for the Left Bight Range.

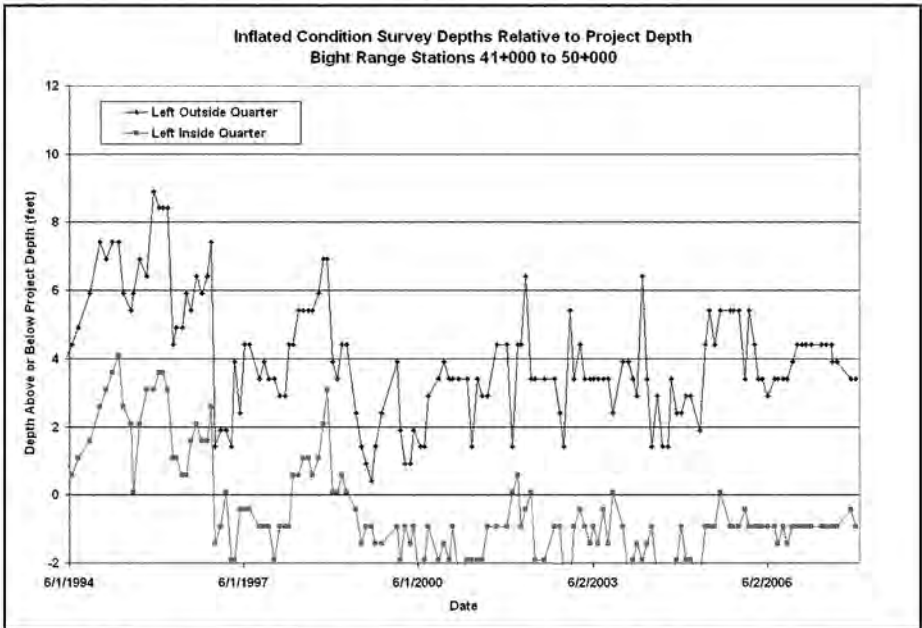


Figure 7-113 Predicted Channel Condition Depths for the Right Bight Range.

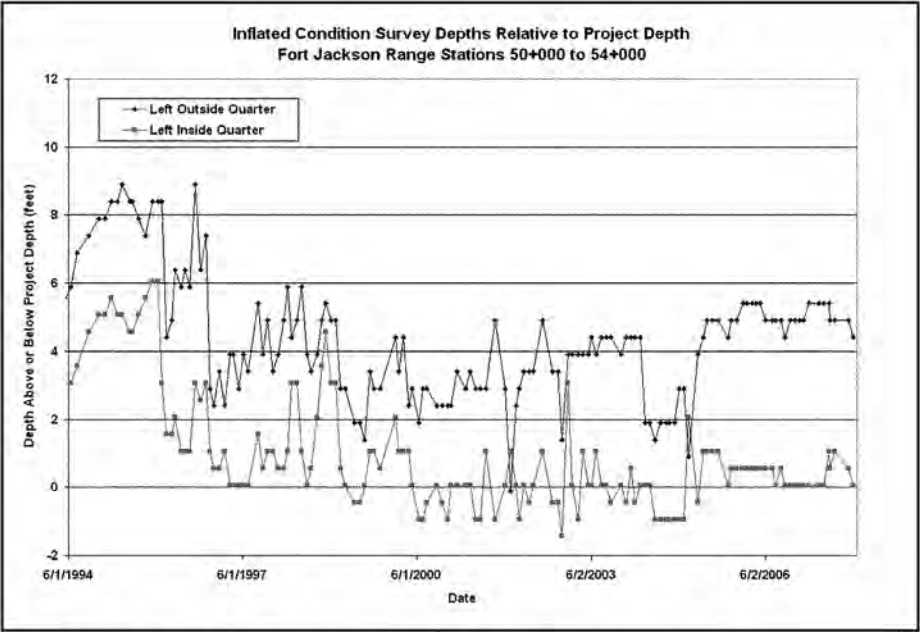


Figure 7-114 Predicted Channel Condition Depths for the Left Ft Jackson Range.

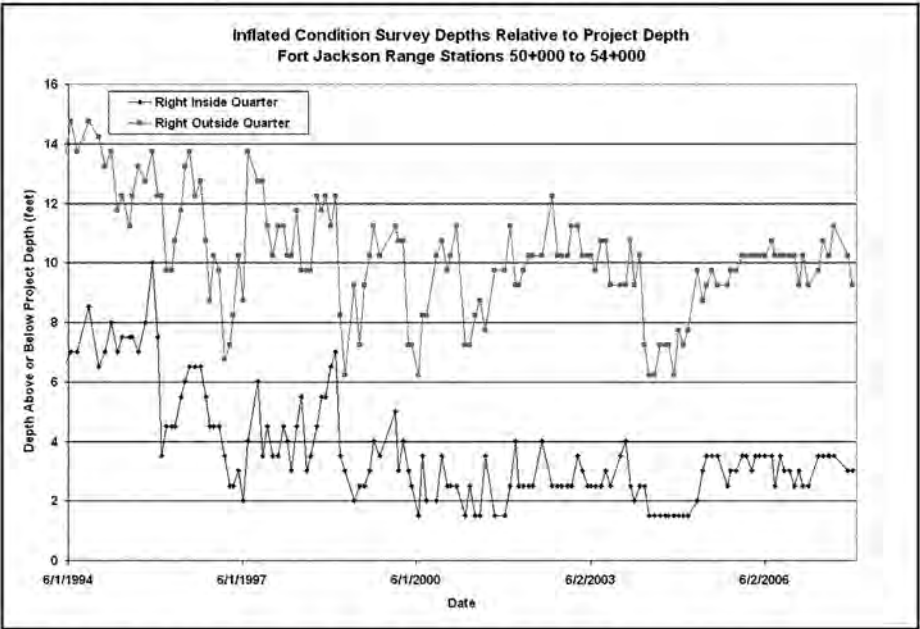


Figure 7-115 Predicted Channel Condition Depths for the Right Ft Jackson Range.

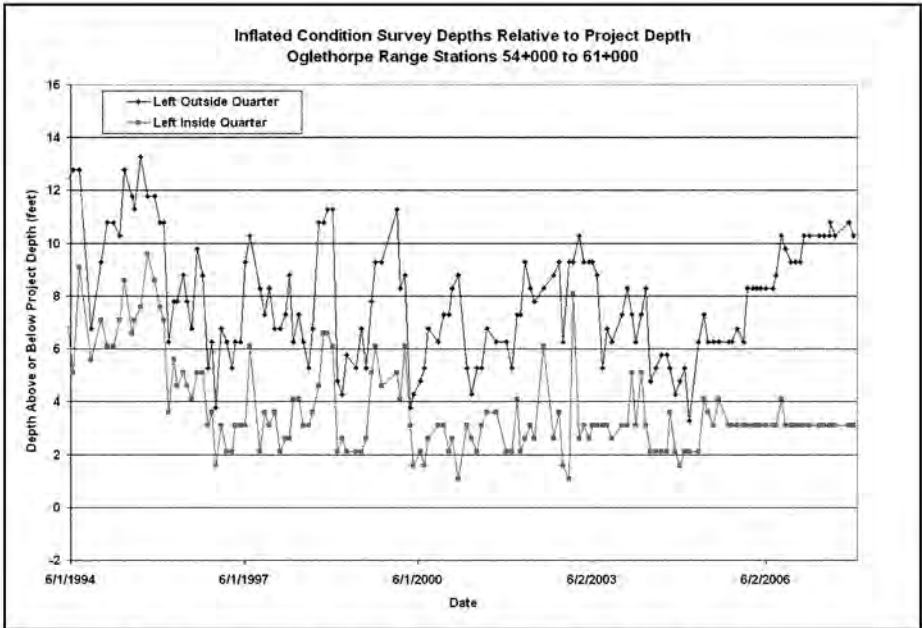


Figure 7-116 Predicted Channel Condition Depths for the Left Oglethorpe Range.

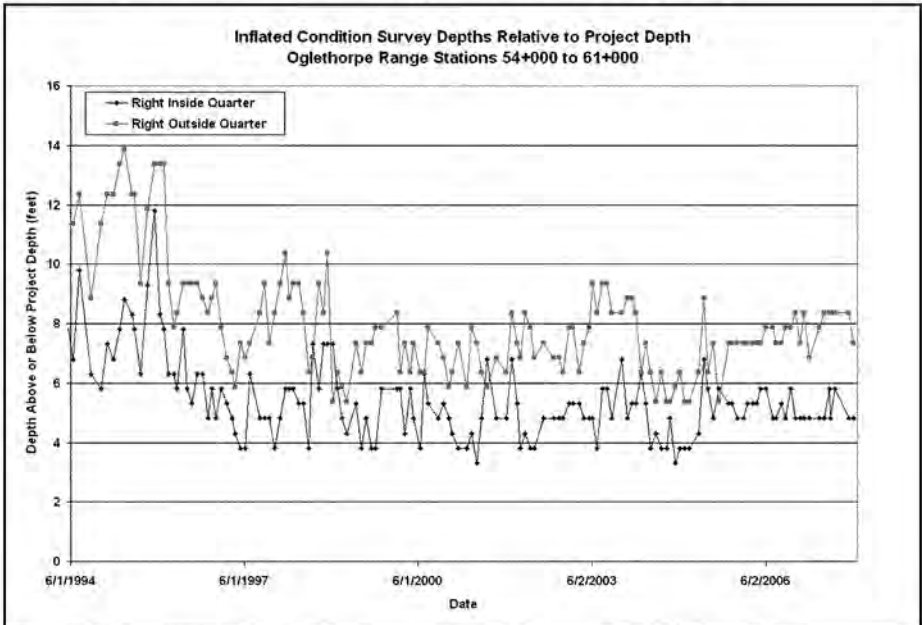


Figure 7-117 Predicted Channel Condition Depths for the Right Oglethorpe Range.

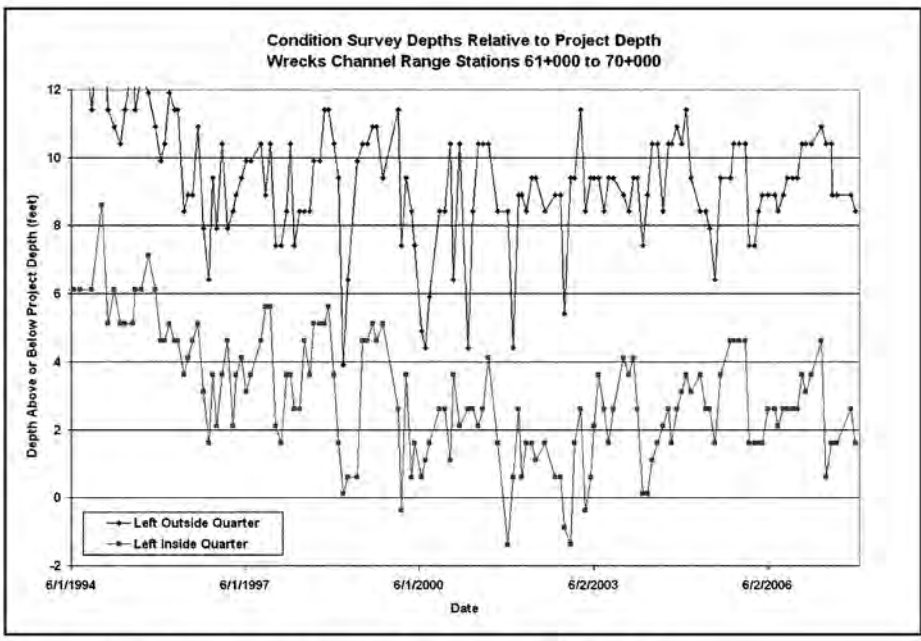


Figure 7-118 Predicted Channel Condition Depths for the Left Wrecks Range.

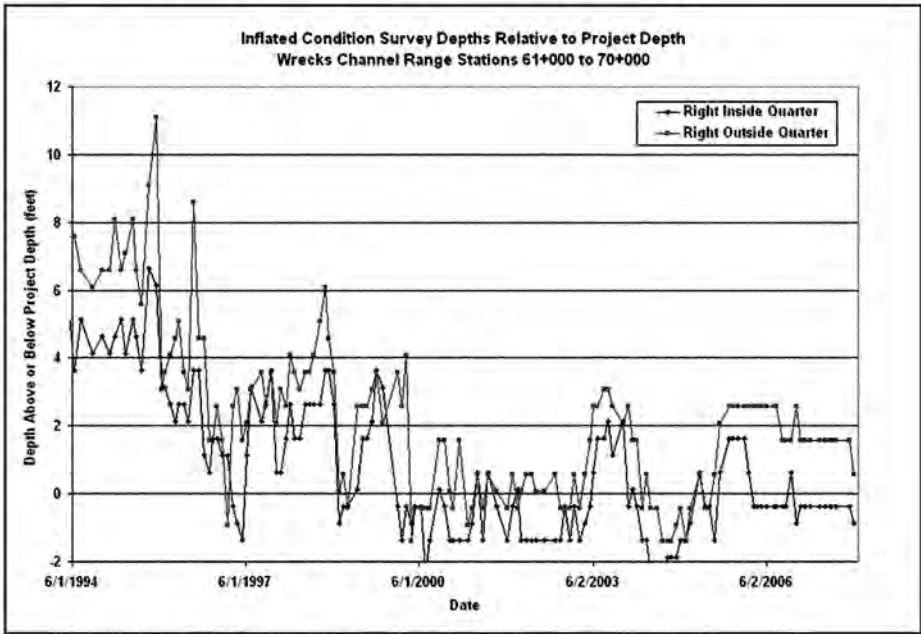


Figure 7-119 Predicted Channel Condition Depths for the Right Wrecks Range.

From the predicted channel condition plots, the adequacy or the need to increase the existing advance maintenance design can be determined. Using the criterion that when a shoal 2 feet or more above the project depth occurs at two adjacent quarters, a contractor is directed to remove the shoal, the following conclusions were reached. The existing advanced maintenance relative to project depth in the Bight Channel Range will be adequate without the operation of the sediment basin. A portion of existing advanced maintenance design in the Ft. Jackson Range will need to be increase by 2 feet. The Oglethorpe Range will need a portion of its advanced maintenance increased by 4 feet. A section of the Wrecks Channel Range advanced maintenance design will need to be increased by 2 feet.

While using the data from the channel condition surveys gives the required increase in the advance maintenance depths, it does not delineate the area within the range which needs to deepen. Surface plots of the shoal thickness above the project depth with the values of the predicted shoal increase at the centerline of the inside quadrants displayed were used to delineate the channel areas that are predicted to violate the dredging criterion. The shoal values at the inside quadrants are shown since the shoals start growing in the outside quadrants and grow inward. When the inside quadrants values are two feet higher the project depth, the dredging criterion is violated.

Figures 7-122 to 7-124 display the predicted shoal thickness above -42 feet MLLW and the amount of shoal increase at the centerline of the inner channel quadrants. The area where the advanced maintenance should be increased is shaded in the figures. Table 7-23 contains the stationing and the amount of increase in advance maintenance for each range.

There are some isolated shoals that appear near the center of the channel at Stations 50+000 and 53+000. These areas did not have a significant shoal to inflate and the uneven post dredging bottom was raised. Historic surveys do not indicate these areas to have shoals and are not anticipated to be a problem.

In portion of the Fig Island Turning Basin that extends beyond the navigation channel shoal in excess of 10 feet occur under existing conditions. With out the operation of the sediment basin, the shoal thickness along a line midway between the edge of the navigation channel and the outer edge of the turning basin will increase by an average of 2.5 feet. The turning basin is in the area recommended for a 2.0 foot increase in the advance maintenance depth.

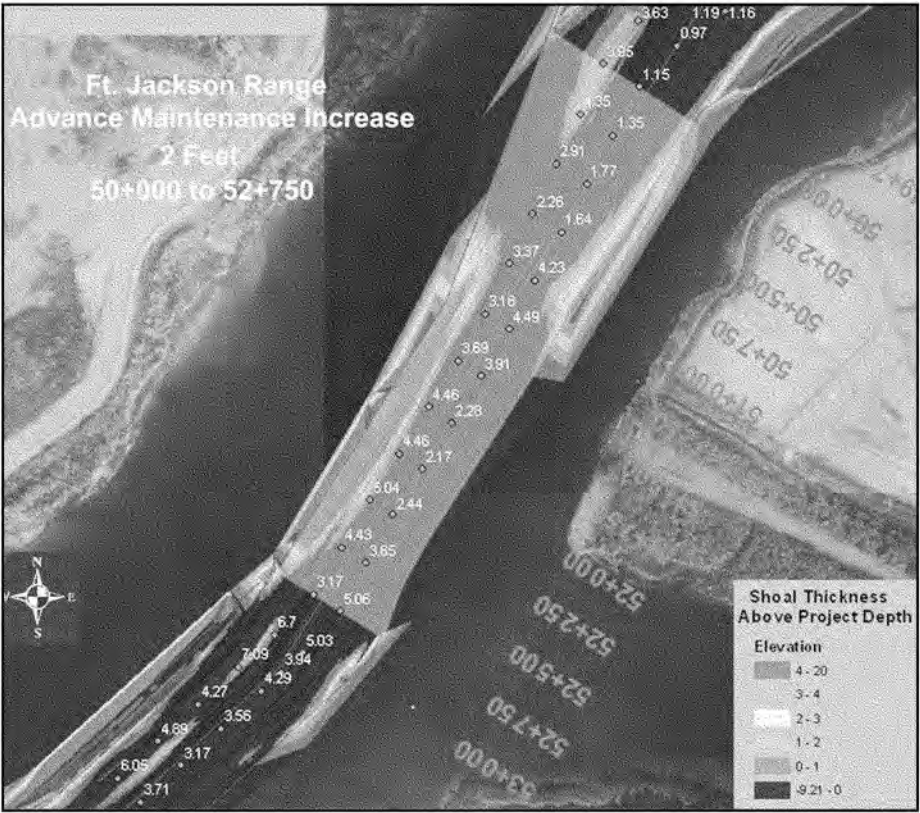


Figure 7-120 Fort Jackson Advance Maintenance Increase.



Figure 7-121 Oglethorpe Range Advance Maintenance Increase.

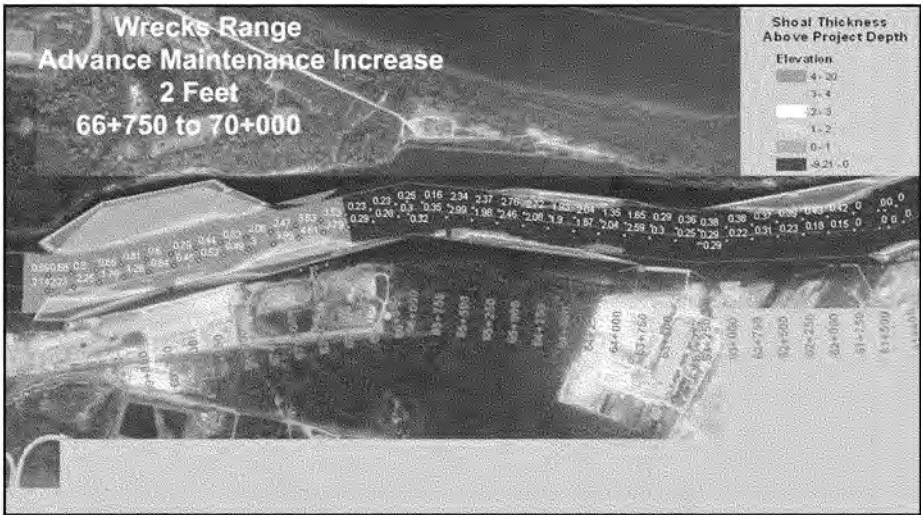


Figure 7-122 Wrecks Channel Range Advance Maintenance Increase.

Range	Stations	Advance Maintenance Depth Increase (feet)
The Bight Channel	None	None
Fort Jackson	50+500 to 52+750	2
Oglethorpe	54+000 to 60+250	4
Wrecks Channel	66+750 and 70+000	2

Table 7-22 Advance Maintenance Increases.

Conclusions

The Savannah Harbor Project captures all of the sediment that enters the harbor. The last channel deepening did not change the inner harbor shoaling volume and future depth increases are predicted not to increase the shoaling volume.

The entrance channel is a sediment sink that is a total interdiction of the littoral transport. Increases in depth will not increase the channel's ability to capture sediment.

Based on the results of physical model test, the Sediment Basin would need to be deepened by 2.0 feet to achieve maximum efficiency.

Based on the small predicted change in the salinity distribution for plan 6a, implementation of plan 6a will not change the shoaling distribution from the 6 foot deepening plan 6.

The existing advance maintenance areas, with the exception of the Kings Island range, are generally allowing an annual maintenance cycle without unacceptably encroaching above the authorized channel depth.

If the operation of the sediment basin is discontinued, the advanced maintenance depth in sections of the Fort Jackson Range, the Oglethorpe Range, and the Wrecks Channel Range will need to be deeper by 2 to 4 feet.

**SAVANNAH HARBOR DEEPENING PROJECT
ATM MARSH SUCCESSION MODEL
MARSH/WETLAND IMPACT EVALUATION**



May 2007

Purpose:

The purpose of the marsh succession modeling (MSM) is to determine the impacts of deepening the Savannah Harbor navigation channel; specifically, the effect on the tidal marsh vegetation communities as a result of salinity increases in the system. The marsh succession modeling was used to provide estimates of tidal marsh vegetation communities within the freshwater and brackish marshes of the Back, Middle, and Front rivers under various deepening and sea level rise conditions.

Model Input Conditions:

Predictions of salinity input for the MSM were developed through the use of a separate hydrodynamic and salinity computer model. The Environmental Fluid Dynamic Code (EFDC) model developed by Dr. John Hamrick and currently supported by Tetra Tech for U.S. Environmental Protection Agency (USEPA) Office of Research and Development (ORD), USEPA Region 4, and USEPA Headquarters was used in this effort. Although a number of models provide some of the features necessary for modeling the hydrodynamics in the Savannah River Estuary, the EFDC hydrodynamic and sediment transport model linked with the Water Quality Analysis Simulation Program (WASP) was determined to provide the most appropriate features necessary for the overall Savannah Harbor Expansion Project study (Tetra Tech, 2006).

EFDC solves three-dimensional, vertically hydrostatic, free surface, turbulent averaged equations of motion for a variable-density fluid. Dynamically-coupled transport equations for turbulent kinetic energy, turbulent length scale, salinity and temperature are also solved (USEPA, 2007). The boundary conditions of the EFDC model used in simulating the processes of the Savannah River Estuary consist of: offshore salinity, temperature, and water surface elevation; upstream flow and temperature; adjacent marsh areas; and meteorological forcing conditions. The main model coefficients are: bathymetry, bottom roughness and vertical mixing. The EFDC model predicts time series of the surface water elevation, currents, flow, temperature, and salinity as a result of changes in the channel geometry. Details on the Savannah Harbor EFDC model development, calibration and validation are provided in Tetra Tech, 2006 *Development of the Hydrodynamic and Water Quality Models for the Savannah Harbor Expansion Project* report.

The EFDC hydrodynamic model makes predictions of water level and salinity parameters within the confines of the estuarine rivers and main tidal creeks. The project needed a way to translate salinity predictions in those hydraulic channels to the marshes where the vegetation communities occur. To accomplish this, the Georgia Ports Authority (GPA) employed the Columbia, South Carolina office of the US Geological Survey (USGS) to develop a tool capable of translating EFDC riverine predictions across the estuary to the marsh root zones. The variability of pore-water salinity in the tidal marshes is a result of the adjacent river salinity concentration, the tidal creek connections to the river, elevation of the marsh and surrounding berms, soil type and the conditions of old abandoned rice fields and berms, and volume of water within the marsh (USGS, 2007). In order to simulate the dynamic response of the water level and salinity in the tidal marshes, the USGS, in collaboration with Advance Data Mining, developed the Model-to-Marsh (M2M) decision support system. The M2M was developed through data-mining techniques and artificial neural network (ANN) models.

The M2M model uses time-series data of the salinity, and water levels in the rivers networks near the USGS and Applied Technology and Management (ATM) marsh gaging sites to simulate water level and pore water salinity within the adjacent marsh. To predict the change in water level and pore water salinity in the marsh likely to result from a potential harbor deepening, simulated water-level and salinity changes in the river resulting from proposed geometric channel changes as predicted by the EFDC model are used. Using the USGS river network time series as input for the marsh, the ANN models accommodate the integration of output from the EFDC model. Details on the Savannah Harbor M2M system development and validation are provided in Conrads et al., 2006 *Simulation of Water Levels and Salinity in the Rivers and Tidal Marshes in the Vicinity of the Savannah National Wildlife Refuge, Coastal South Carolina and Georgia*.

The wetland/marsh impact evaluation input data was developed by the Savannah Harbor Expansion Wetland Interagency Coordination Team. The group developed four model input scenarios for evaluation (See Table 1).

Table 1- Model Input Conditions

RUN SCENARIO	RIVER FLOW	SEA LEVEL RISE	EVALUATION PERIOD
Basic Evaluation	Average/Typical	Existing Sea Level	1-March to 1-October
Sensitivity Analysis #1	Low Flow/Dry	Existing Sea Level	1-March to 1-October
Sensitivity Analysis #2A	Average/Typical	25 cm Sea Level Rise	1-March to 1-October
Sensitivity Analysis #2B	Average/Typical	50 cm Sea Level Rise	1-March to 1-October

*25 and 50 cm sea level rise conditions were specified by the Interagency Coordination Team, based on Environmental Protection Agency and National Oceanic Atmospheric Administration projections.

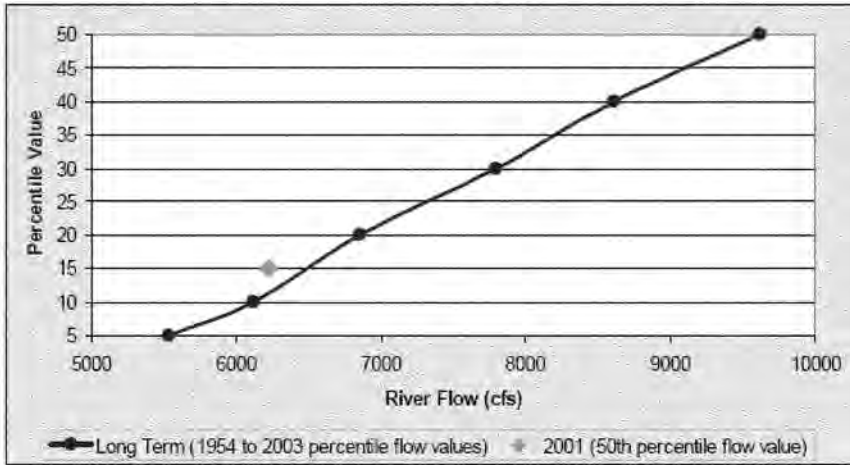
Average/typical river flows needed for the Basic Evaluation and Sensitivity Analysis #2A and B were determined using recorded gage data for Savannah River at Clio, GA. The EFDC model has continuous input boundary conditions for a 7 year period (1997 - 2003) available for simulation. 1997 was found to have flow conditions representative of the long term average flows.

Table 2- Average River Flows from USGS gaging station at Clio, GA

Period of Record	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Overall
	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
Long Term (1954-2003)	17,998	17,205	12,029	10,254	9,118	9,035	8,566	8,615	11,603
1997 Only	22,016	11,380	12,527	9,729	8,853	9,944	6,370	7,627	11,056
Percent Difference	-22%	34%	-4%	5%	3%	-10%	26%	11%	5%

The maximum percent difference is 34% occurring in April, meaning April of 1997 had less freshwater flowing downstream into the estuary than the long term average. Overall, the percent difference between the long term average and 1997 is 5%. Therefore, the growing season (March through October) of 1997 was considered to be an average flow period for modeling purposes. The flow boundary conditions for Sensitivity Analysis #1 are low flow or dry year conditions. Using the recorded gage data at Clio, GA, 2001 (March through October) was considered to be a low flow/dry period (See Figure 1).

Figure 1- River Flows from USGS gaging station at Clio, GA



The long term Clio gage data shows that low flow values range from 5,534cfs (5th percentile) to 6,858 cfs (20th percentile). The 50th percentile flow value during 2001 is 6,228 cfs. This value, 6,228 cfs, is approximately the 15th percentile value when looking at the long term Clio flow data. Therefore, 2001 was considered a low flow/dry year for model simulations.

The two sea level rise conditions used in Sensitivity Analysis #2A and B were modeled by adding an additional 25 or 50 cm, depending on the run scenario, to the water surface elevations on the open ocean boundary cells in the EFDC model. The sea level rise sensitivity analyses are based only on a change in the ocean boundary water surface elevation. There was no consideration of any potential change in the ocean boundary salinity density in EFDC modeling effort.

All other model boundary inputs remain unaltered and correspond to the run time of 1 March to 1 October for 1997 or 2001, depending on the run scenario being modeled.

Model Limitations:

The reliability of the model is dependent on the quality of the data and range of measured conditions used in its development. The available period of record for the river and/or marsh

data-collection networks can limit the conditions that the given model can accurately simulate. The pore water salinity observed at the upstream and downstream boundaries during marsh data collection and for which the model was developed were within the gradient range of 0 to 14.5 part per thousand (ppt) with river flows between 4,320 – 14,100 cfs.

The model simulates long term impacts from changes in pore water salinity within the marsh system from harbor deepening and sea level rise. Other aspects of extreme short term events such as riverine floods and storm surges and impacts of climate change, such as CO₂ concentration, and the varying response of C3 and C4 plants were not evaluated.

Output Generated:

Two types of maps were generated to aid in evaluation of the salinity impacts of deepening on the freshwater marshes: (1) plan view maps showing distributions of the predicted marsh vegetation communities (baseline conditions (42- depth), 44-, 45-, 46-, and 48-ft depths) and (2) plan view maps showing changes in distribution of the predicted marsh vegetation communities from baseline conditions.

To help further aid in the evaluation of salinity impacts of deepening on the freshwater and brackish tidal marshes tables providing the predicted total acreages of each vegetation community for both the without project condition and each deepening scenario and net changes in acreages of each type of vegetation community under each deepening scenario are provided. These tables are intended to provide reviewers with a sense of the general magnitude of the patterns of simulated changes that are depicted in the ecological community maps.

Findings:

Basic Evaluation: The Basic Evaluation includes five model runs each with a different channel depth: existing conditions (42-ft depth), 44-ft, 45-ft, 46-ft and 48-ft depths. The input conditions for the runs are pore water salinity of the marsh based on average/typical river flow and existing sea level. The evaluation period is 1 March to 1 October 1997.

Ecological Community Shift maps provided in Appendix A show changes in marsh vegetation communities throughout the estuary associated with salinity changes from channel deepening. The impacts with deepening just an additional 2 ft, extend above Steamboat River on the Front, Middle and Little Back rivers. The largest changes in vegetation communities are in the *Murdannia keisak* and *Zizaniopsis miliacea* (MK/ZM) and *Eleocharis montevidensis* (EM+) classes along the upper reaches of the Little Back River. In this area there is an increase of *E. montevidensis* and *Z. miliacea* (EM/ZM) and *Scirpus validus* and *Z. miliacea* (SV/ZM). Other large changes are seen in the SV/ZM and EM/ZM dominated classes near the secondary channels along the Back River south of New Cut. In this area there is an increase in the co-dominated *Spartina alterniflora* and *S. validus* (SA/SV) class. Along the Front River the largest simulated changes are in the EM+ class near Steamboat River. In these location areas of the EM+ class is replaced largely by a co-dominated EM/ZM class. Along the Middle River, the largest changes are north of Steamboat River, in the EM/ZM class. In these areas portions of the EM/ZM class is replaced largely by SV/ZM.

The general trend is a loss of freshwater tidal marsh occurring with the increased channel depth. The maximum increases are generally found on the Front River where the deepening is occurring and along the more freshwater location of the Little Back River. A quick view of the Wetland/Marsh Impact table provided in Appendix A does not tell the full story of salinity impacts associated with deepening. The Ecological Community maps and the Ecological Community Shift maps in Appendix A provide a clearer picture of what is happening in the areas of greatest concern: Middle, Little Back, and Back Rivers.

Sensitivity Analysis #1: Sensitivity Analysis #1 includes five model runs each with a different channel depth: existing conditions (42-ft depth), 44-ft, 45-ft, 46-ft and 48-ft depths. The input conditions for the runs are pore water salinity of the marsh based on low flow/dry river flow and existing sea level. The evaluation period is 1 March to 1 October 2001.

Ecological Community Shift maps provided in Appendix B show changes in marsh vegetation communities throughout the estuary associated with changes in salinity from channel deepening. The impacts with deepening just an additional 2 ft, extend above Steamboat River on the Front, Middle and Little Back rivers. The largest change in vegetation communities are in the EM/ZM class along the Little Back and Front river; the EM+ dominated class along the Front River north of Steamboat River; and the *Z. miliacea* (ZM+) dominated class along the Little Back River. Areas of the EM/ZM class along the Little Back River are replaced largely by classes dominated by SA/SV and MK/ZM under the 2-foot deepening, *S. validus* (SV+) and MK/ZM under the 3-foot deepening and SV/ZM under the 4- and 6-foot deepening. Areas of the EM/ZM co-dominated class along the Front River near Steamboat River are replaced largely by classes co-dominated by *S. validus* (SV/EM and SV/ZM). Areas of the EM+ dominated class along the Front River north of Steamboat River are replaced largely by classes co-dominated by EM/ZM. Areas of the ZM+ dominated class along the Little Back River are replaced largely by classes co-dominated with MK/ZM under the 2- and 3-foot deepening and EM/ZM under the 4- and 6-foot deepening. Along the Middle River north of Steamboat River, areas of the EM/ZM dominated class are replaced largely by a co-dominated SV/EM class under the 6-foot deepening condition. Other changes are seen in the SV/ZM and EM/ZM dominated classes near the secondary channels along the Back River. In this area there is an increase in SA/SV.

The general trend is a loss of freshwater tidal marsh occurring with the increased channel depth. The maximum increases are generally found on the Front River where the deepening is occurring and along the freshwater of the Little Back River; however, with increasing channel depth there are increased losses of freshwater tidal marsh vegetation communities along the Middle River north of Steamboat River as well. A quick view of the Wetland/Marsh Impact table provided in Appendix B does not tell the full story of salinity impacts associated with deepening. The Ecological Community maps and the Ecological Community Shift maps provided in Appendix B provide a clearer picture of what is happening in the areas of greatest concern: Middle, Little Back, and Back Rivers.

Sensitivity Analysis #2A: Sensitivity Analysis #2A includes five model runs each with a different channel depth: existing conditions (42-ft depth), 44-ft, 45-ft, 46-ft and 48-ft depths. The input conditions for the runs are pore water salinity of marsh based on average/typical river flow and a 25 cm sea level rise. The evaluation period is 1 March to 1 October 1997.

Ecological Community Shift maps provided in Appendix C show changes in marsh vegetation communities throughout the estuary associated with salinity changes from channel deepening under 25 cm sea level rise. The impacts with deepening just an additional 2 ft, extend above Steamboat River on the Front, Middle and Little Back rivers. The largest changes in vegetation communities are in the co-dominated MK/ZM class along the upper reaches of the Little Back River and the EM+ and EM/ZM dominated classes along the Little Back and Front rivers. Areas of the MK/ZM class along the upper reaches of the Little Back River are replaced largely by classes dominated by EM/ZM under the 2- and 3-foot deepenings and EM/ZM and SV/ZM under the 4- and 6-foot deepenings. Areas of the EM/ZM dominated class along the Little Back River are replaced largely by classes co-dominated by SV/ZM and ZM+. Areas of the EM/ZM dominated class along the Front River near Steamboat River are replaced largely by classes co-dominated with *S. validus* (SV/EM and SV/ZM). Areas of the EM+ class along the Little Back River and Front River near Steamboat River are replaced largely by an EM/ZM dominated class. Other large changes are seen in the SV/ZM and EM/ZM dominated classes near the secondary channels along the Back River and along areas of the Front River south of Steamboat River. In these areas there are increases in the SA/SV and SV+ classes.

The general trend is a loss of freshwater tidal marsh occurring with the increased channel depth. The maximum increases are generally found on the Front River where the deepening is occurring and along the more freshwater Little Back River. A quick view of Wetland/Marsh Impact table provided in Appendix C does not tell the full story of salinity impacts associated with deepening. The Ecological Community maps and the Ecological Community Shift maps in Appendix C provide a clearer picture of what is happening in the areas of greatest concern: Middle, Little Back, and Back Rivers.

Sensitivity Analysis #2B: Sensitivity Analysis #2B includes five model runs each with a different channel depth: existing conditions (42-ft depth), 44-ft, 45-ft, 46-ft and 48-ft depths. The input conditions for the runs are pore water salinity of marsh sediments based on average/typical river flow and a 50 cm sea level rise. The evaluation period is 1 March to 1 October 1997.

Ecological Community Shift maps provided in Appendix D show changes in marsh vegetation communities throughout the estuary associated with salinity changes from channel deepening under a 50 cm sea level rise. The impacts with deepening just an additional 2 ft, extend above Steamboat River on the Front, Middle and Little Back rivers. The largest change in vegetation communities are in the co-dominated EM/ZM class along the Front, Middle and the Little Back rivers and the SV/ZM dominated class along the Back, Little Back, Middle, and Front rivers. Areas of the EM/ZM dominated class along the Front and the Middle rivers are replaced largely by classes of SV/EM and SV/ZM. Whereas areas of the EM/ZM dominated class along the Little Back River are replaced largely by classes co-dominated by SA/SV and SV+ under the 4- and 6-foot deepenings. Areas of the SV/ZM dominated class near the secondary channels along the Back, Little Back, Middle, and Front rivers are replaced largely by SA/SV and SV+ classes.

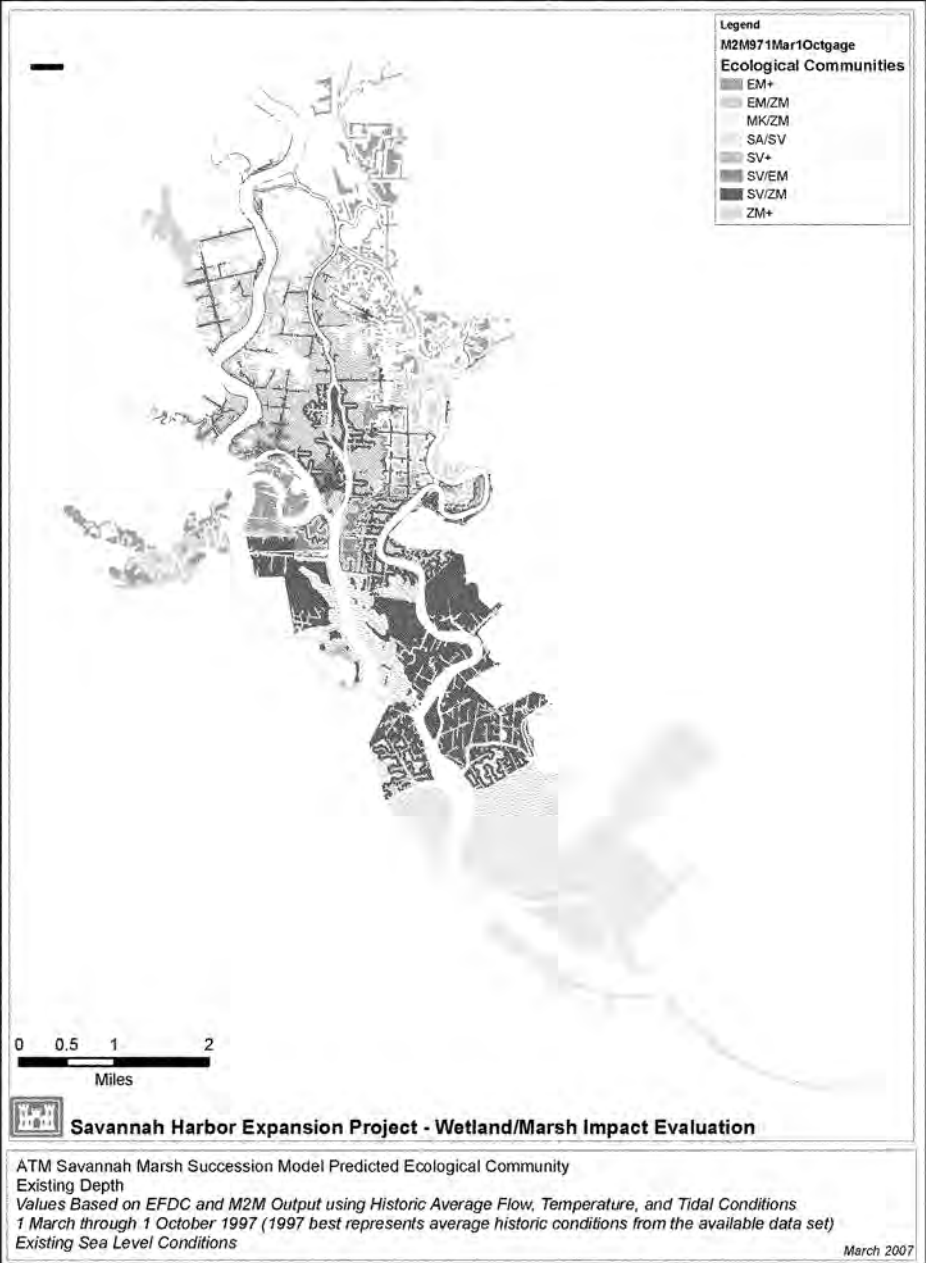
The general trend is a loss of freshwater tidal marsh occurring with the increased channel depth. The maximum increases are generally found on the Front River where the deepening is occurring and along the more freshwater Little Back River. A quick view of the Wetland/Marsh Impact Evaluation table in Appendix D does not tell the full story of pore water salinity increase

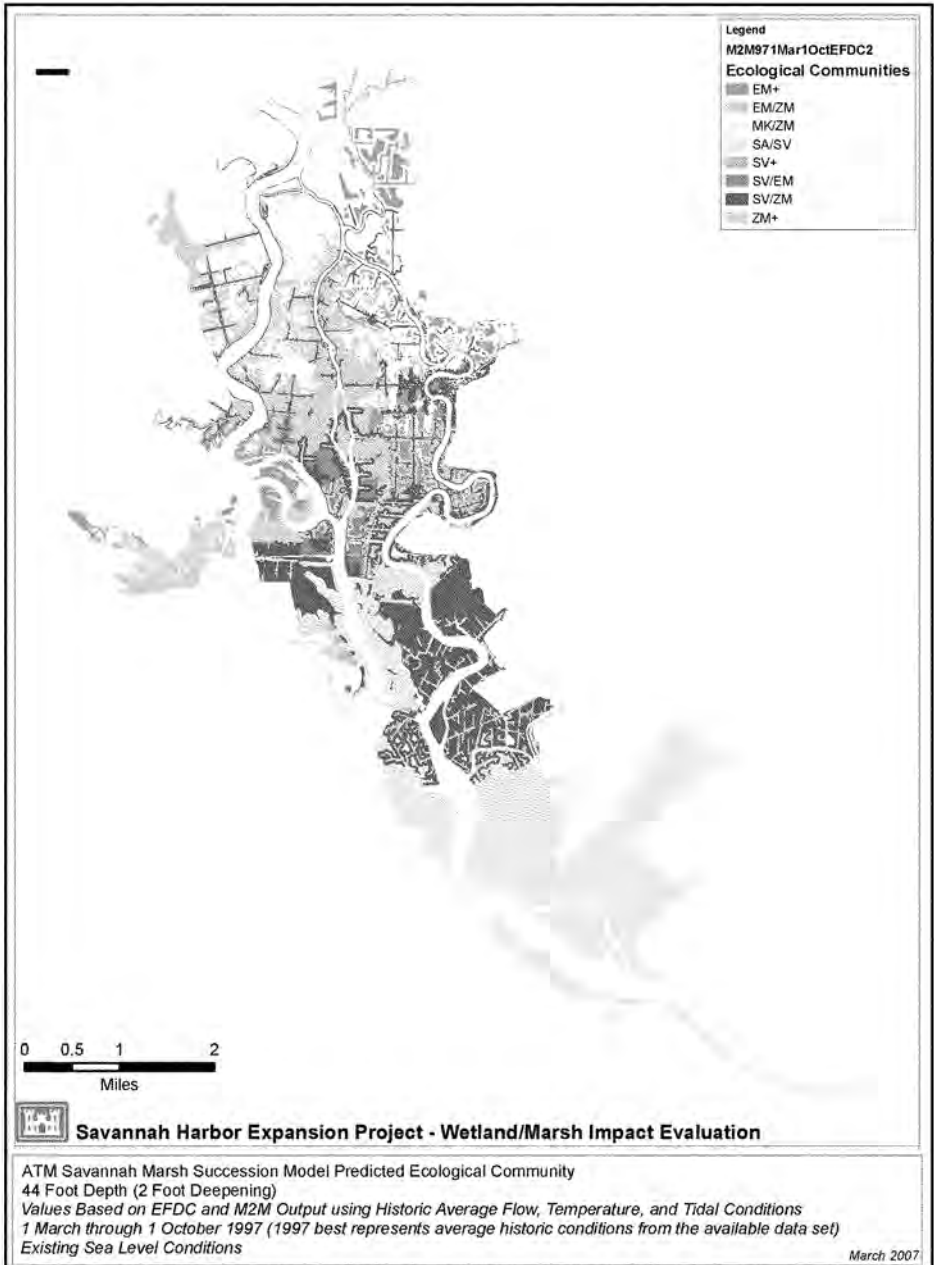
associated with deepening. The Ecological Community map and Ecological Community Shift maps in Appendix D provide a clearer picture of what is happening in the areas of greatest concern: Middle, Little Back, and Back rivers.

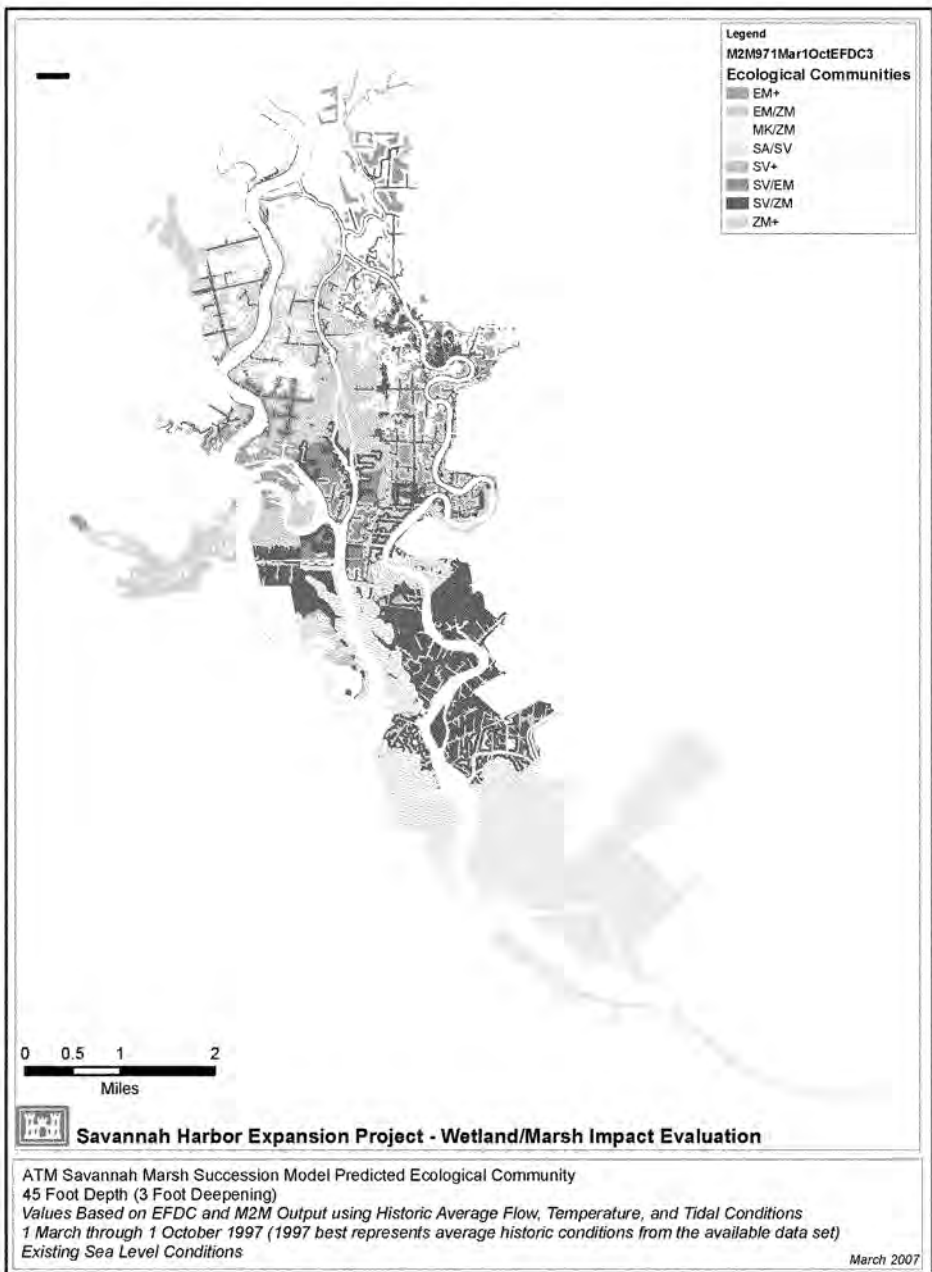
Conclusion:

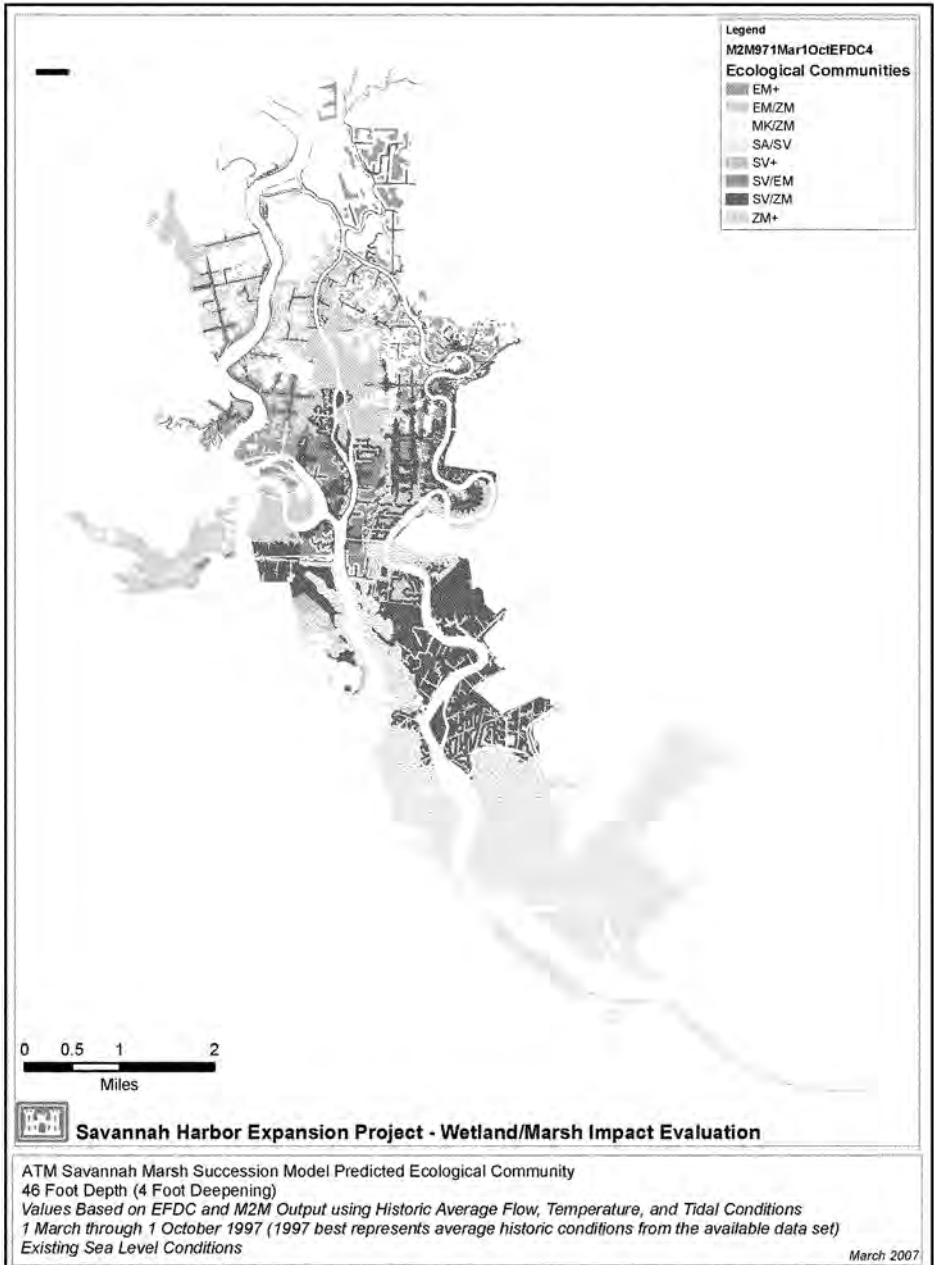
The MSM modeling predicts that there will be impacts on the freshwater marsh vegetation communities with each deepening. The level of impact depends directly on the proposed depth of the navigation channel. The trends indicate that as the navigation channel is deepened salinity intrudes further and further upstream resulting in a shift to more salt tolerant species. Rising sea levels results in salt tolerant species propagating even further upstream.

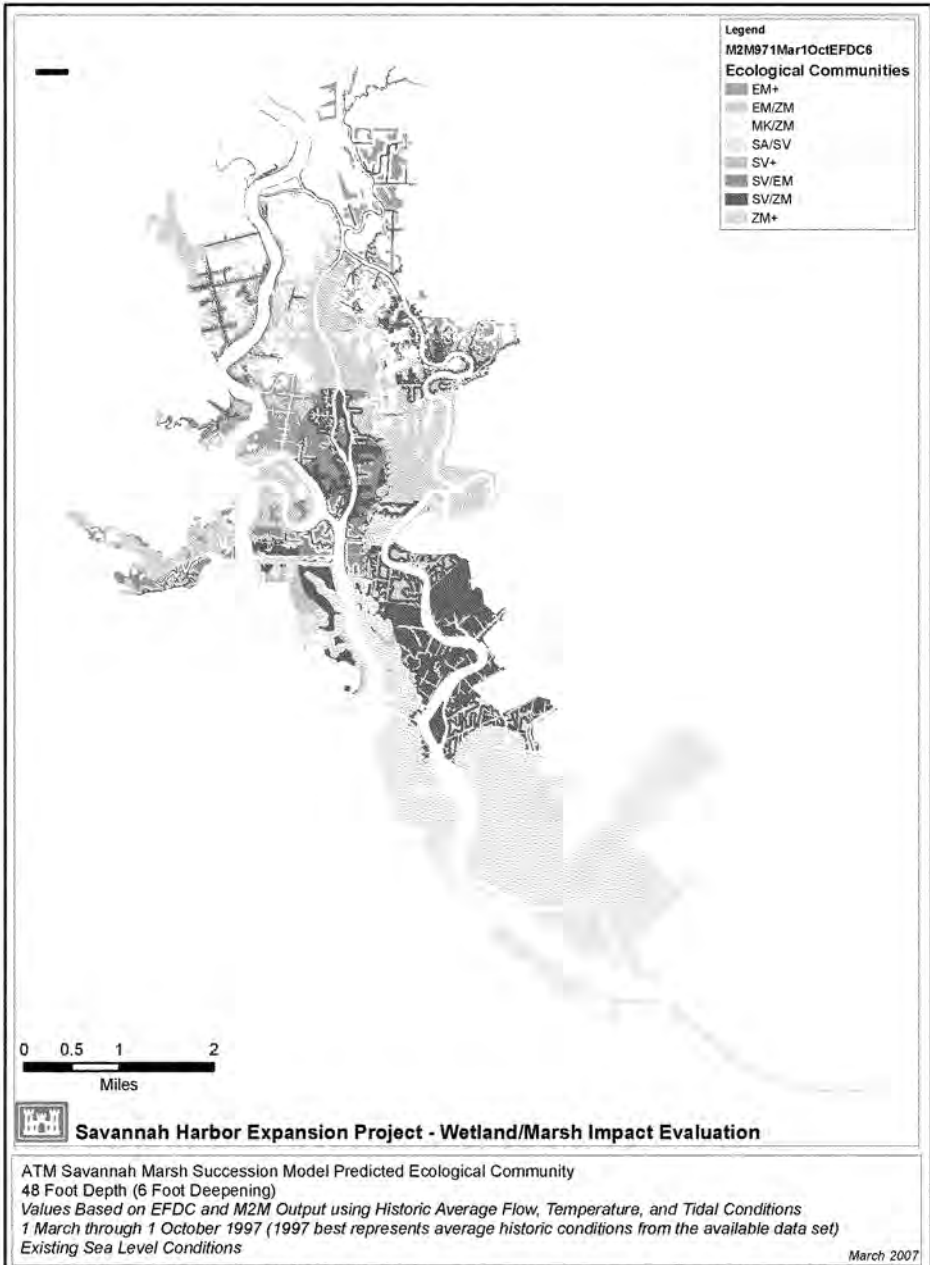
APPENDIX A
BASIC EVALUATION
ECOLOGICAL COMMUNITY MAPS &
ECOLOGICAL COMMUNITY SHIFT MAPS

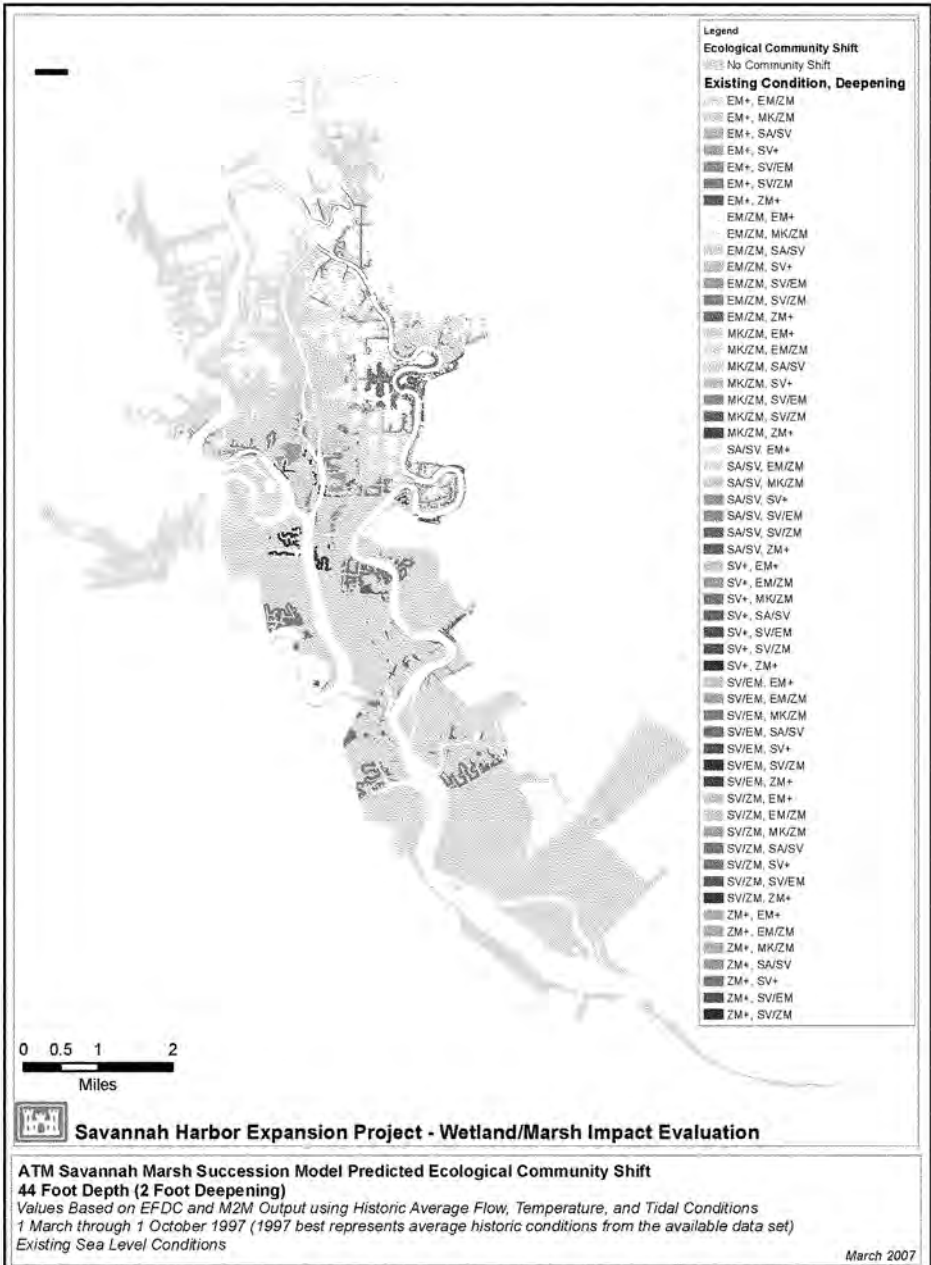


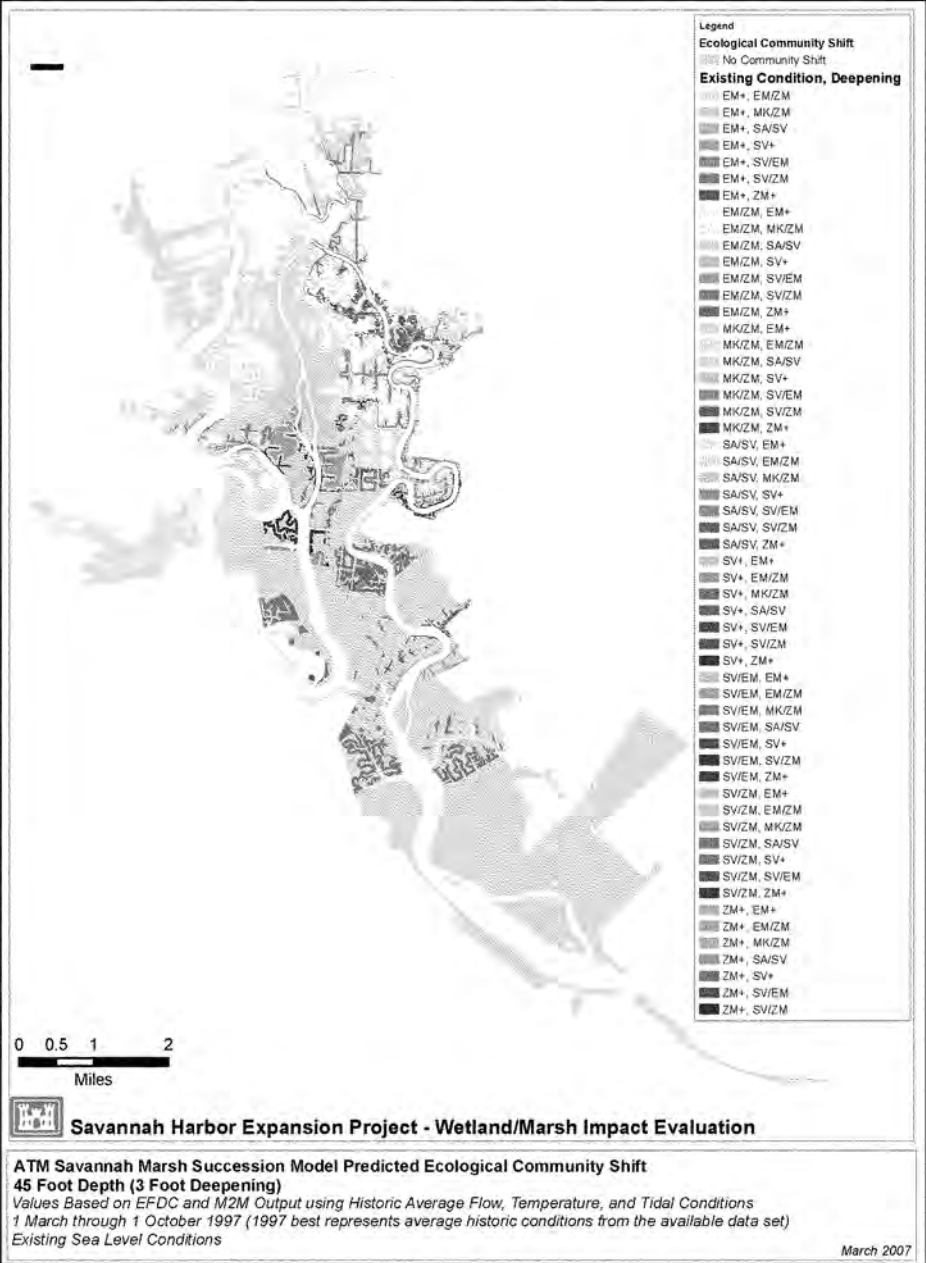


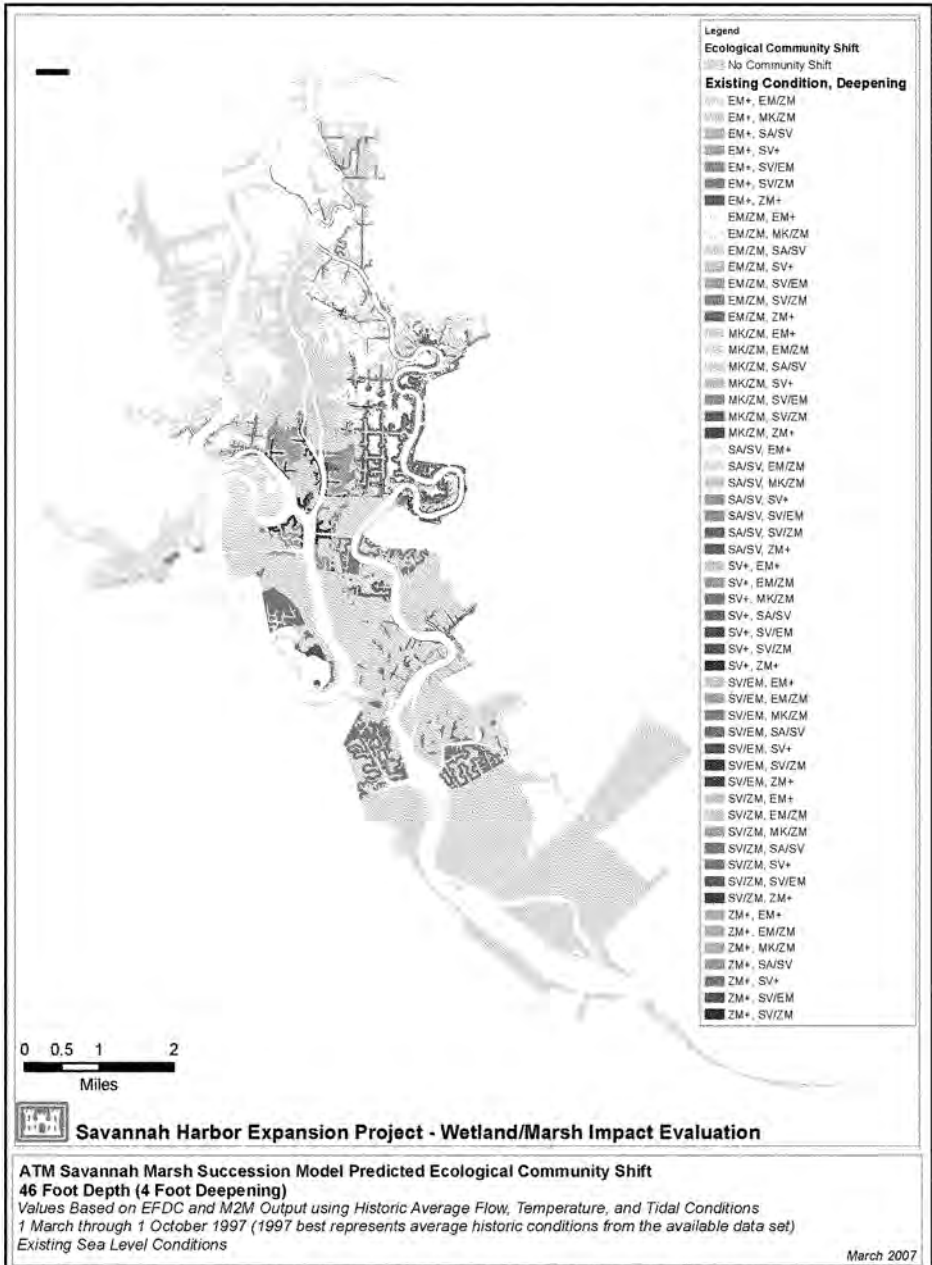


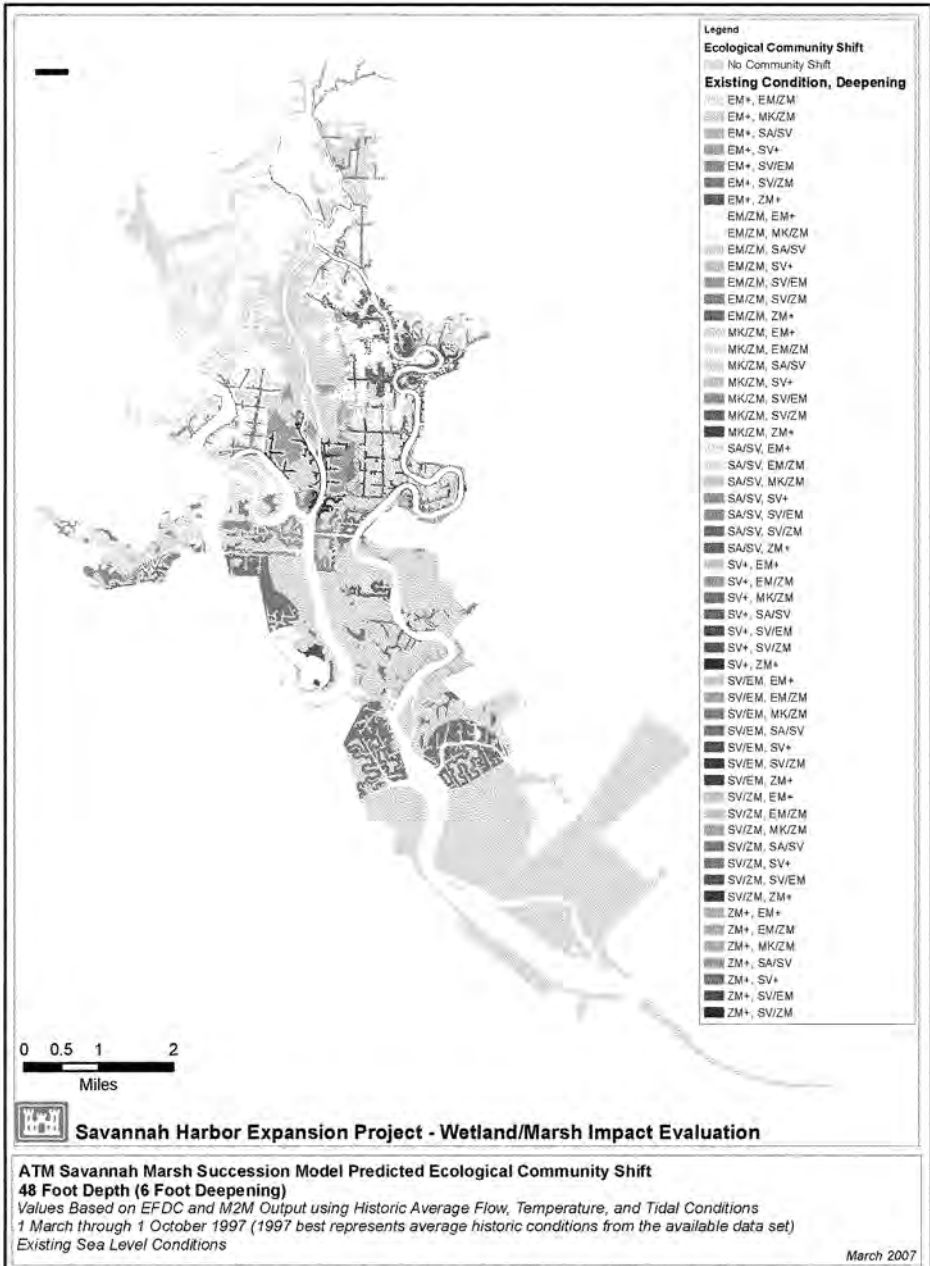












Savannah Harbor Expansion Project
ATM MSM Wetland/Marsh Impact Evaluation
Predicted Vegetation Community Shifts

Community	No Deepening Average Flow Associated Acreages	44 ft Deepening Average Flow Associated Acreages	Net Change (net negative), net positive
EM+	690	534	(156)
EM/ZM	1729	1880	151
MK/ZM	424	216	(208)
ZM+	259	228	(30)
SV/EM	85	122	37
SV/ZM	1938	1983	45
SV+	15	27	12
SA/SV	2861	3011	149
TOTAL	8001	8001	

Community	No Deepening Average Flow Associated Acreages	45 ft Deepening Average Flow Associated Acreages	Net Change (net negative), net positive
EM+	690	521	(170)
EM/ZM	1729	1946	218
MK/ZM	424	145	(279)
ZM+	259	213	(46)
SV/EM	85	146	62
SV/ZM	1938	1924	(14)
SV+	15	42	26
SA/SV	2861	3064	203
TOTAL	8001	8001	

Community	No Deepening Average Flow Associated Acreages	46 ft Deepening Average Flow Associated Acreages	Net Change (net negative), net positive
EM+	690	532	(158)
EM/ZM	1729	1812	83
MK/ZM	424	125	(299)
ZM+	259	197	(62)
SV/EM	85	180	96
SV/ZM	1938	1953	15
SV+	15	52	37
SA/SV	2861	3149	287
TOTAL	8001	8001	

Community	No Deepening Average Flow Associated Acreages	48 ft Deepening Average Flow Associated Acreages	Net Change (net negative), net positive
EM+	690	463	(227)
EM/ZM	1729	1794	66
MK/ZM	424	100	(324)
ZM+	259	249	(9)
SV/EM	85	303	219
SV/ZM	1938	1606	(332)
SV+	15	102	87
SA/SV	2861	3383	522
TOTAL	8001	8001	

* Values Based on EFDC and M2M Marsh Pore Water Salinity Input for Historic Average Flow, Temperature, and Tidal Conditions

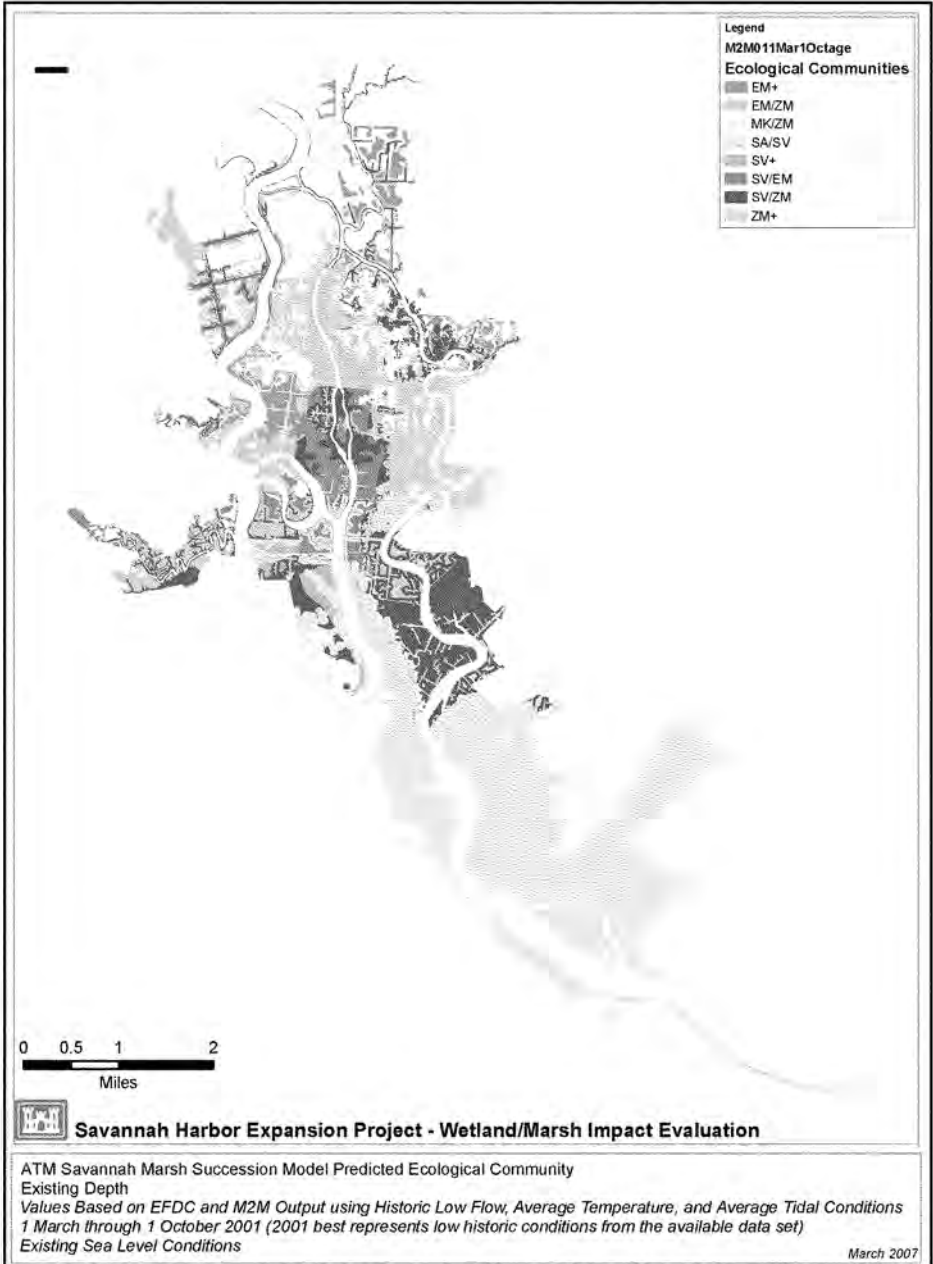
† March through 1 October 1997 (1997 best represents average historic conditions from the available data set)

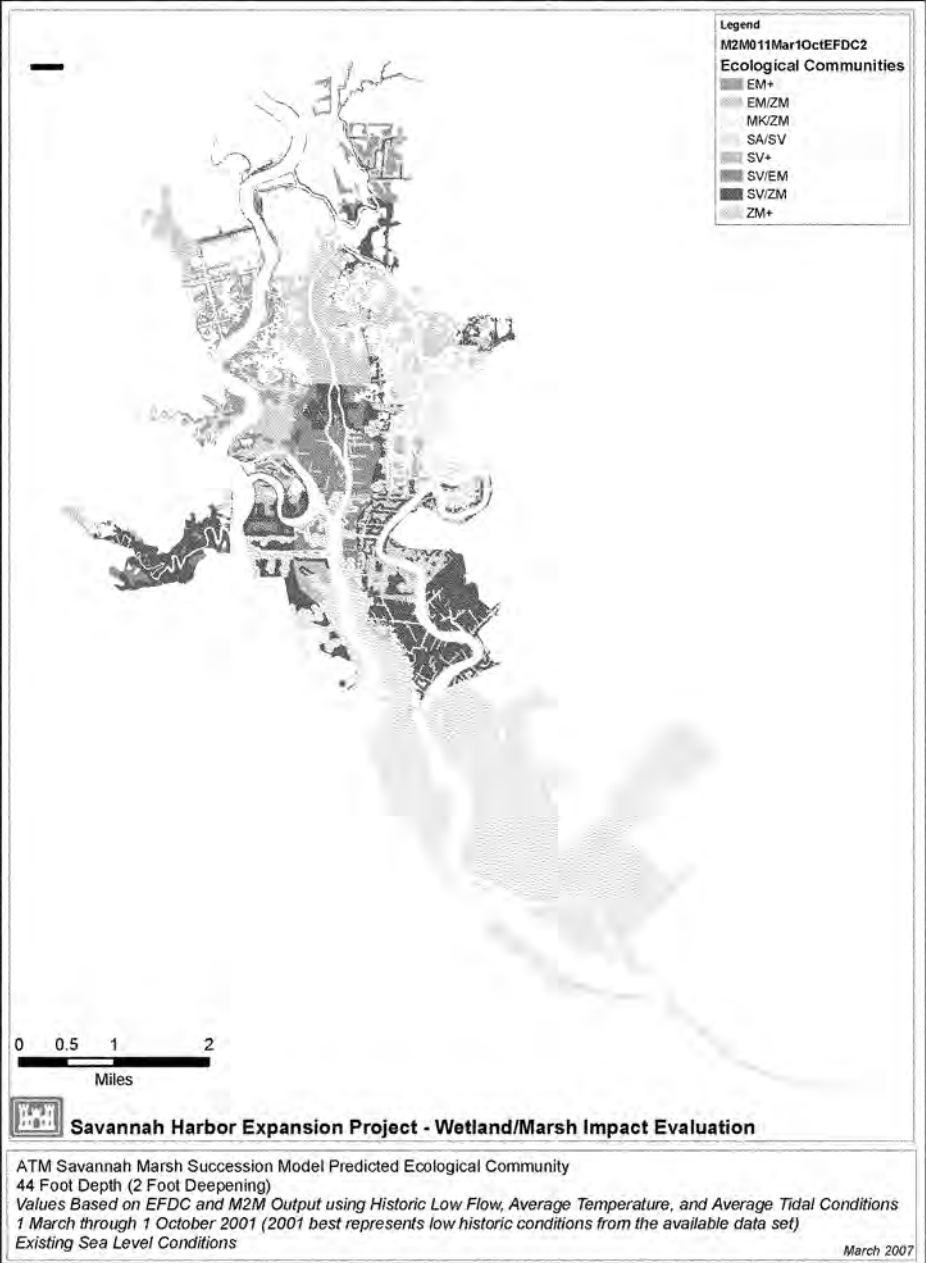
Existing Sea Level Conditions

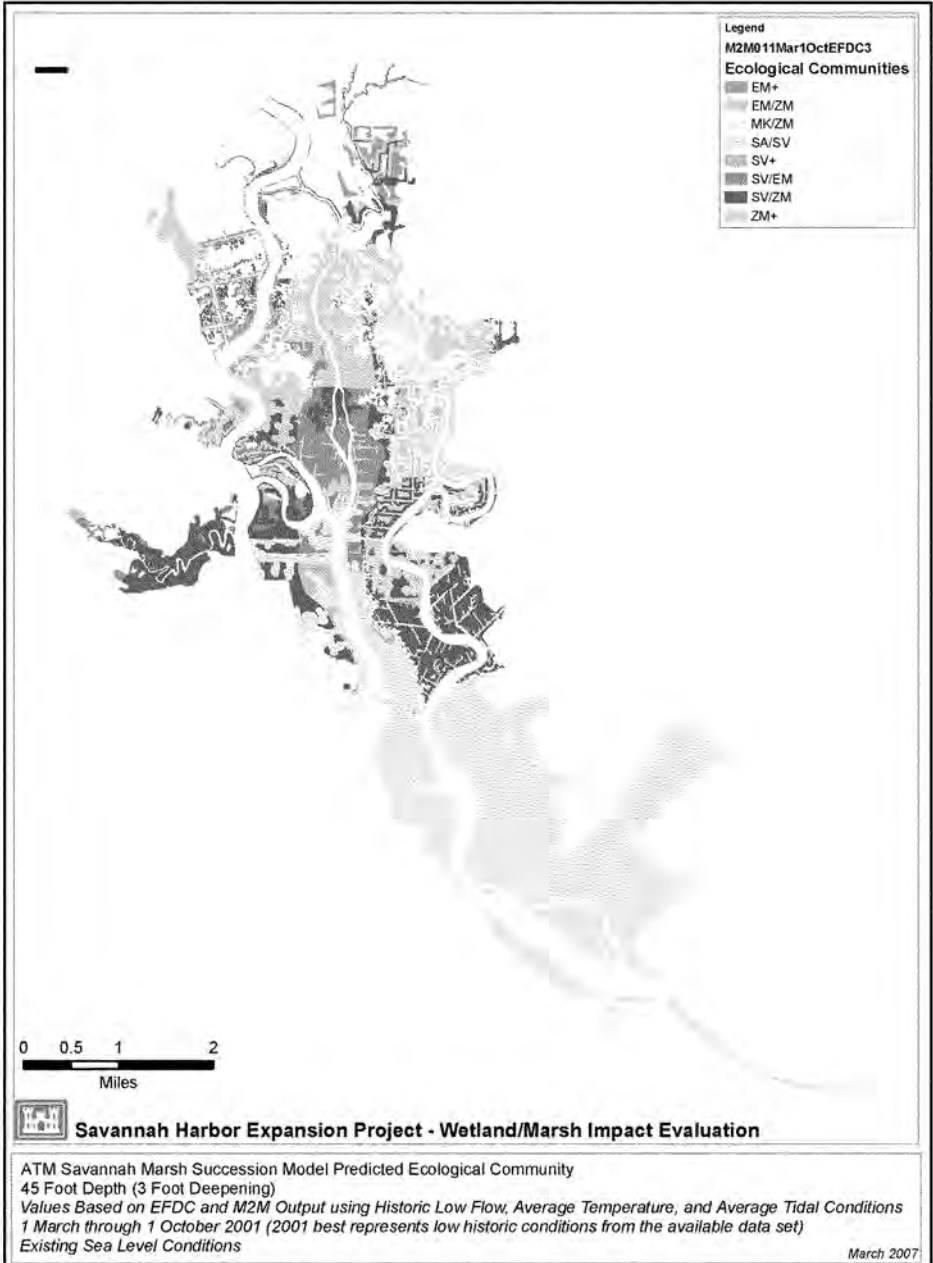


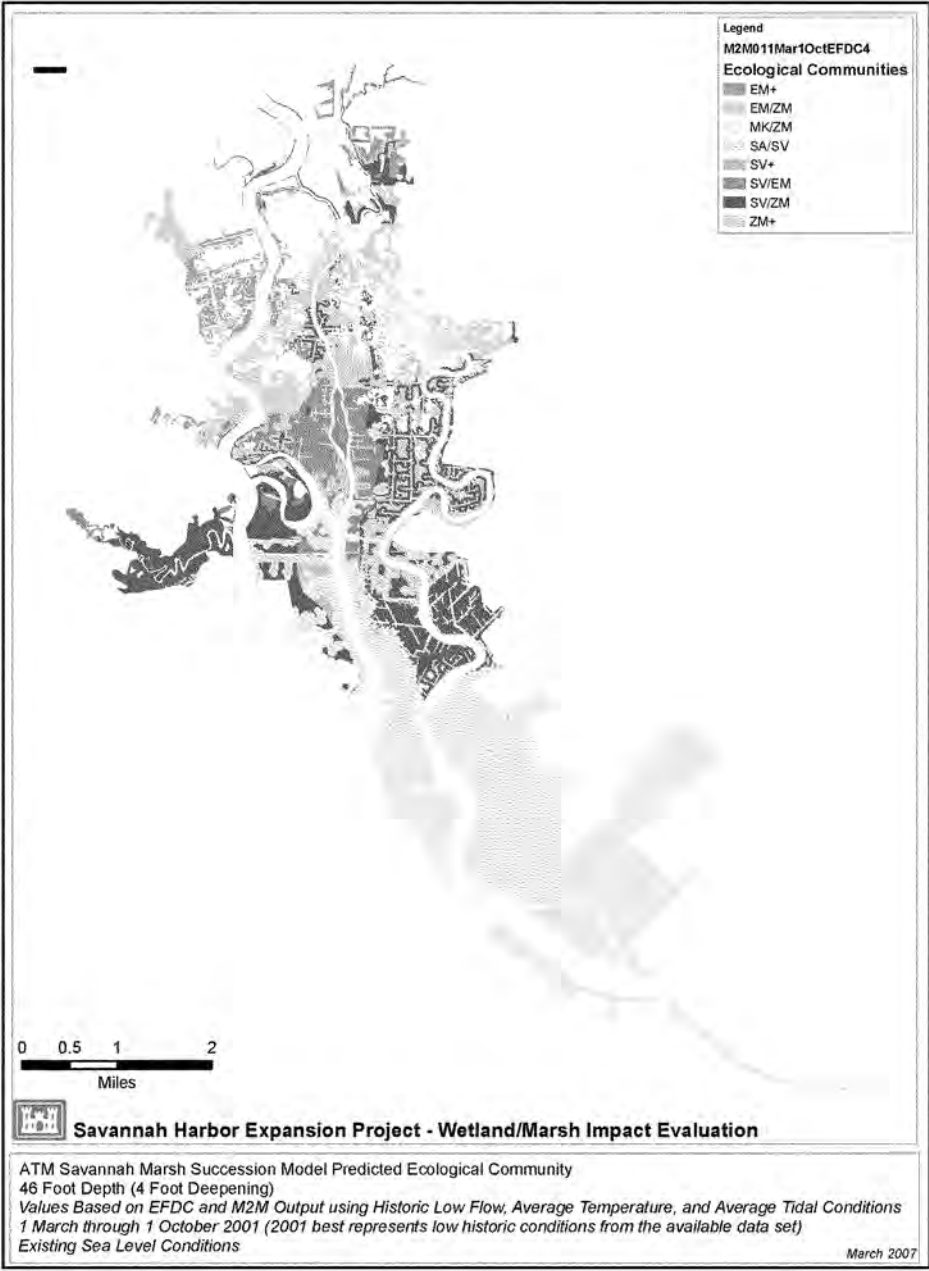
March 2007

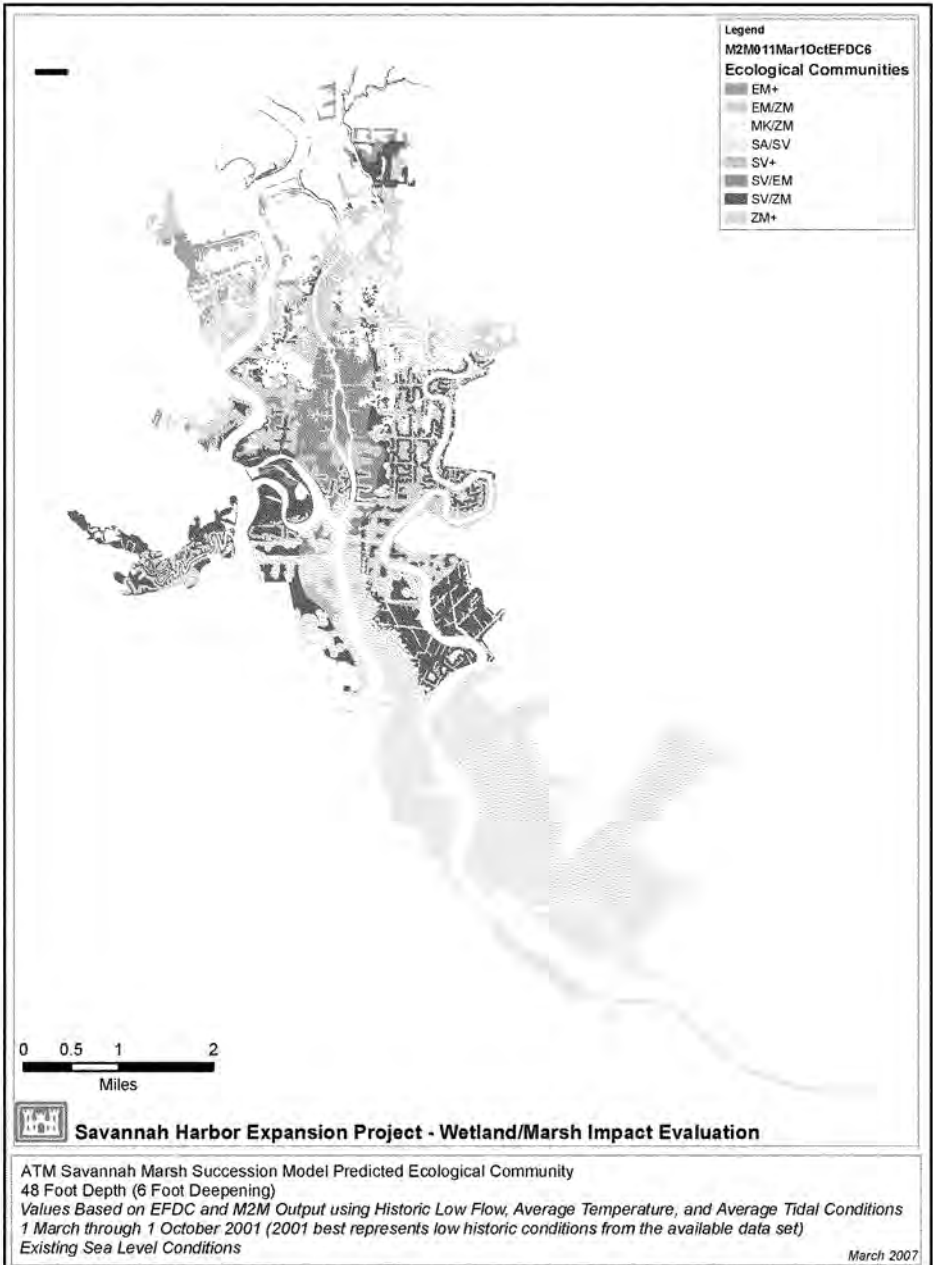
APPENDIX B
SENSITIVITY ANALYSIS #1
ECOLOGICAL COMMUNITY MAPS &
ECOLOGICAL COMMUNITY SHIFT MAPS

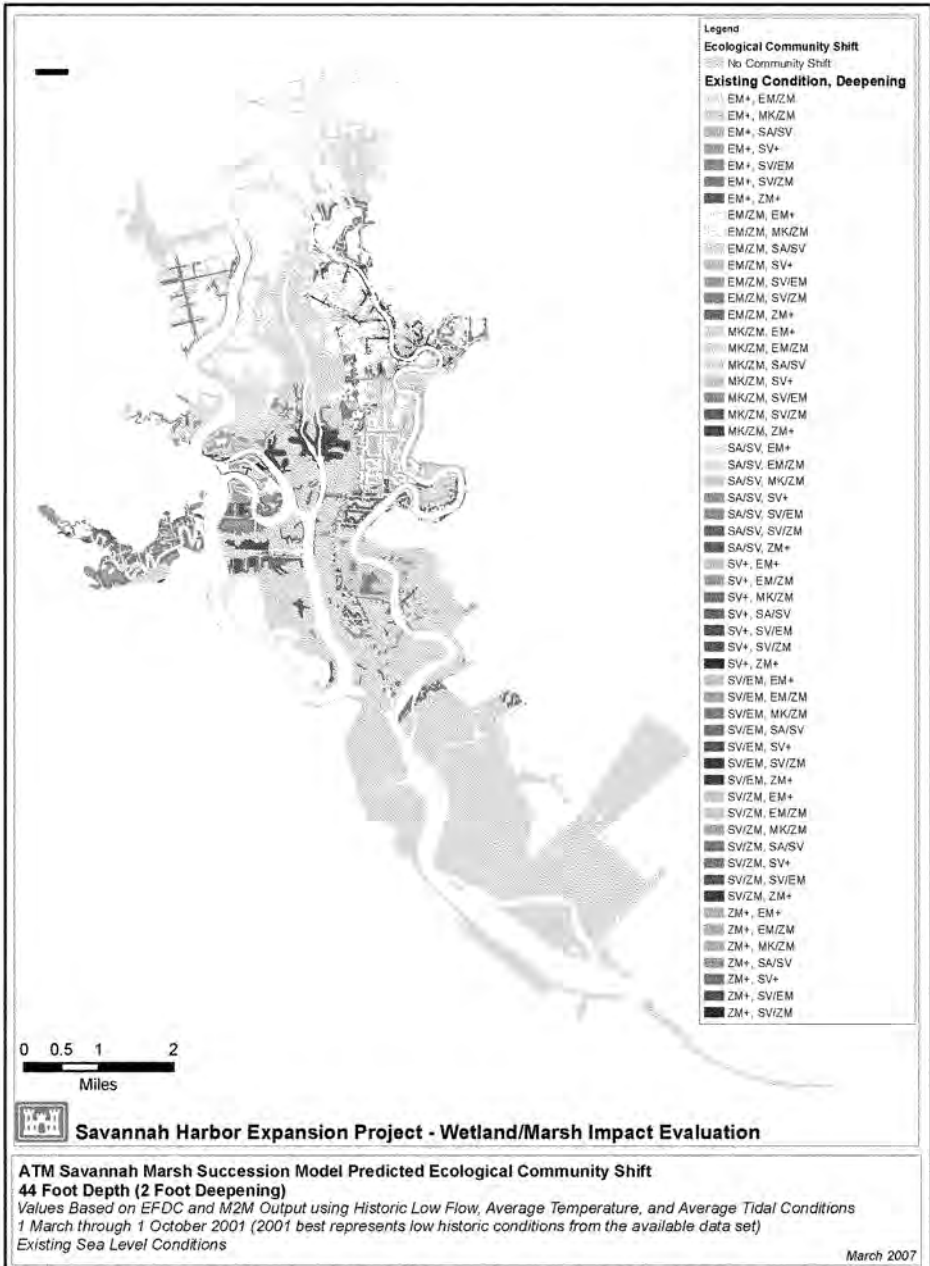


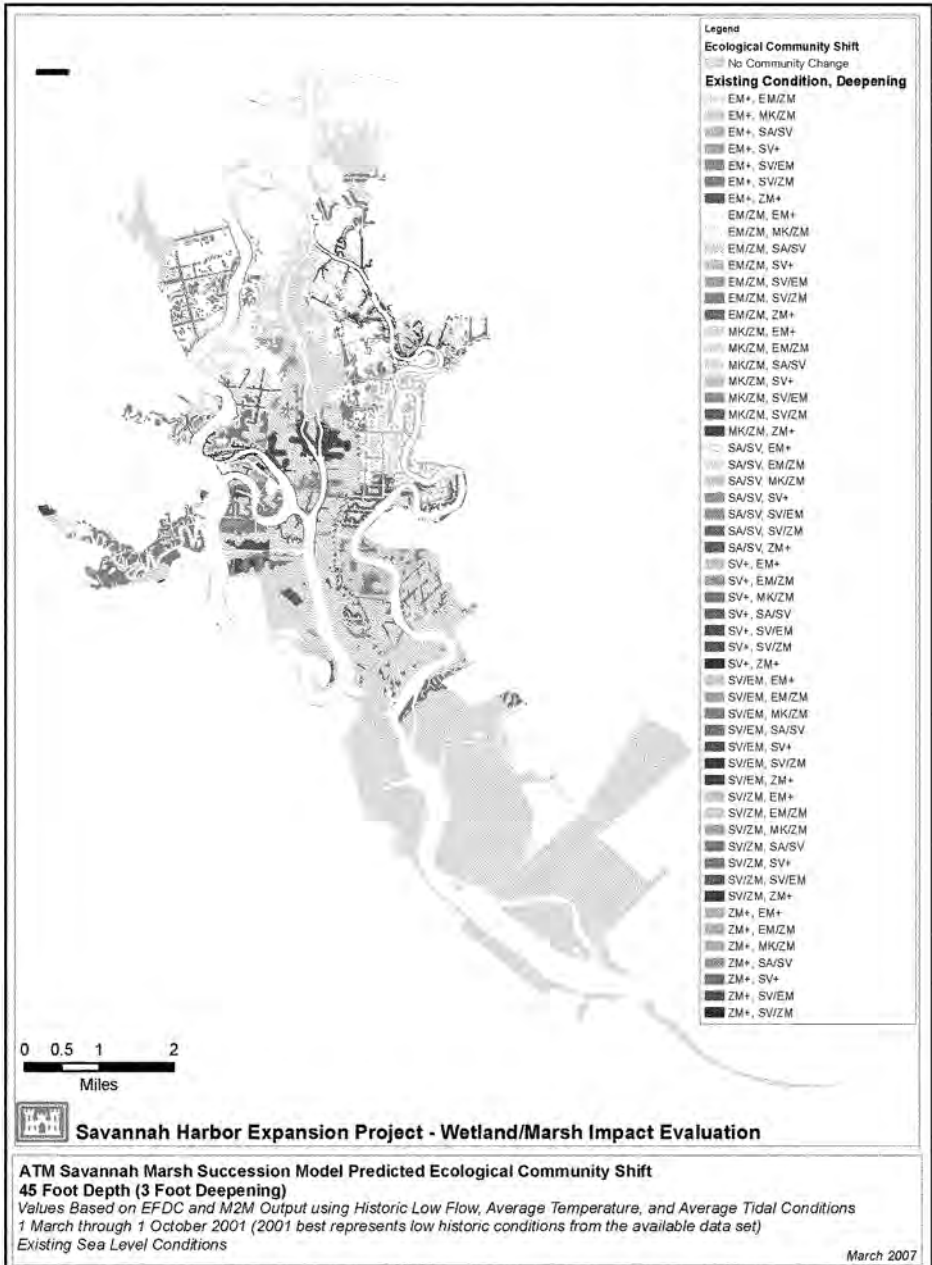


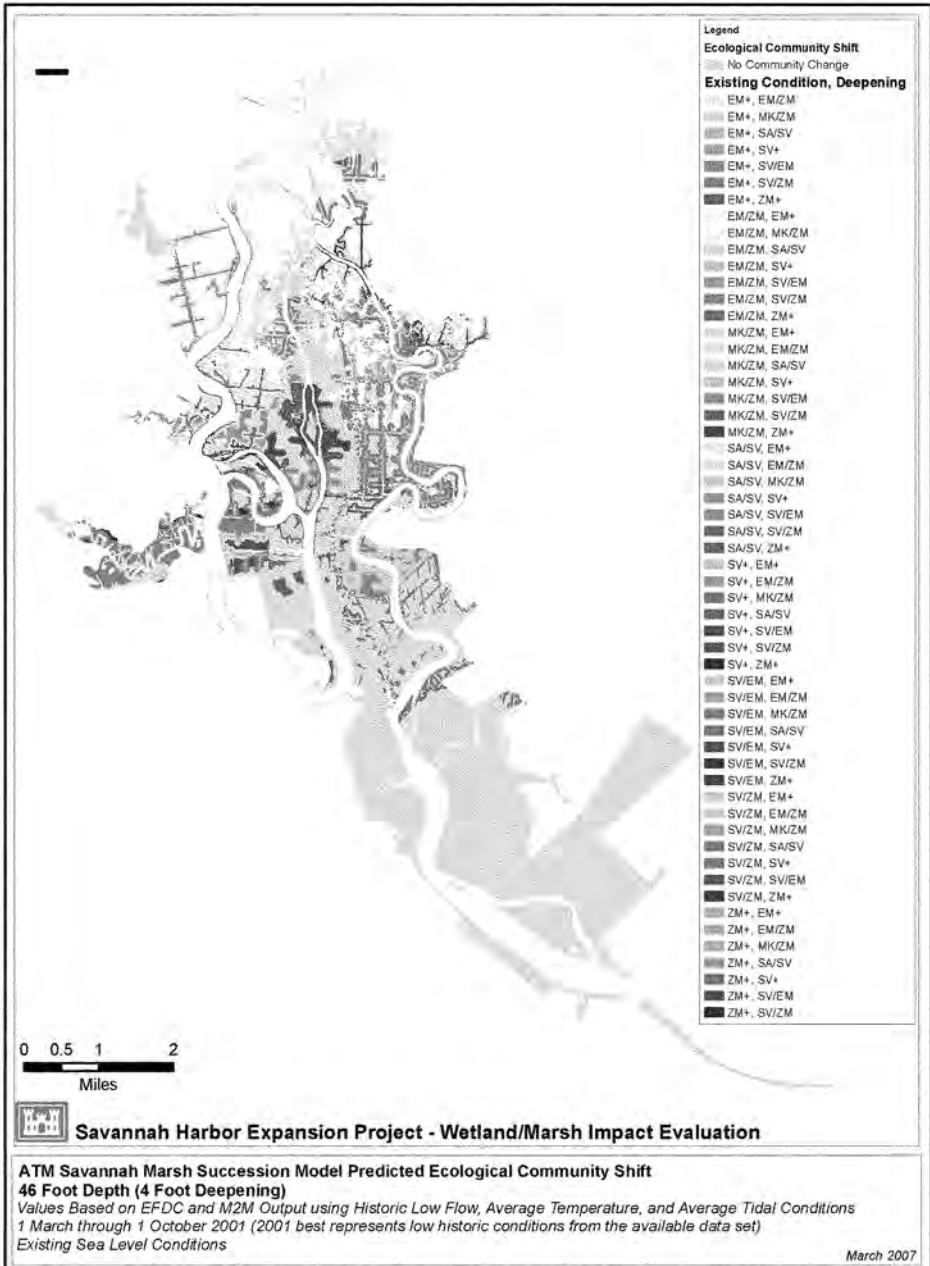


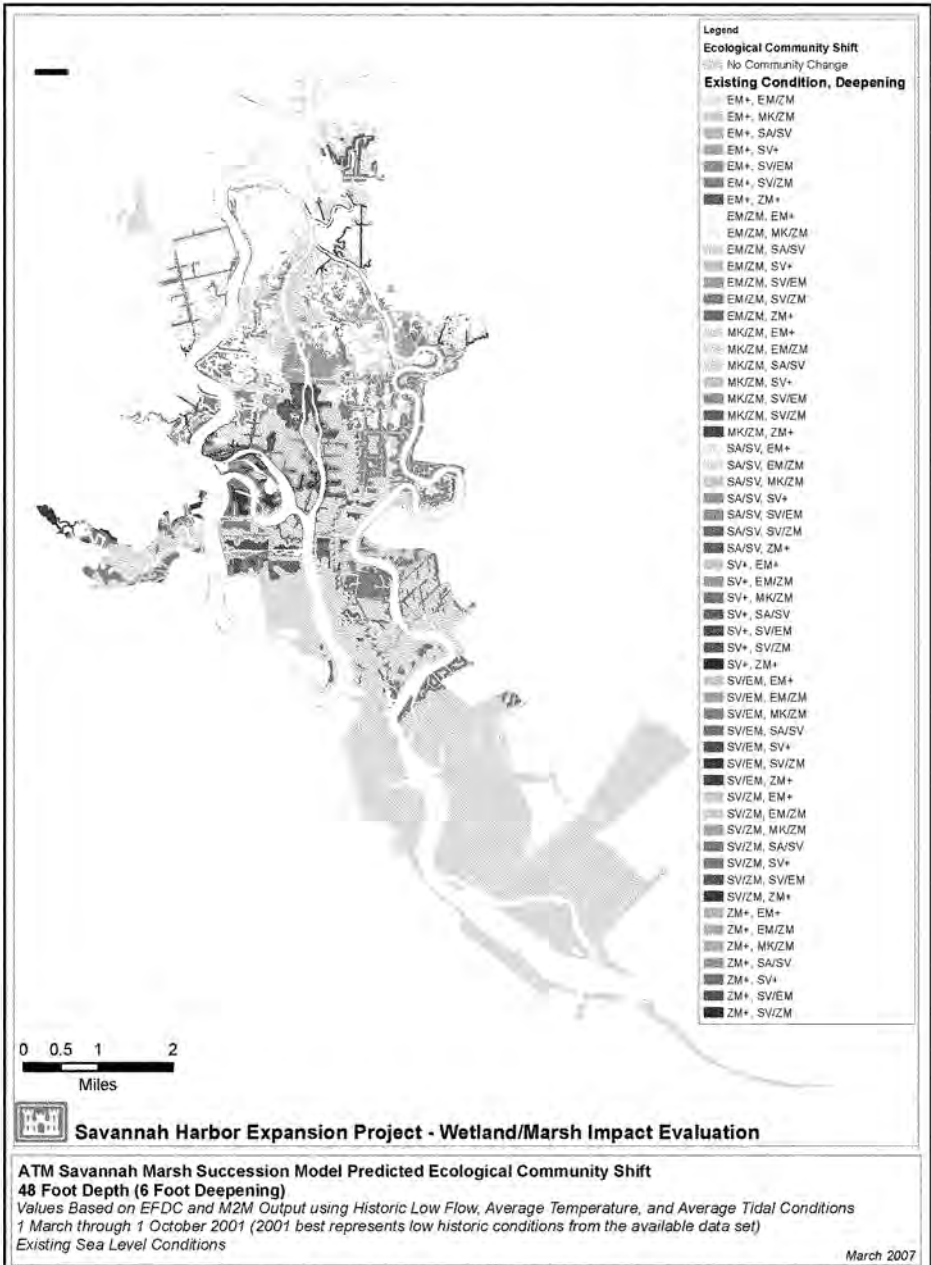












Savannah Harbor Expansion Project
ATM MSM Wetland/Marsh Impact Evaluation
Predicted Vegetation Community Shifts

Community	Existing Depth Low Flow Associated Acreages	44 ft Depth Low Flow Associated Acreages	Net Change (net negative), net positive
EM+	439	368	(71)
EM/ZM	1709	1366	(343)
MK/ZM	98	214	116
ZM+	228	143	(85)
SV/EM	372	473	101
SV/ZM	1394	1385	(9)
SV+	134	150	16
SA/SV	3627	3902	275
TOTAL	8001	8001	

Community	Existing Depth Low Flow Associated Acreages	45 ft Depth Low Flow Associated Acreages	Net Change (net negative), net positive
EM+	439	259	(180)
EM/ZM	1709	1411	(298)
MK/ZM	98	199	101
ZM+	228	170	(58)
SV/EM	372	481	110
SV/ZM	1394	1449	55
SV+	134	148	14
SA/SV	3627	3882	255
TOTAL	8001	8001	

Community	Existing Depth Low Flow Associated Acreages	46 ft Depth Low Flow Associated Acreages	Net Change (net negative), net positive
EM+	439	259	(180)
EM/ZM	1709	1475	(234)
MK/ZM	98	47	(51)
ZM+	228	168	(60)
SV/EM	372	513	141
SV/ZM	1394	1491	97
SV+	134	99	(35)
SA/SV	3627	3949	322
TOTAL	8001	8001	

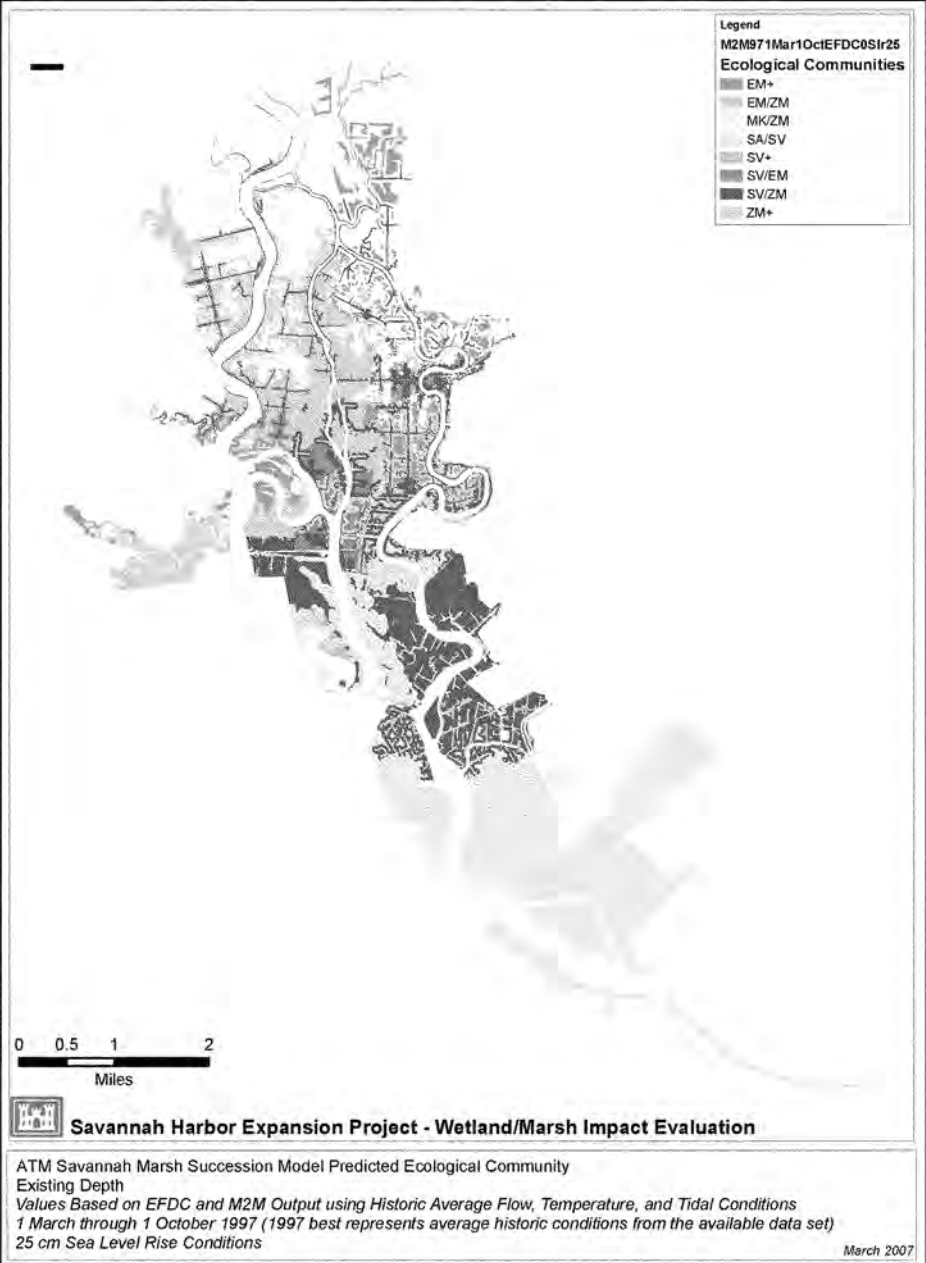
Community	Existing Depth Low Flow Associated Acreages	48 ft Depth Low Flow Associated Acreages	Net Change (net negative), net positive
EM+	439	196	(243)
EM/ZM	1709	1505	(205)
MK/ZM	98	75	(23)
ZM+	228	114	(114)
SV/EM	372	496	124
SV/ZM	1394	1408	14
SV+	134	114	(20)
SA/SV	3627	4093	466
TOTAL	8001	8001	

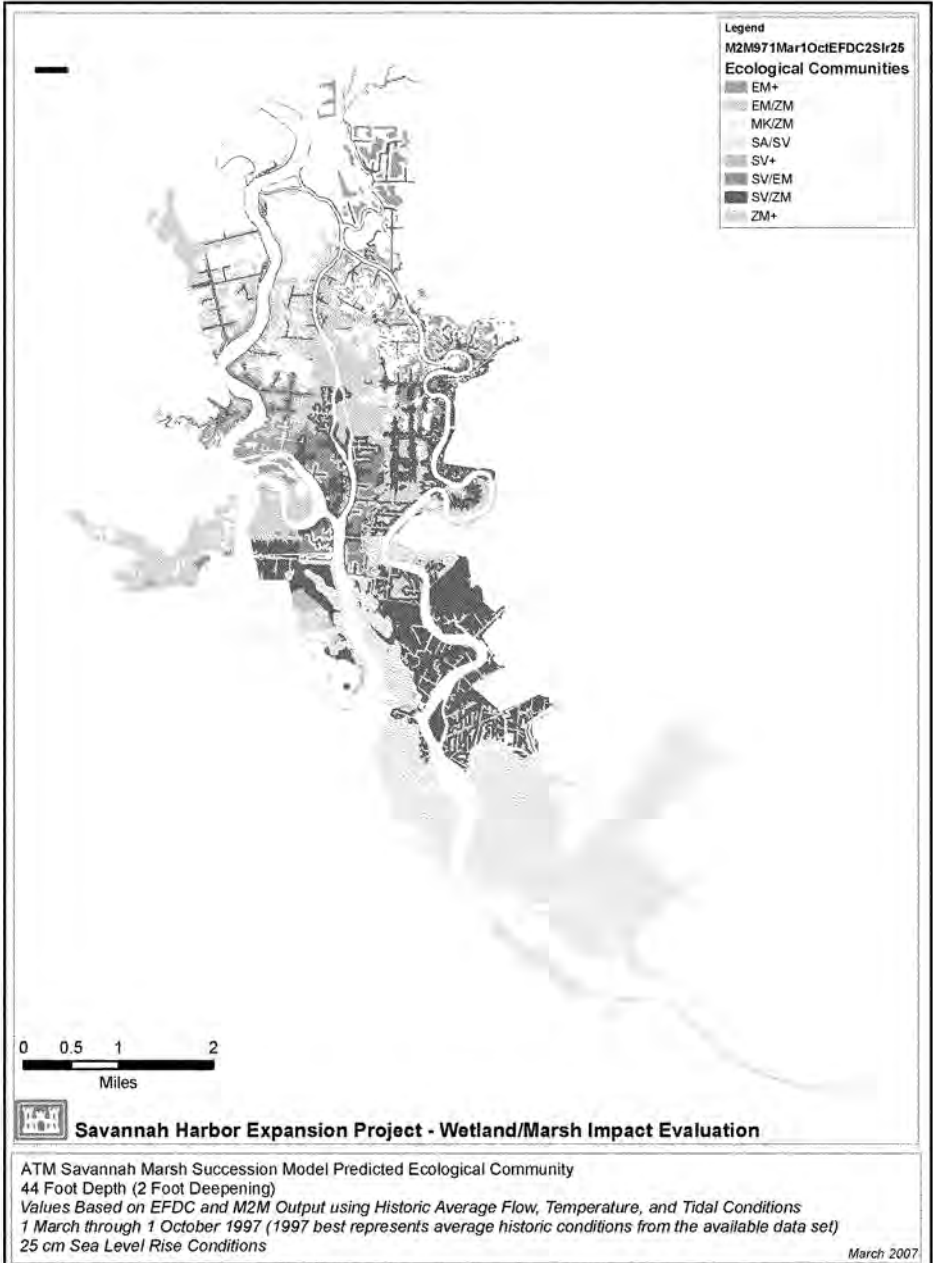
* Values Based on EFDC and M2M Marsh Pore Water Salinity Input for Historic Low Flow, Average Temperature, and Average Tidal Conditions
 1 March through 1 October 2001 (2001 best represents low historic conditions from the available data set)
 Existing Sea Level Conditions.

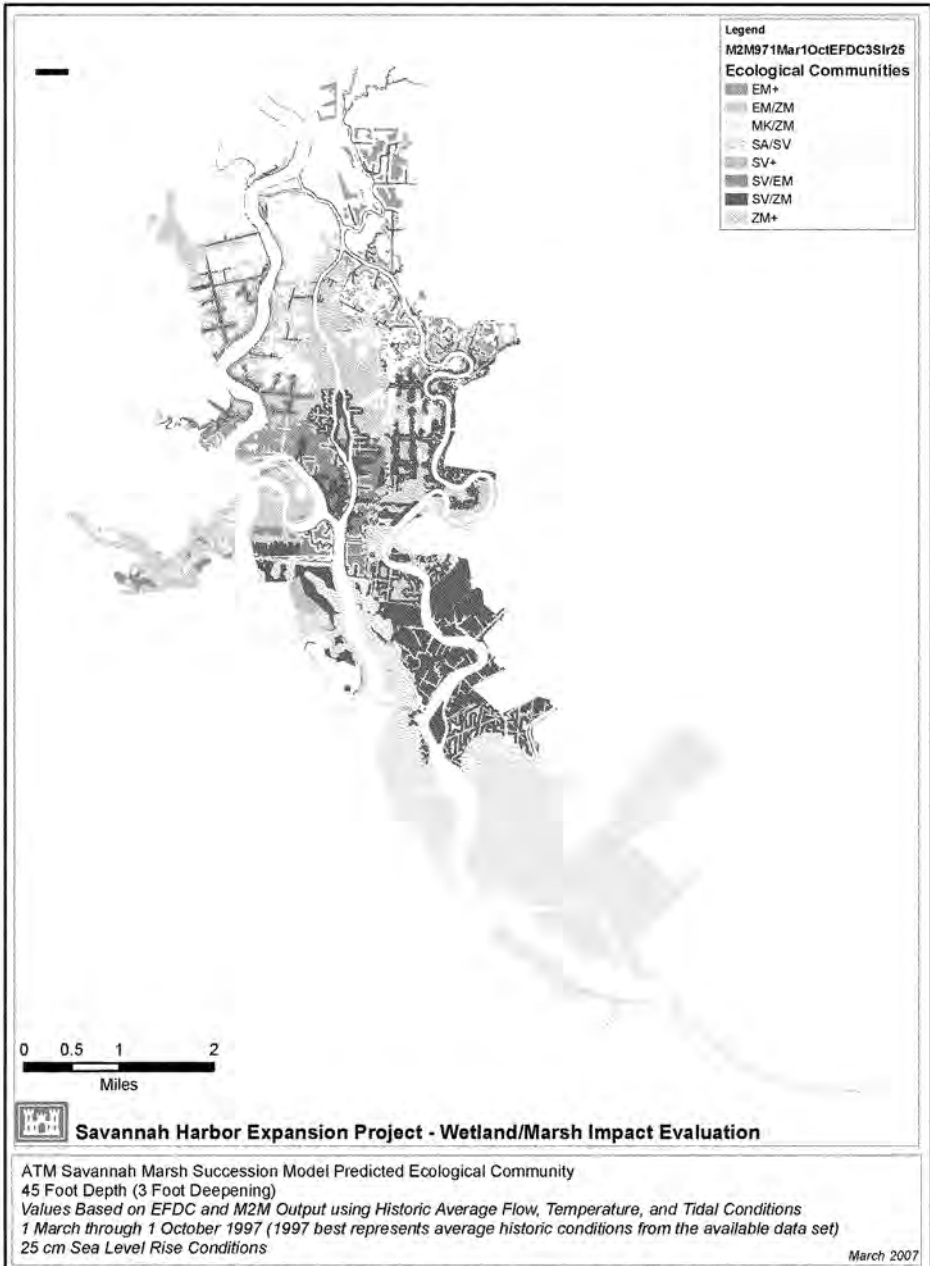


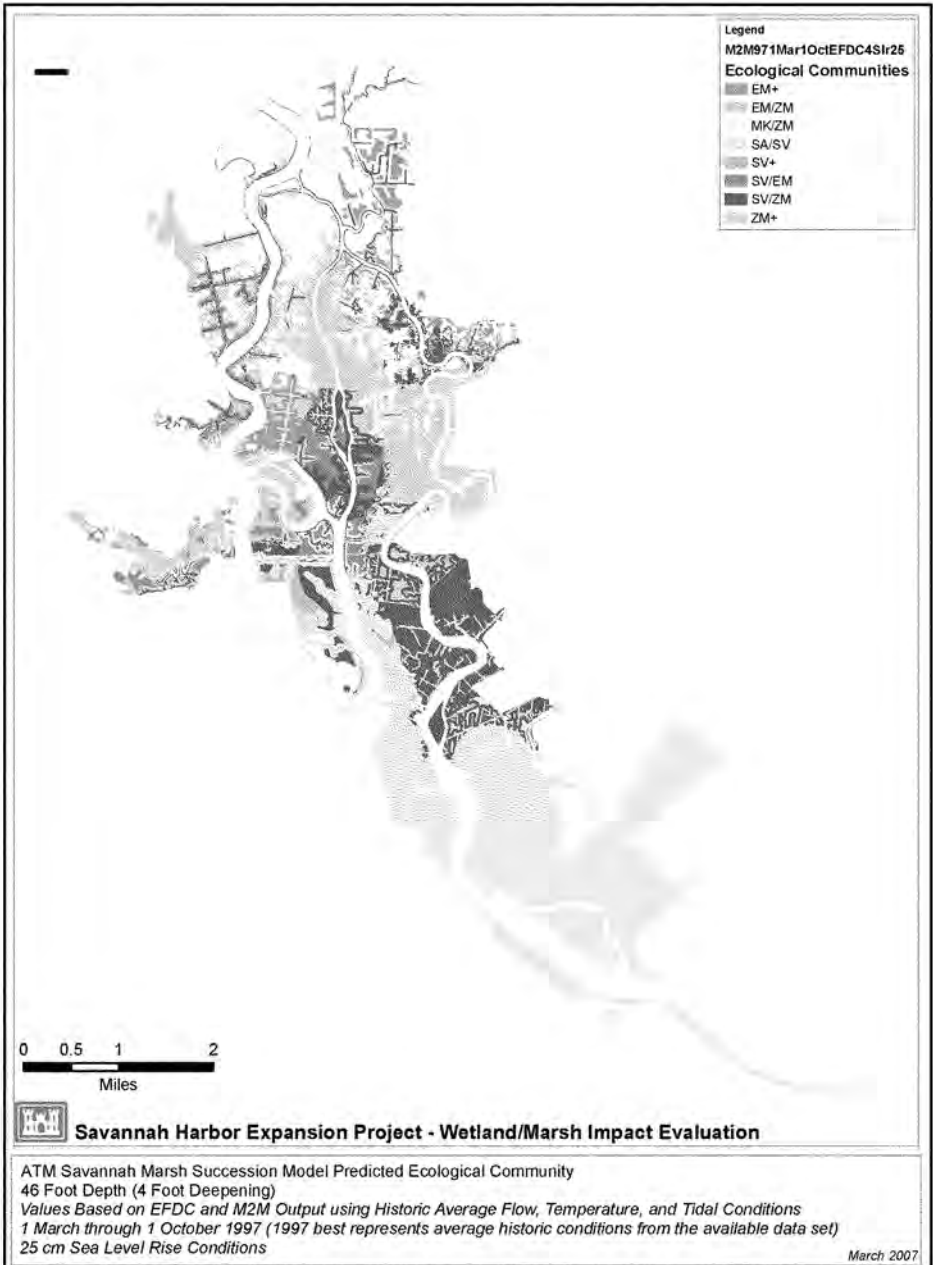
March 2007

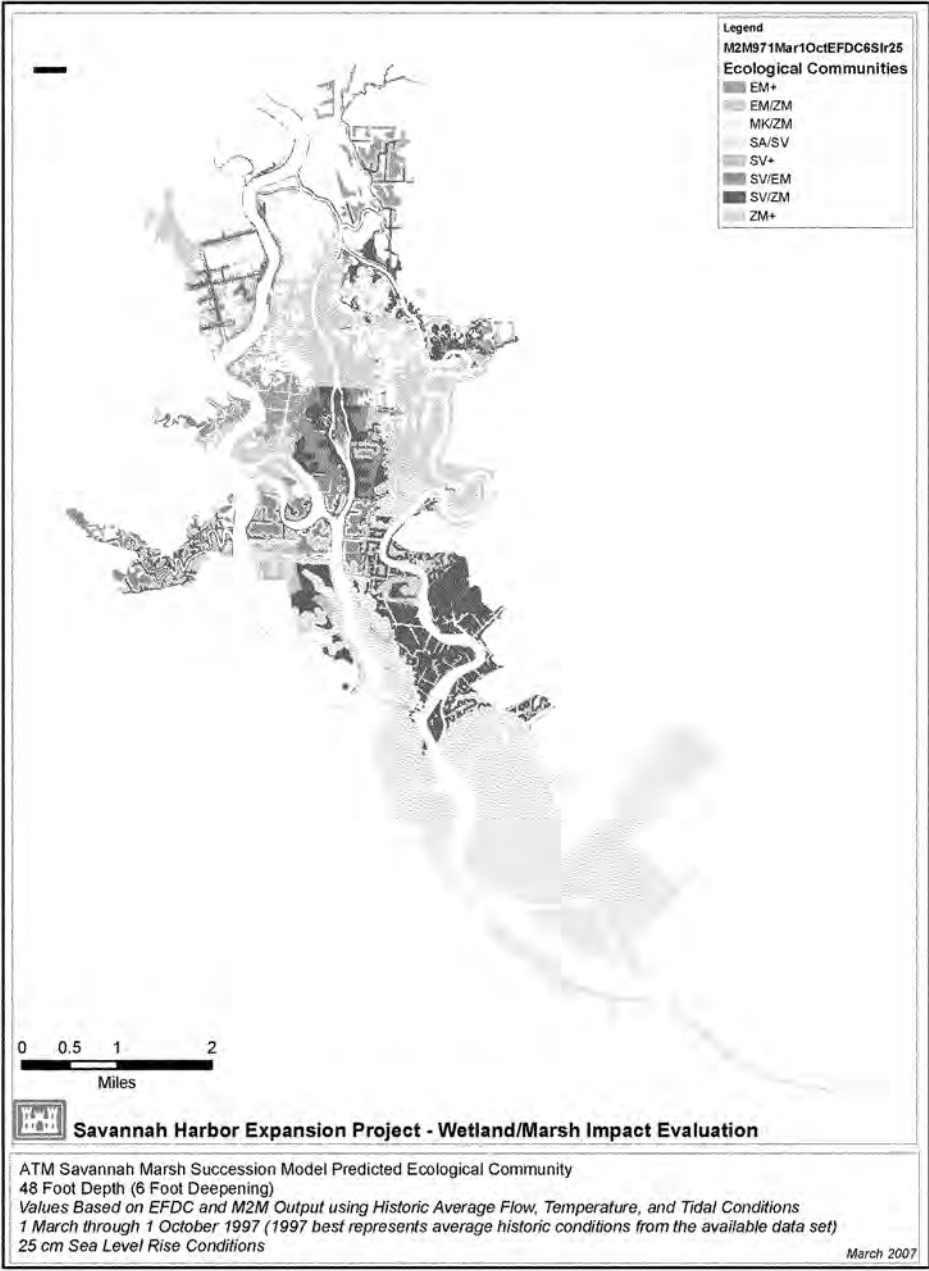
APPENDIX C
SENSITIVITY ANALYSIS #2A
ECOLOGICAL COMMUNITY MAPS &
ECOLOGICAL COMMUNITY SHIFT MAPS

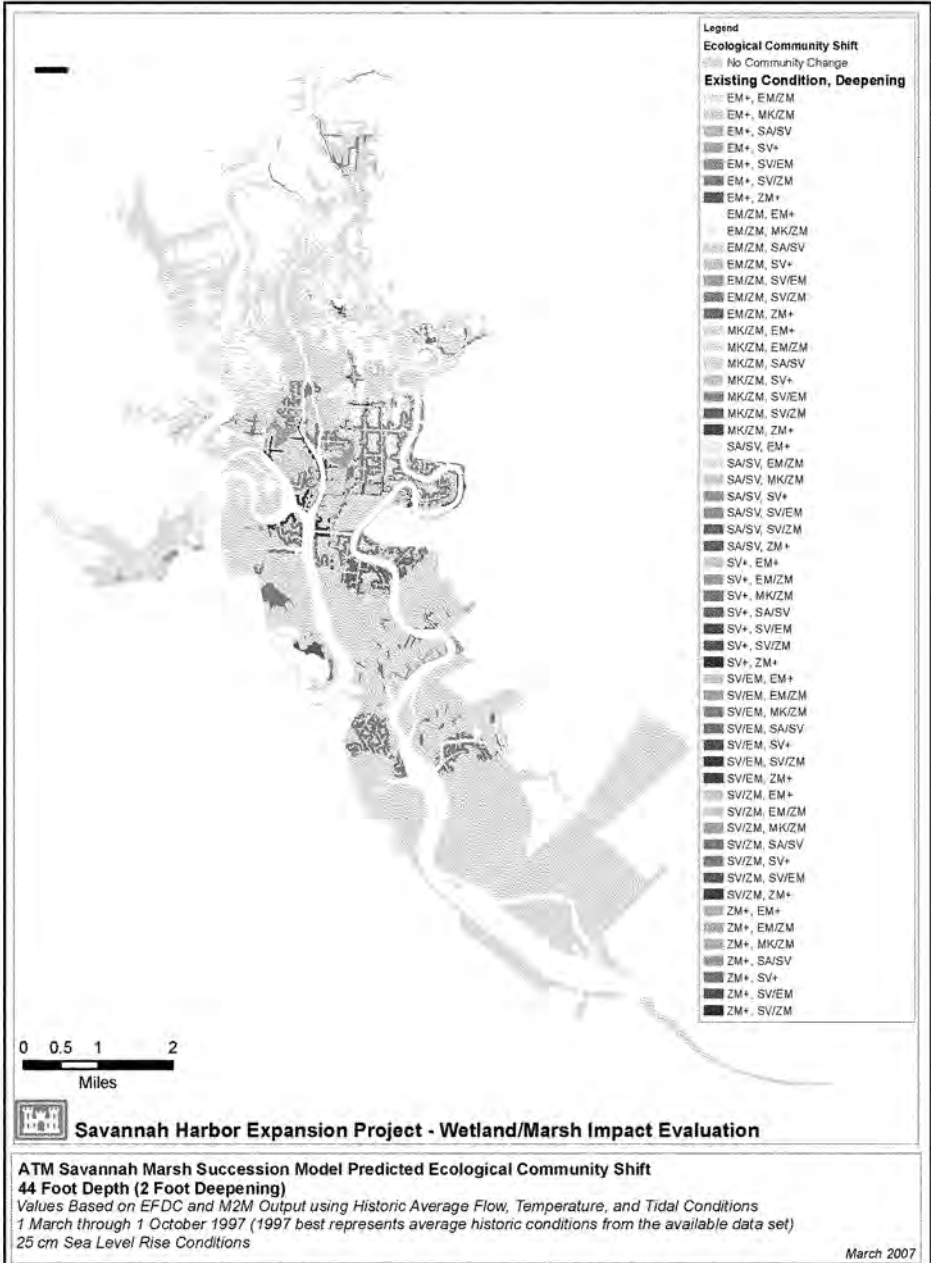


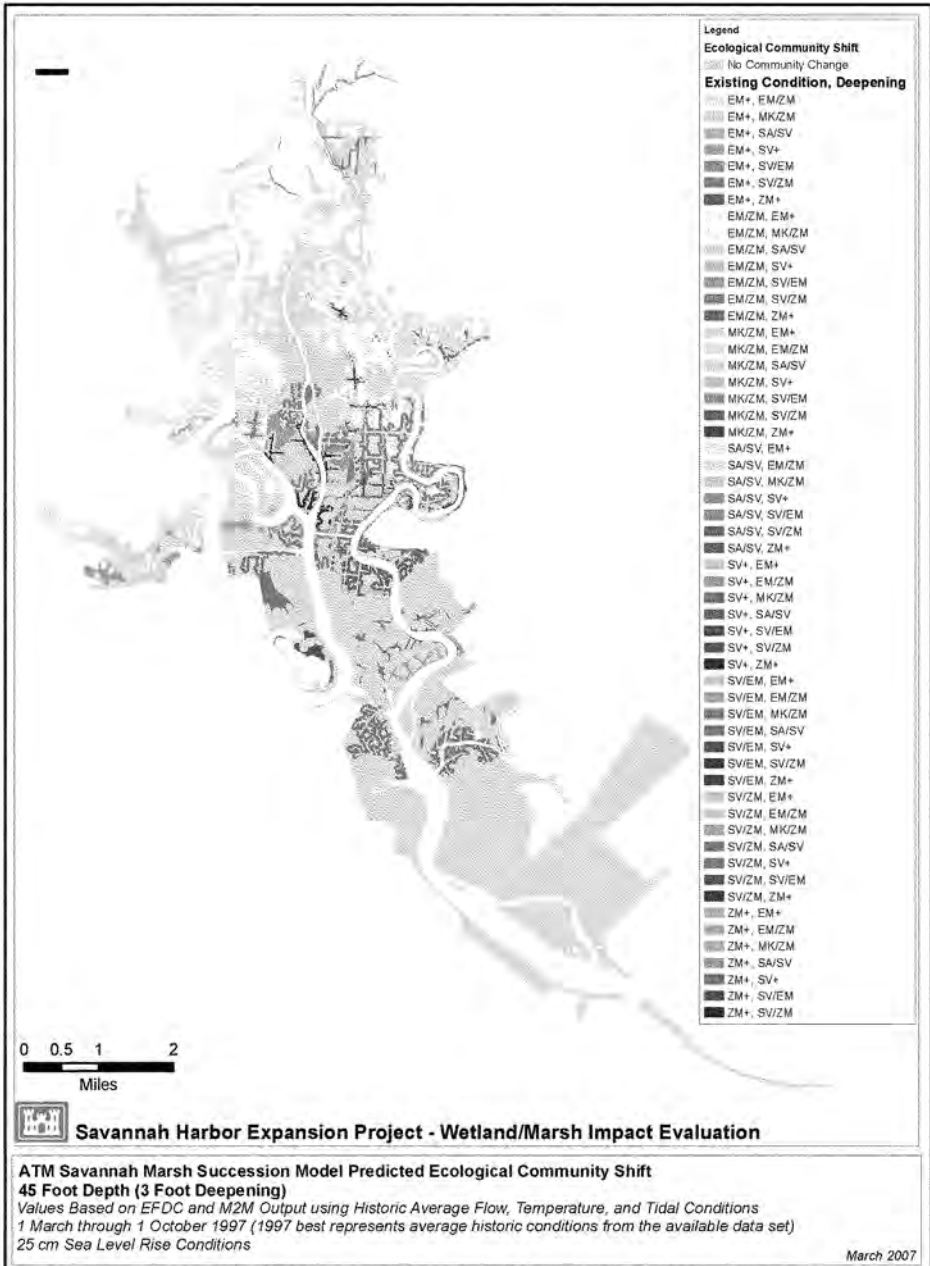


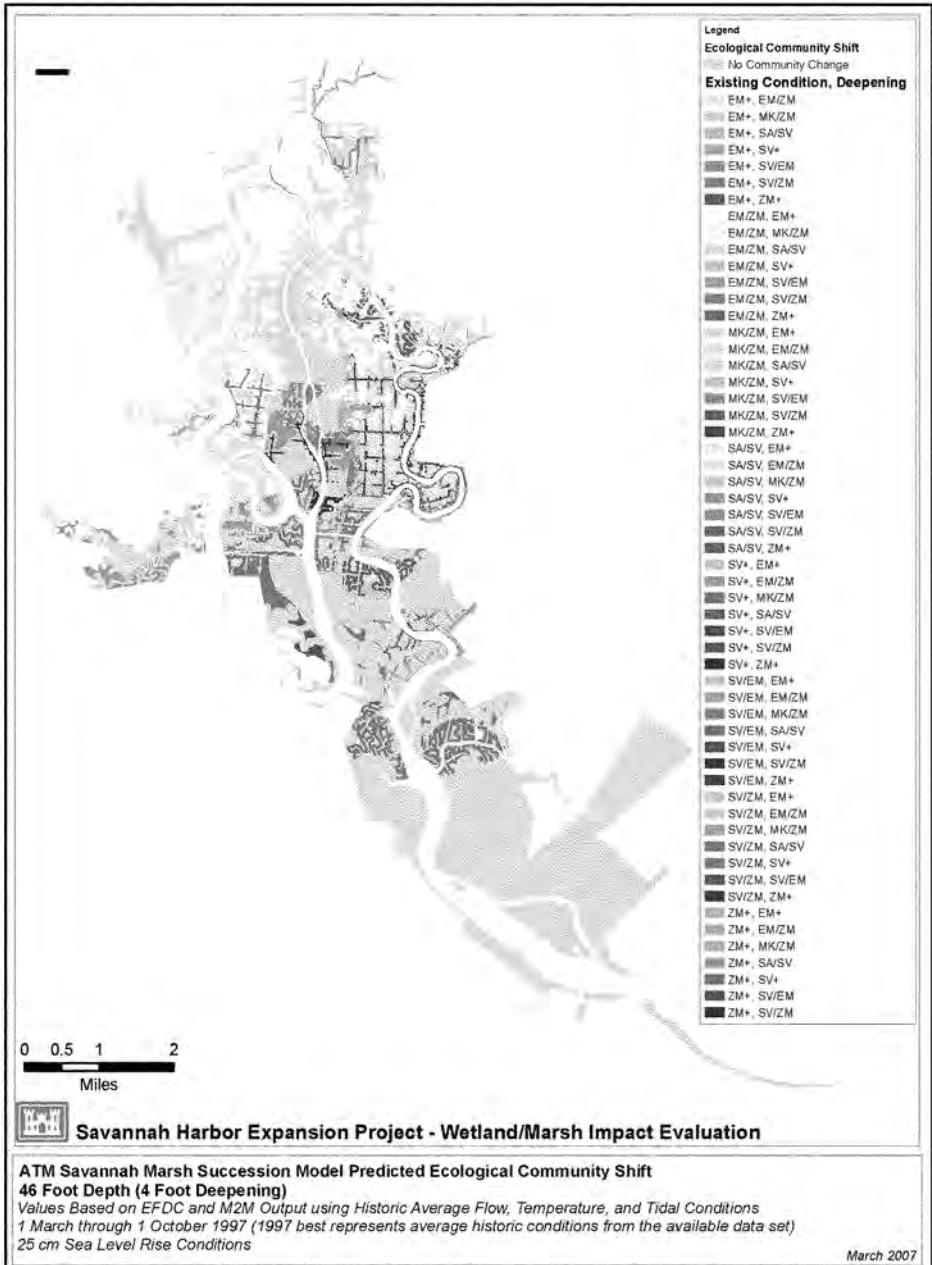


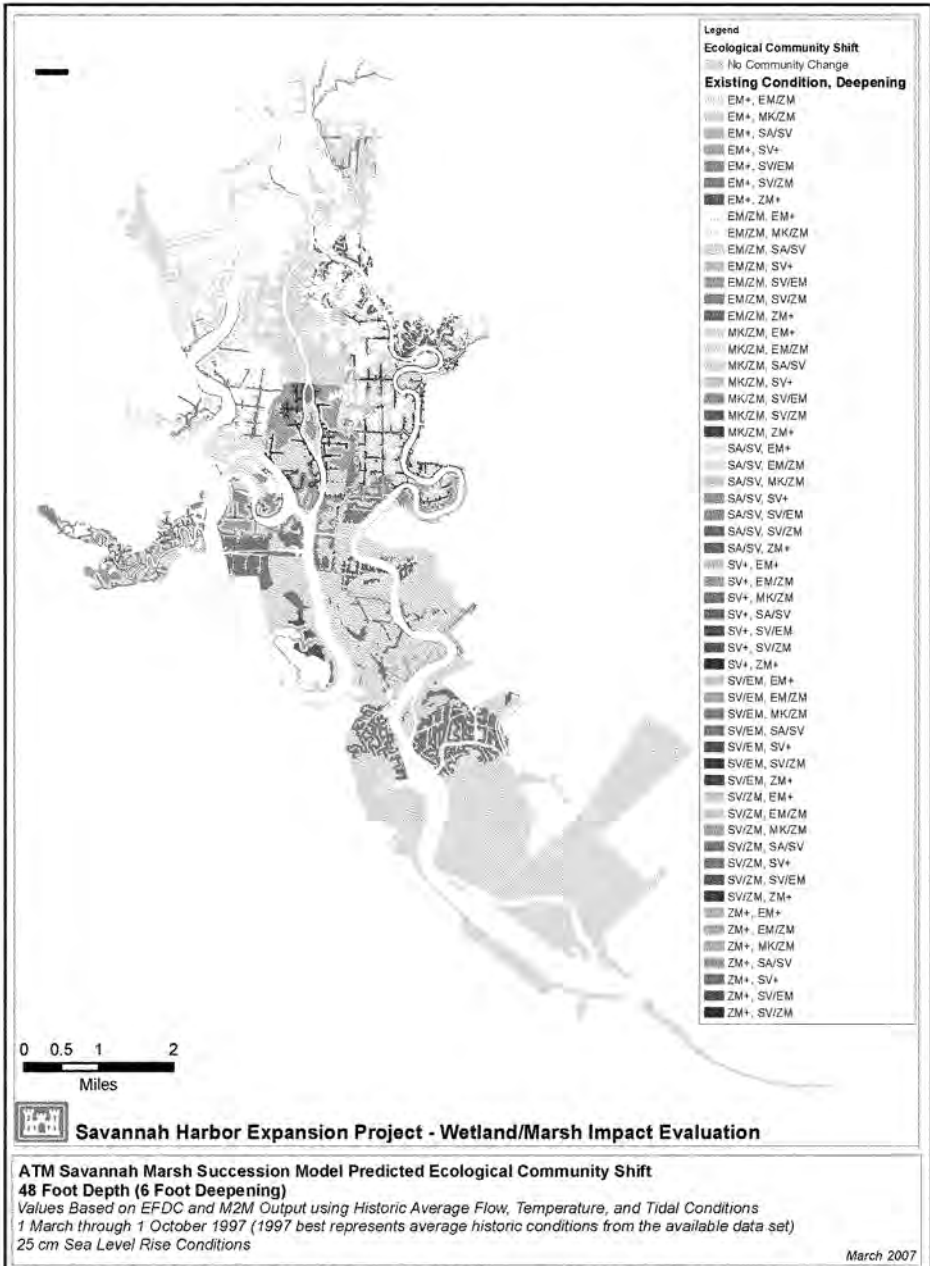












Savannah Harbor Expansion Project
ATM MSM Wetland/Marsh Impact Evaluation
Predicted Vegetation Community Shifts

Community	Existing Depth 25 cm Sea Level Rise Associated Acreages	44 ft Depth 25 cm Sea Level Rise Associated Acreages	Net Change (net negative), net positive
EM+	527	495	(32)
EM/ZM	1884	1849	(35)
MK/ZM	211	116	(96)
ZM+	227	195	(32)
SV/EM	124	184	60
SV/ZM	1973	1936	(36)
SV+	27	54	27
SA/SV	3028	3172	145
TOTAL	8001	8001	

Community	Existing Depth 25 cm Sea Level Rise Associated Acreages	45 ft Depth 25 cm Sea Level Rise Associated Acreages	Net Change (net negative), net positive
EM+	527	480	(47)
EM/ZM	1884	1792	(92)
MK/ZM	211	96	(115)
ZM+	227	186	(42)
SV/EM	124	242	118
SV/ZM	1973	1887	(85)
SV+	27	66	39
SA/SV	3028	3252	224
TOTAL	8001	8001	

Community	Existing Depth 25 cm Sea Level Rise Associated Acreages	46 ft Depth 25 cm Sea Level Rise Associated Acreages	Net Change (net negative), net positive
EM+	527	463	(64)
EM/ZM	1884	1853	(31)
MK/ZM	211	100	(111)
ZM+	227	246	19
SV/EM	124	287	163
SV/ZM	1973	1561	(412)
SV+	27	101	74
SA/SV	3028	3390	362
TOTAL	8001	8001	

Community	Existing Depth 25 cm Sea Level Rise Associated Acreages	48 ft Depth 25 cm Sea Level Rise Associated Acreages	Net Change (net negative), net positive
EM+	527	420	(107)
EM/ZM	1884	1756	(128)
MK/ZM	211	64	(148)
ZM+	227	219	(9)
SV/EM	124	387	263
SV/ZM	1973	1435	(537)
SV+	27	117	90
SA/SV	3028	3604	577
TOTAL	8001	8001	

* Values Based on Pore Water Salinity Input from M2M using Historic Average Flow, Temperature, and Tidal Conditions

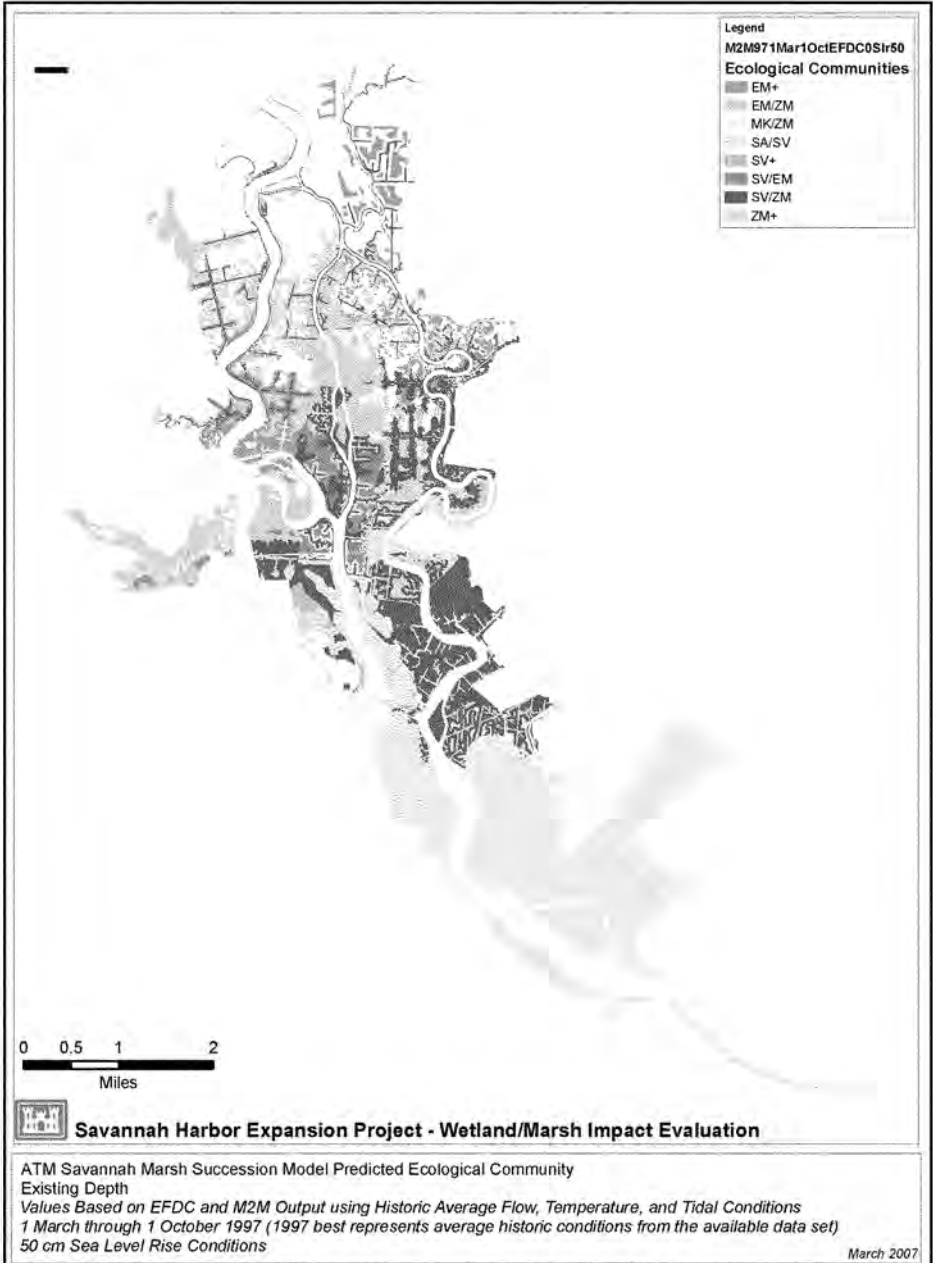
1 March through 1 October 1997 (1997 best represents average historic conditions from the available data set)

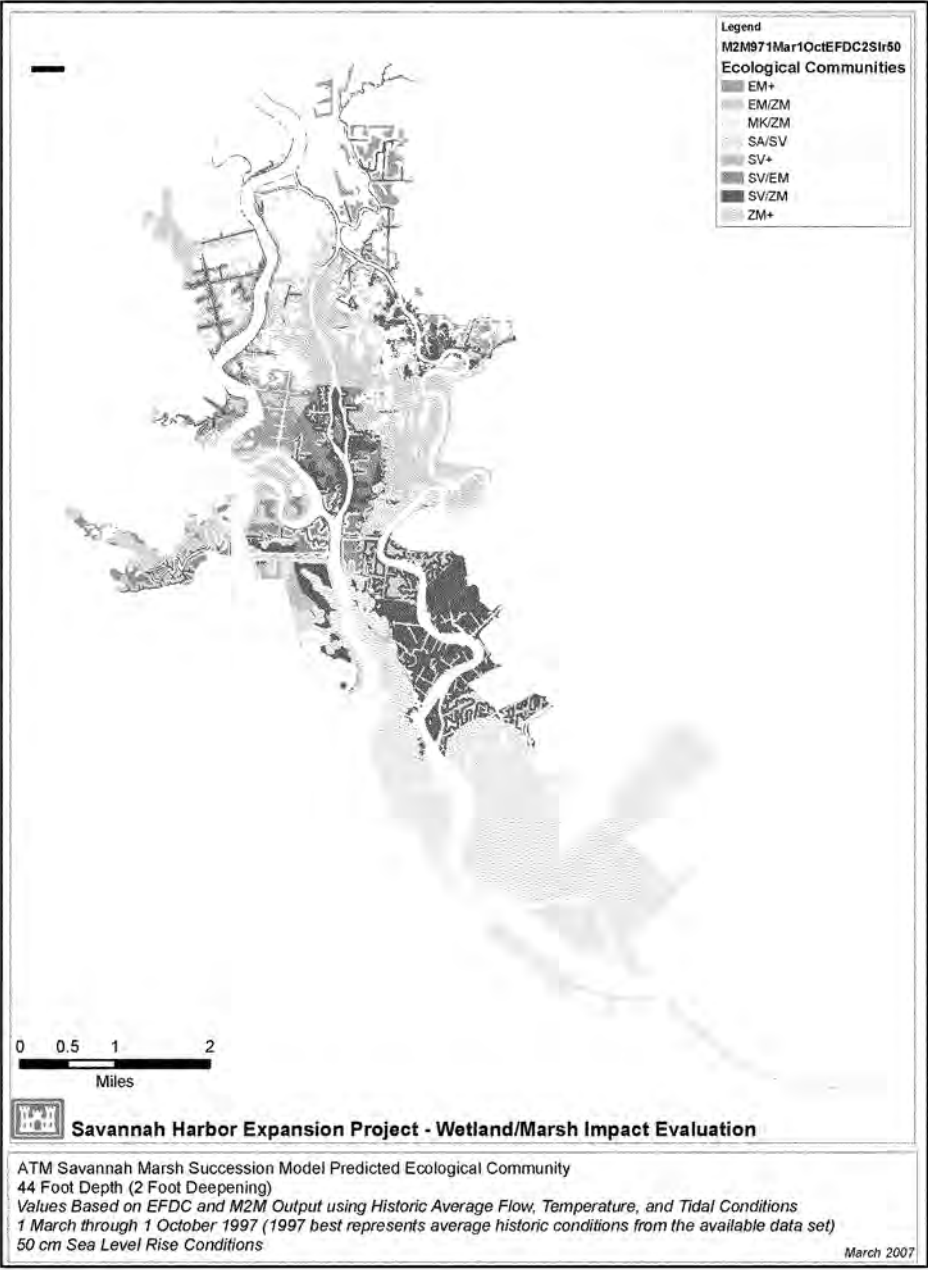
25 cm Sea Level Rise Conditions.

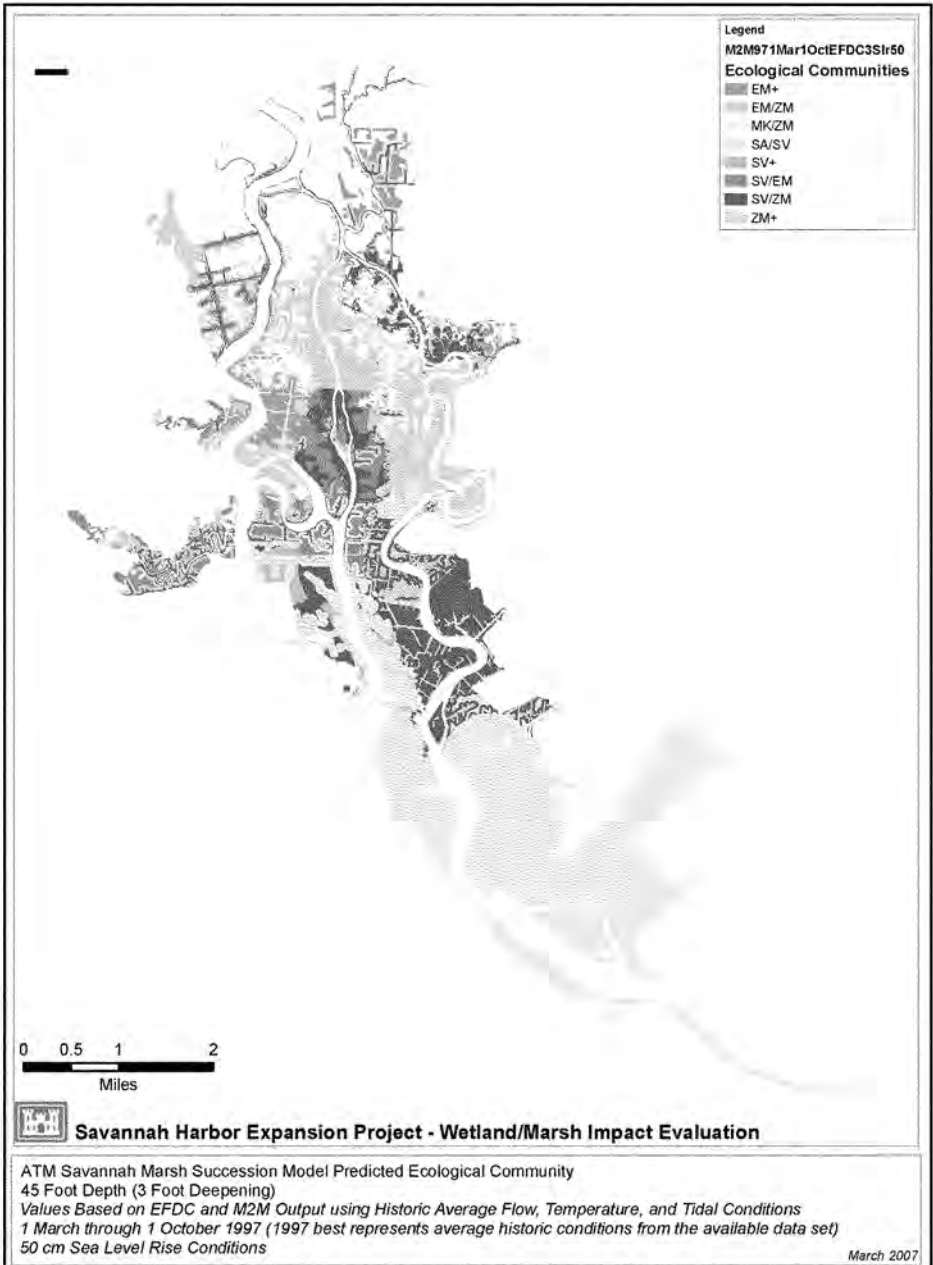


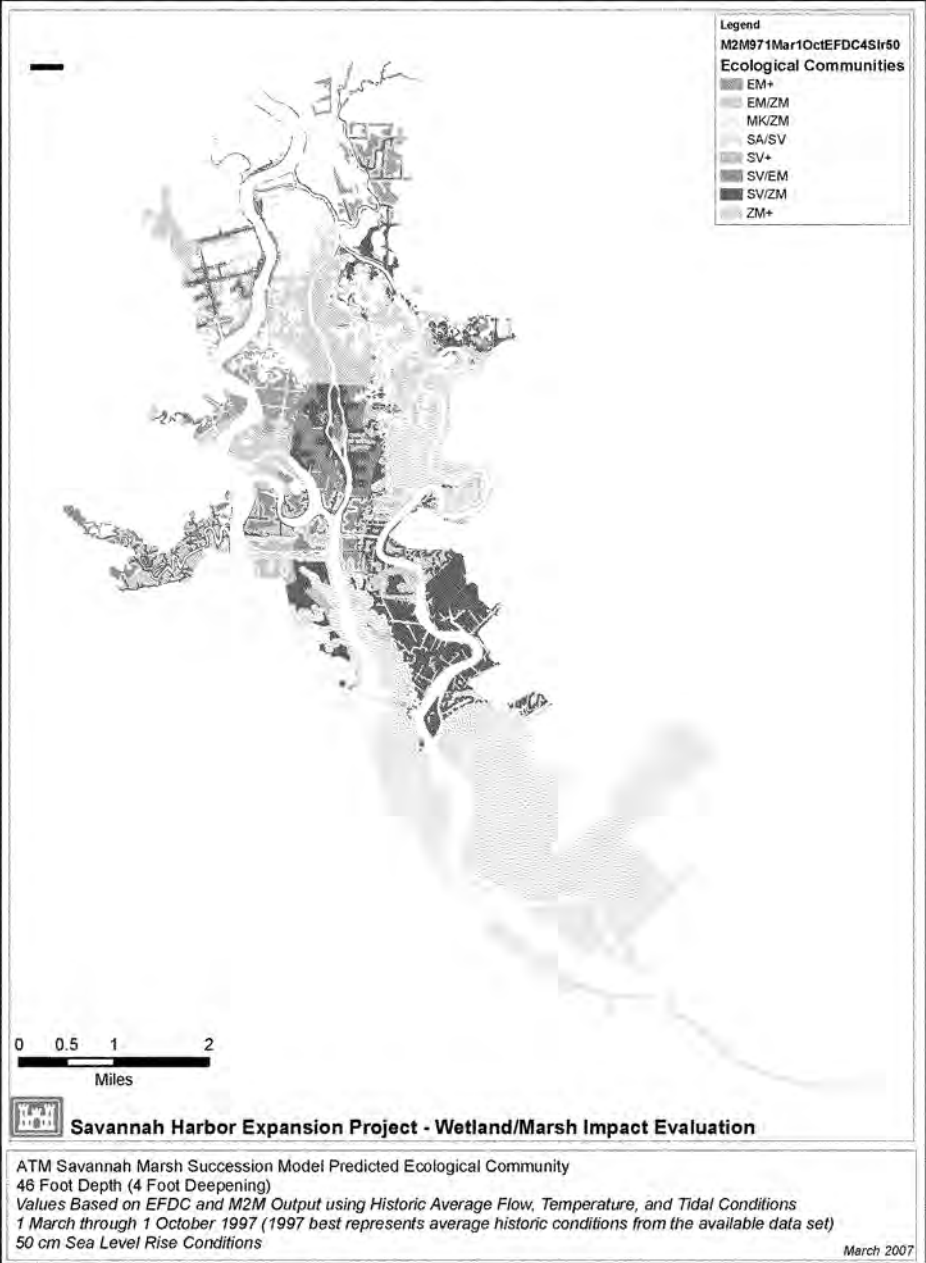
March 2007

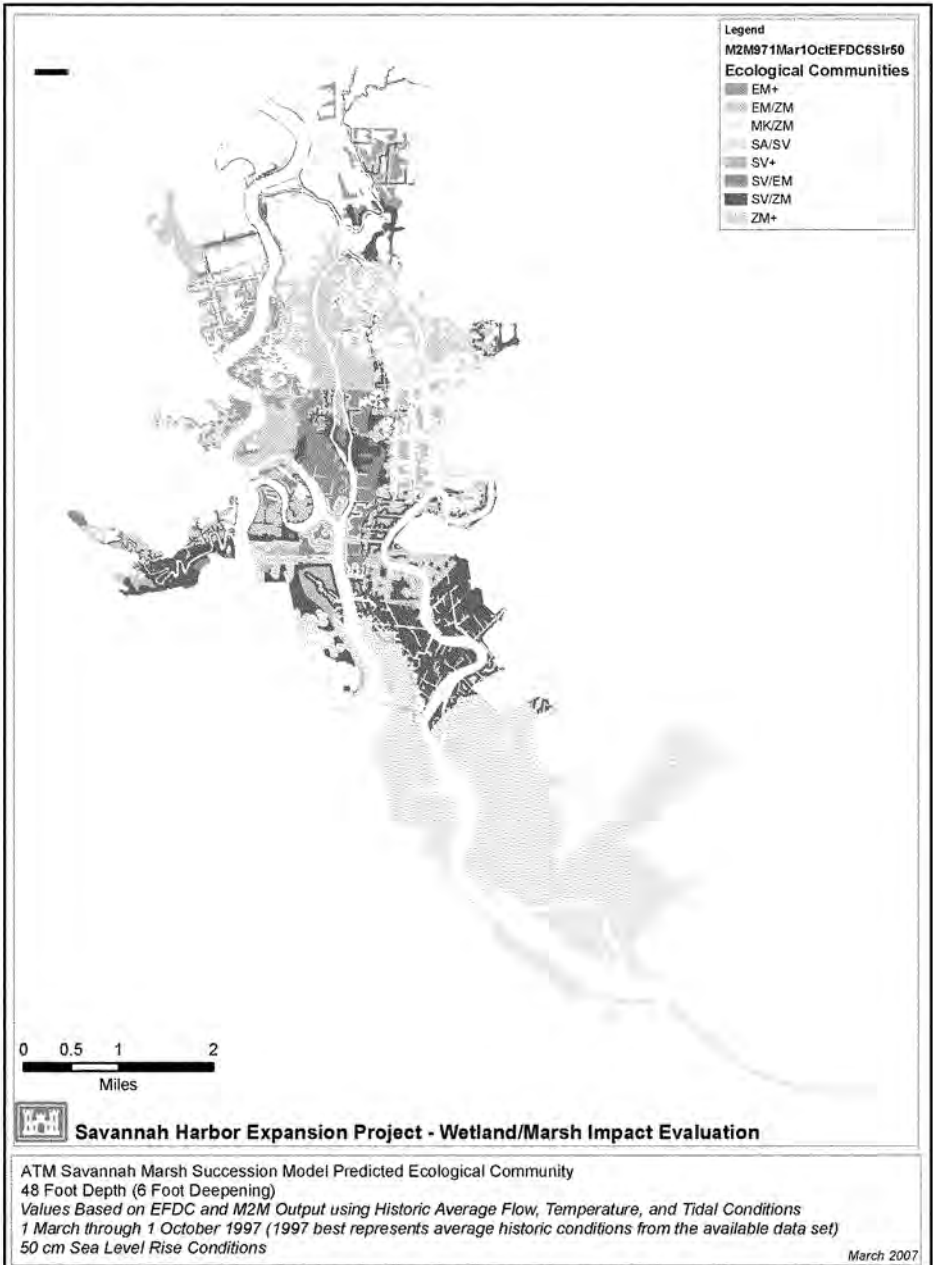
APPENDIX D
SENSITIVITY ANYSIS #2B
ECOLOGICAL COMMUNITY MAPS &
ECOLOGICAL COMMUNITY SHIFT MAPS

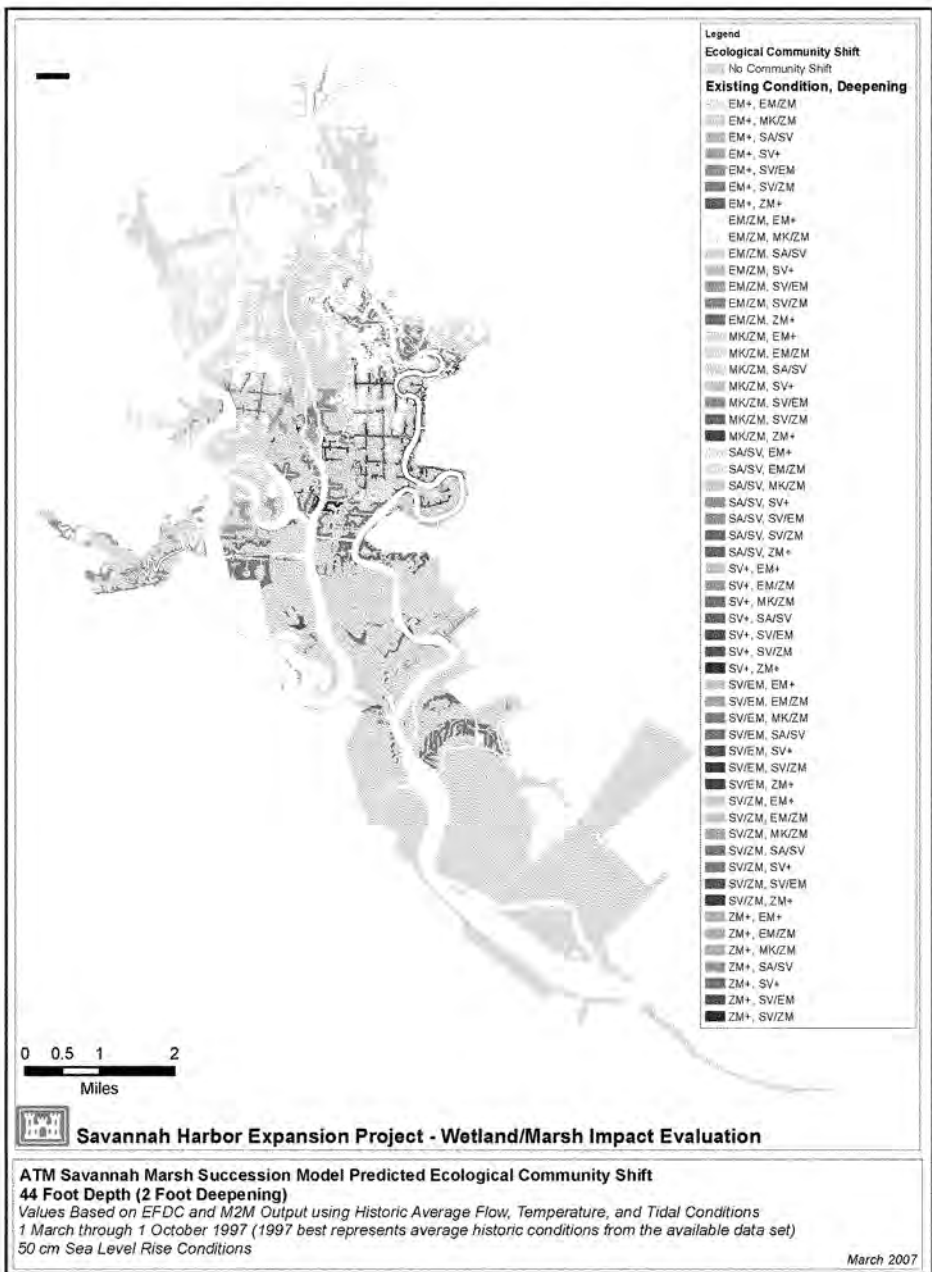


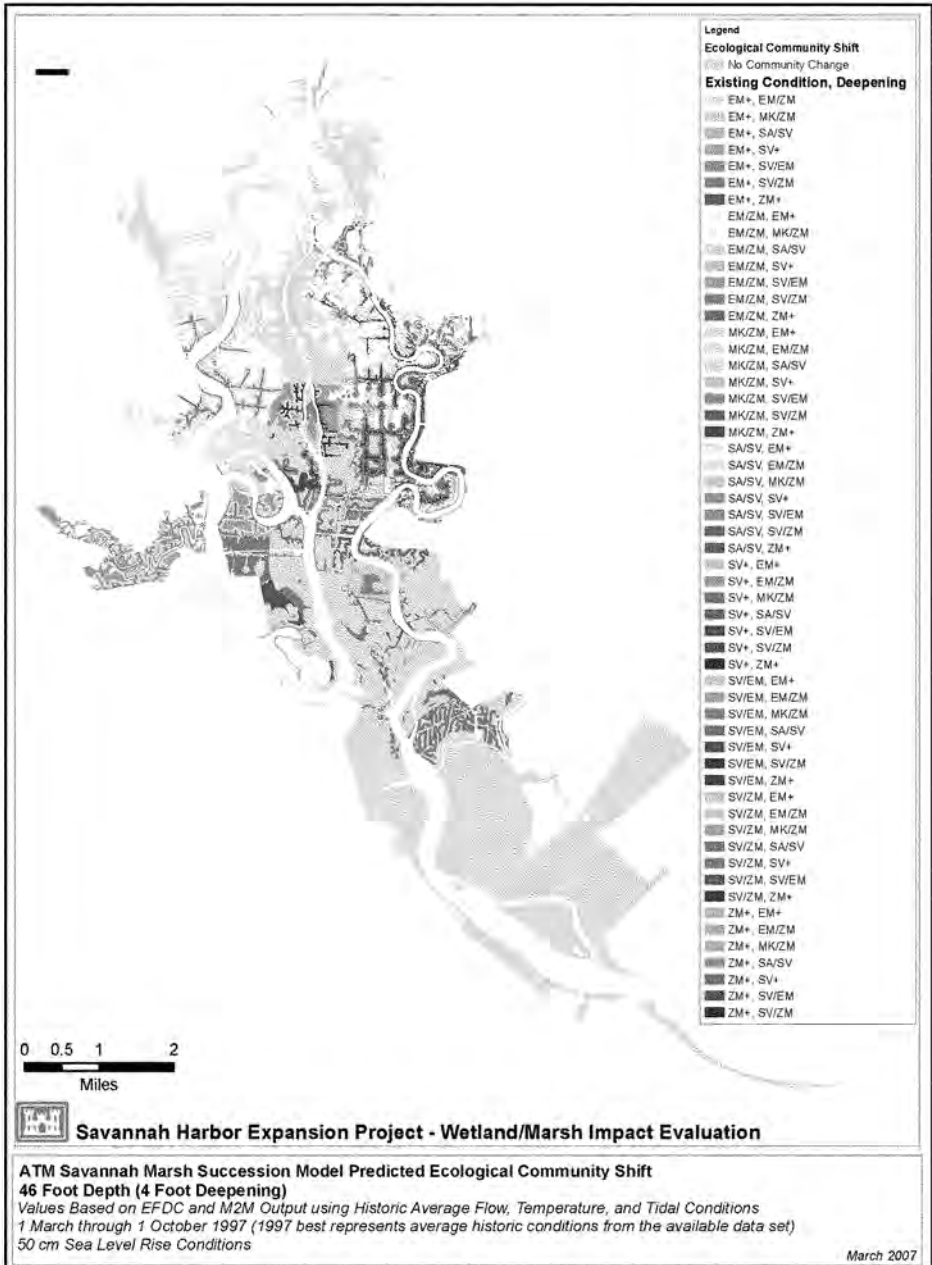


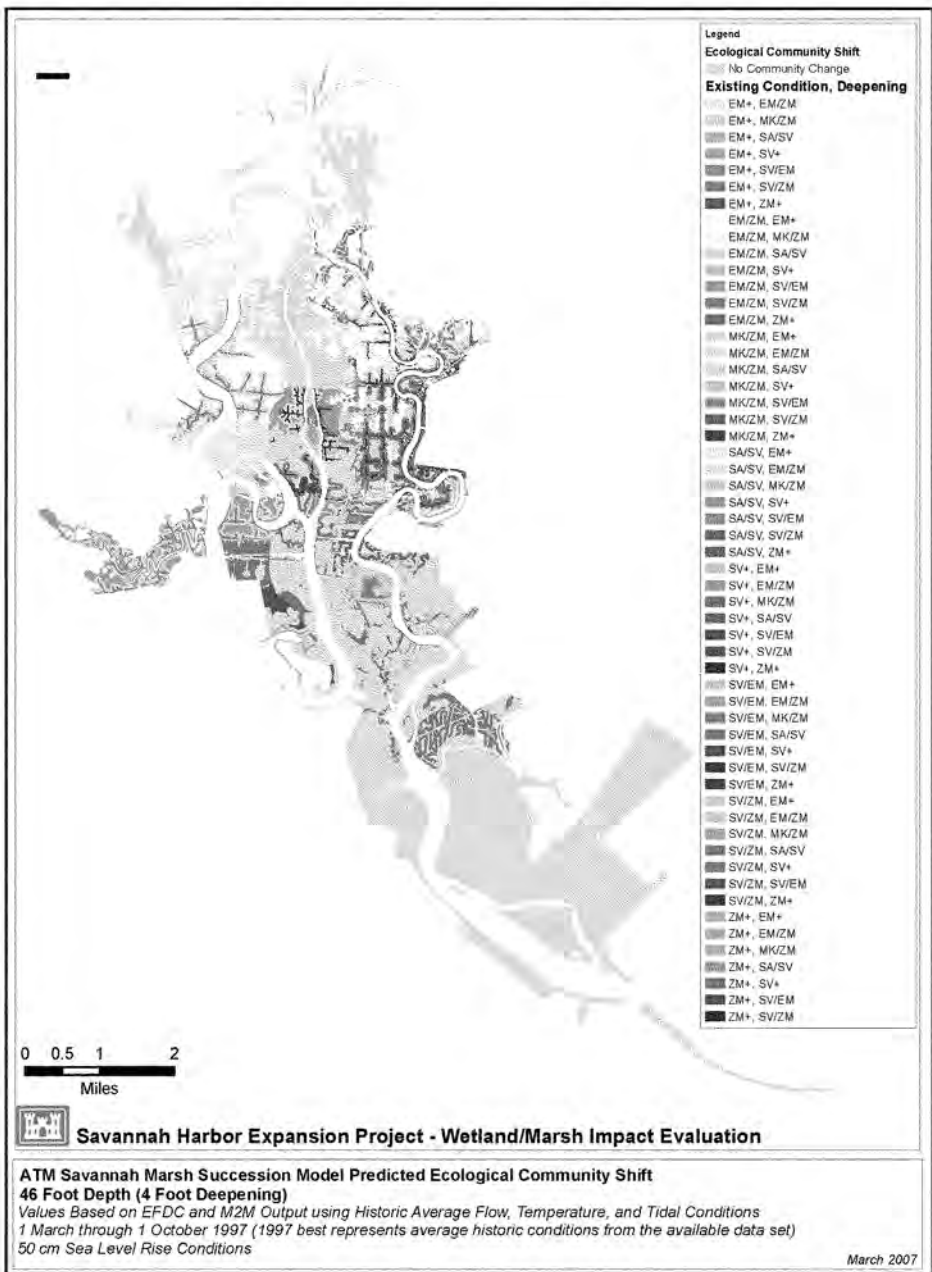


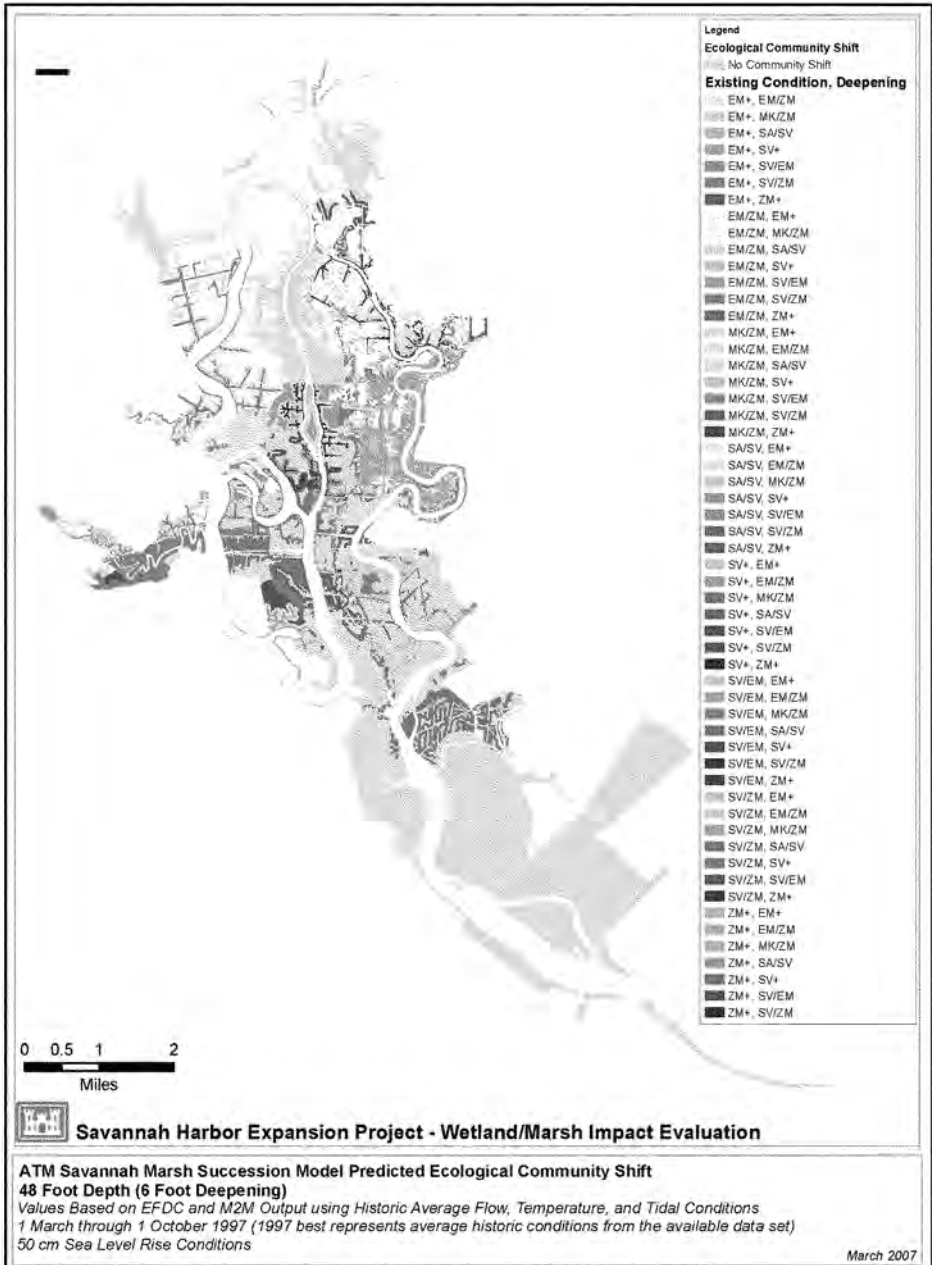












Savannah Harbor Expansion Project
ATM MSM Wetland/Marsh Impact Evaluation
Predicted Vegetation Community Shifts

Community	Existing Depth 50 cm Sea Level Rise Associated Acreages	44 ft Depth 50 cm Sea Level Rise Associated Acreages	Net Change (net negative), net positive
EM+	465	447	(18)
EM/ZM	1863	1836	(27)
MK/ZM	110	102	(9)
ZM+	193	243	50
SV/EM	198	323	125
SV/ZM	1902	1520	(382)
SV+	54	94	39
SA/SV	3214	3436	223
TOTAL	8001	8001	

Community	Existing Depth 50 cm Sea Level Rise Associated Acreages	45 ft Depth 50 cm Sea Level Rise Associated Acreages	Net Change (net negative), net positive
EM+	465	424	(42)
EM/ZM	1863	1743	(120)
MK/ZM	110	76	(35)
ZM+	193	234	41
SV/EM	198	379	181
SV/ZM	1902	1485	(417)
SV+	54	111	56
SA/SV	3214	3549	335
TOTAL	8001	8001	

Community	Existing Depth 50 cm Sea Level Rise Associated Acreages	46 ft Depth 50 cm Sea Level Rise Associated Acreages	Net Change (net negative), net positive
EM+	465	407	(58)
EM/ZM	1863	1595	(268)
MK/ZM	110	72	(38)
ZM+	193	221	27
SV/EM	198	384	186
SV/ZM	1902	1371	(531)
SV+	54	129	74
SA/SV	3214	3823	609
TOTAL	8001	8001	

Community	Existing Depth 50 cm Sea Level Rise Associated Acreages	48 ft Depth 50 cm Sea Level Rise Associated Acreages	Net Change (net negative), net positive
EM+	465	373	(93)
EM/ZM	1863	1577	(286)
MK/ZM	110	324	214
ZM+	193	133	(60)
SV/EM	198	388	190
SV/ZM	1902	1326	(576)
SV+	54	234	179
SA/SV	3214	3646	432
TOTAL	8001	8001	

* Values Based on EFDC and M2M Marsh Pore Water Salinity Input for Historic Average Flow, Temperature, and Tidal Conditions

† March through † October 1997 (1997 best represents average historic conditions from the available data set)



March 2007

**SAVANNAH HARBOR DEEPENING PROJECT
USGS/USFWS MARSH SUCCESSION MODEL
MARSH/WETLAND IMPACT EVALUATION**



June 2007

Purpose:

The purpose of the Marsh Succession Modeling is to determine the impacts of deepening the Savannah Harbor navigation channel; specifically, the effect on the tidal marsh vegetation communities as a result of salinity increases in the system. The marsh succession modeling was used to provide estimates of tidal marsh vegetation communities within the freshwater and brackish marshes of the Back, Middle, and Front rivers under various deepening and sea level rise conditions.

Model Input Conditions:

Predictions of salinity input for the MSM were developed through the use of a separate hydrodynamic and salinity computer model. The Environmental Fluid Dynamic Code (EFDC) model developed by Dr. John Hamrick and currently supported by Tetra Tech for U.S. Environmental Protection Agency (USEPA) Office of Research and Development (ORD), USEPA Region 4, and USEPA Headquarters was used in this effort. Although a number of models provide some of the features necessary for modeling the hydrodynamics in the Savannah River Estuary, the EFDC hydrodynamic and sediment transport model linked with the Water Quality Analysis Simulation Program (WASP) was determined to provide the most appropriate features necessary for the overall Savannah Harbor Expansion Project study (Tetra Tech, 2006).

EFDC solves three-dimensional, vertically hydrostatic, free surface, turbulent averaged equations of motion for a variable-density fluid. Dynamically-coupled transport equations for turbulent kinetic energy, turbulent length scale, salinity and temperature are also solved (USEPA, 2007). The boundary conditions of the EFDC model used in simulating the processes of the Savannah River Estuary consist of: offshore salinity, temperature, and water surface elevation; upstream flow and temperature; adjacent marsh areas; and meteorological forcing conditions. The main model coefficients are: bathymetry, bottom roughness and vertical mixing. The EFDC model predicts time series of the surface water elevation, currents, flow, temperature, and salinity as a result of changes in the channel geometry. Details on the Savannah Harbor EFDC model development, calibration and validation is provided in Tetra Tech, 2006 *Development of the Hydrodynamic and Water Quality Models for the Savannah Harbor Expansion Project* report.

The EFDC hydrodynamic model makes predictions of water level and salinity parameters within the confines of the estuarine rivers and main tidal creeks. The project needed a way to translate salinity predictions in those hydraulic channels to the marshes where the vegetation communities occur. To accomplish this, the Georgia Ports Authority (GPA) employed the Columbia, South Carolina office of the US Geological Survey (USGS) to develop a tool capable of translating EFDC riverine predictions across the estuary to the marsh root zones. The variability of pore-water salinity in the tidal marshes is a result of the adjacent river salinity concentration, the tidal creek connections to the river, elevation of the marsh and surrounding berms, soil type and the conditions of old abandoned rice fields and berms, and volume of water within the marsh (USGS, 2007). In order to simulate the dynamic response of the water level and salinity in the tidal marshes, the USGS, in collaboration with Advance Data Mining, developed the Model-to-Marsh (M2M) decision support system. The M2M was developed using data-mining techniques and artificial neural network (ANN) models.

The M2M model uses time-series data of the salinity, and water levels in the rivers networks near the USGS and ATM marsh gaging sites to simulate water level and pore water salinity within the adjacent marsh. To predict the change in water level and pore water salinity in the marsh likely to result from a potential harbor deepening, simulated water-level and salinity changes in the river resulting from proposed geometric channel changes as predicted by the EFDC model are used. Using the USGS river network time series as input for the marsh, the ANN models accommodate the integration of output from the EFDC model. Details on the Savannah Harbor M2M system development and validation is provided in Conrads et al., 2006 *Simulation of Water Levels and Salinity in the Rivers and Tidal Marshes in the Vicinity of the Savannah National Wildlife Refuge, Coastal South Carolina and Georgia*.

The wetland/marsh impact evaluation input data was developed by the Savannah Harbor Expansion Wetland Interagency Coordination Team. The group developed four model input scenarios for evaluation (See Table 1).

Table 1- Model Input Conditions

RUN SCENARIO	RIVER FLOW	SEA LEVEL RISE	EVALUATION PERIOD
Basic Evaluation	Average/Typical	Existing Sea Level	1-March to 1-October
Sensitivity Analysis #1	Low Flow/Dry	Existing Sea Level	1-March to 1-October
Sensitivity Analysis #2A	Average/Typical	25 cm Sea Level Rise	1-March to 1-October
Sensitivity Analysis #2B	Average/Typical	50 cm Sea Level Rise	1-March to 1-October

*25 and 50 cm sea level rise conditions were specified by the Interagency Coordination Team, based on Environmental Protection Agency and National Oceanic Atmospheric Administration projections.

Average/typical river flows needed for the Basic Evaluation and Sensitivity Analysis #2A and B were determined using recorded gage data for Savannah River at Clyo, GA. The EFDC model has continuous input boundary conditions for a 7 year period (1997 - 2003) available for simulation. 1997 was found to have flow conditions representative of the long term average flows.

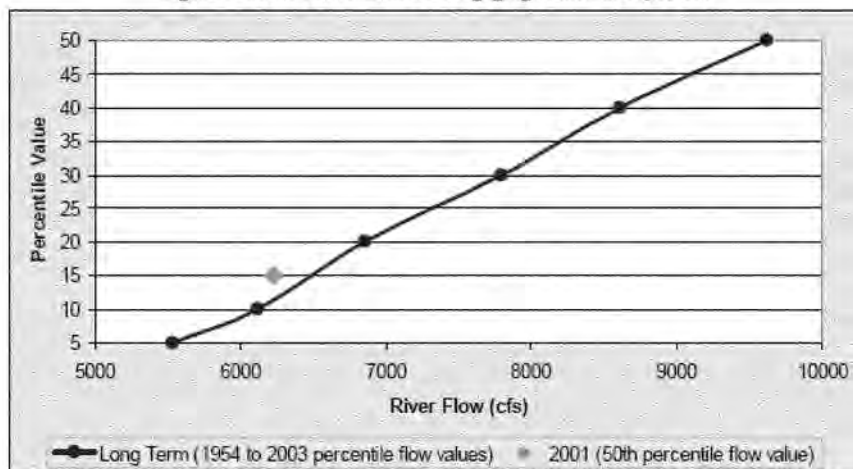
Table 2- Average River Flows from USGS gaging station at Clyo, GA

<i>Period of Record</i>	<i>Mar.</i>	<i>Apr.</i>	<i>May</i>	<i>June</i>	<i>July</i>	<i>Aug.</i>	<i>Sept.</i>	<i>Oct.</i>	<i>Overall</i>
	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
Long Term (1954-2003)	17,998	17,203	12,029	10,254	9,118	9,035	8,566	8,615	11,603
1997 Only	22,016	11,380	12,527	9,729	8,853	9,944	6,370	7,627	11,056
Percent Difference	-22%	34%	-4%	5%	3%	-10%	26%	11%	5%

The maximum percent difference is 34% occurring in April, meaning April of 1997 had less freshwater flowing downstream into the estuary than the long term average. Overall, the percent

difference between the long term average and 1997 is 5%. Therefore, the growing season (March through October) of 1997 was considered to be an average flow period for modeling purposes. The flow boundary conditions for Sensitivity Analysis #1 are low flow or dry year conditions. Using the recorded gage data at Clyo, GA, 2001 (March through October) was considered to be a low flow/dry period (See Figure 1).

Figure 1- River Flows from USGS gaging station at Clyo, GA



The long term Clyo gage data shows that low flow values range from 5,534cfs (5th percentile) to 6,858 cfs (20th percentile). The 50th percentile flow value during 2001 is 6,228 cfs. This value, 6,228 cfs, is approximately the 15th percentile value when looking at the long term Clyo flow data. Therefore, 2001 was considered a low flow/dry year for model simulations.

The two sea level rise conditions used in Sensitivity Analysis #2A and B were modeled by adding an additional 25 or 50 cm, depending on the run scenario, to the water surface elevations on the open ocean boundary cells in the EFDC model. The sea level rise sensitivity analyses are based only on a change in the ocean boundary water surface elevation. There was no consideration of any potential change in the ocean boundary salinity density in EFDC modeling effort.

All other model boundary inputs remain unaltered and correspond to the run time of 1 March to 1 October for 1997 or 2001, depending on the run scenario being modeled.

Model Limitations:

The reliability of the model is dependent on the quality of the data and range of measured conditions used in its development. The available period of record for the river and/or marsh data-collection networks can limit the conditions that the given model can accurately simulate. The pore water salinity observed during marsh data collection and for which the model decision

trees were developed for the MSM were within the gradient range of 0 to 7 ppt with river flows between 4,320 – 39,600 cfs.

USGS marsh sampling stations used to determine the ecological community response to changes in the pore water salinity were located throughout the marsh, but these were predominantly stratified along the Back River to document tide gate disruptions in the 1980's. Three marsh sites were added in the freshest areas of the Front and Middle rivers in 2000. Community compositions and distributions along the more saline sections of the Middle and Front rivers did not provide as much coverage and likely have less predictive value (Welch, 2006).

The majority of the misclassification and error in the model came from a mixed community of *Eleocharis montevidensis* (ELEM0), *Scirpus validus* (SCIVA) and *Zizaniopsis miliacea* and *Polygonum* spp (ZIZMI_POLSP) groups all occurring at low salinities, < 52 m from the nearest creek but in soils with > 55 % organic content. This leaf consisted of 18 % of the data samples and was representative of the highly competitive, variable and diverse marshes that occur in the more freshwater areas of the Savannah River (Welch and Kitchens, 2006).

The model simulates long term impacts from changes in pore water salinity within the marsh system from harbor deepening and sea level rise. Other aspects of extreme short term events such as riverine floods and storm surges and impacts of climate change, such as CO₂ concentration, and the varying response of C3 and C4 plants were not evaluated.

Output Generated:

Two types of maps were generated to aid in evaluation of the salinity impacts of deepening on the freshwater marshes: (1) plan view maps showing distributions of the predicted marsh vegetation communities (baseline conditions (42-ft depth), 44-, 45-, 46-, and 48-ft depth) and (2) plan view maps showing changes in distribution of the predicted marsh vegetation communities from baseline conditions.

To help further aid in the evaluation of salinity impacts of deepening on the freshwater and brackish tidal marshes tables providing the predicted total acreages of each vegetation community for both the without project condition and each deepening scenario and net changes in acreages of each type of vegetation community under each deepening scenario are provided. These tables are intended to provide reviewers with a sense of the general magnitude of the patterns of simulated changes that are depicted in the ecological community maps.

Findings:

Basic Evaluation: The Basic Evaluation includes five model runs each with a different channel depth: existing conditions (42-ft depth), 44-ft, 45-ft, 46-ft and 48-ft depths. The input conditions for the runs are pore water salinity of marsh sediments based on average/typical river flow and existing sea level. The evaluation period is 1 March to 1 October 1997.

Ecological Community Shift maps in Appendix A show predicted changes in marsh vegetation communities throughout the estuary associated with pore water salinity changes within the marsh

from channel deepening. These maps are a comparison between the baseline average/typical river flow under existing sea level and each deepened condition. The predicted impacts with deepening just an additional 2 ft, extend above Steamboat River on the Front and Middle rivers. The largest change in vegetation communities are in the *Eleocharis montevidensis*, *Galium tinctorum* and *Sagittaria latifolia* (ELEM0_GALTI_SAGLT) community along the Middle River north of Steamboat River. In this location there is an increased presence of *Zizaniopsis miliacea*, *Polygonum* spp. and *Murdania kesiak* (ZIZMI_POLSP_MURKE) and *Scirpus validus* (SCIVA). Other changes are seen in the SCIVA dominated community along the Back River south of New Cut and in the ZIZMI_POLSP_MURKE dominated community along the Middle and Front rivers near Steamboat River and the Back River north of New Cut. Portions of the intermediate/transitional SCIVA community are replaced by a brackish community dominated by *Spartina* spp. (SPASP), with subdominants *Scirpus robustus* (SCIRO) and *Aster tenuifolius* (ASTTE). Portions of the freshwater community ZIZMI_POLSP_MURKE are replaced by an intermediate/transitional community dominated SCIVA.

The general trend is a loss of freshwater tidal marsh occurring with the increased channel depth. Although all the deepening scenarios show an impact on the freshwater tidal marsh communities the largest community shifts are seen under the 6-foot deepening scenario. A quick view of the Wetland/Marsh Impact Evaluation table in Appendix A does not tell the full story of pore water salinity impacts to freshwater tidal marsh communities with deepening. The Ecological Community maps and Ecological Community Shift in Appendix A maps provide a clearer picture of what is happening in the areas of greatest concern; Middle, Little Back, and Back rivers.

Sensitivity Analysis #1: Sensitivity Analysis #1 includes five model runs each with a different channel depth: existing conditions (42-ft depth), 44-ft, 45-ft, 46-ft and 48-ft depths. The input conditions for the runs are pore water salinity of marsh sediments based on low flow/dry river flow and existing sea level. The evaluation period is 1 March to 1 October 2001.

Ecological Community Shift maps in Appendix B show changes in marsh vegetation communities throughout the estuary associated with pore water salinity changes within the marsh from channel deepening. The impacts with deepening just an additional 2 ft, extend above Steamboat River on the Front and Middle rivers. The largest change is in the *E. montevidensis* (ELEM0) dominate community along the Front and Middle rivers north of Steamboat River and in the *E. montevidensis*, *S. Validus*, and *Z. miliacea* and *Polygonum* (ELEM0, SCIVA, ZIZMI_POLSP) community located adjacent to the primary and secondary channels along the Front and Middle rivers. In these areas there is a shift to a SCIVA dominate community. Other areas of community shifts are along the Back River and lower Middle River. In these areas the freshwater community dominated by ZIZMI_POLSP is replaced by an intermediate/transitional community dominated by SCIVA. Areas of the intermediate/transitional community dominated by SCIVA are replaced in dominance by the brackish community species of SPASP and SCIRO.

The general trend is a loss of freshwater tidal marsh occurring with the increased channel depth. Although all the deepening scenarios show an impact on the freshwater tidal marsh communities the largest community shifts are seen under the 6-foot deepening scenario. The maximum increases are generally found on the Front River where the deepening is occurring and along the

Middle River; however, under the 6-foot deepening there is a greater shift in communities along the Little Back River. A quick view of the Wetland/Marsh Impact Evaluation table in Appendix B does not tell the full story of pore water salinity impacts with deepening. The Ecological Community maps and Ecological Community Shift maps in Appendix B provide a clearer picture of what is happening in the areas of greatest concern: Middle, Little Back, and Back rivers.

Sensitivity Analysis #2A: Sensitivity Analysis #2A includes five model runs each with a different channel depth: existing conditions (42-ft depth), 44-ft, 45-ft, 46-ft and 48-ft depths. The input conditions for the runs are pore water salinity of marsh sediments based on average/typical river flow and a 25 cm sea level rise. The evaluation period is 1 March to 1 October 1997.

Ecological Community Change maps in Appendix C show shifts in marsh vegetation communities throughout the estuary associated with pore water salinity changes from channel deepening. The impacts with deepening just an additional 2 ft, extend above Steamboat River on the Front and Middle rivers. The largest change in vegetation communities are in the ELEM0_GALTI_SAGLT community along the Front, Middle and Back rivers north of Steamboat River. In these locations there is an increased presence of ZIZMI_POLSP_MURKE and SCIVA. Other large changes are seen in the SCIVA dominated community along the Back River and lower Middle River near New Cut and in the ZIZMI_POLSP_MURKE dominated communities along the Front, Middle and Back rivers. Areas of the SCIVA community along the Back and lower Middle River is replaced by a dominate SPASP community, with subdominants SCIRO and ASTTE. Areas of the ZIZMI_POLSP_MURKE dominate community along the Front Middle and Back rivers are replaced by SCIVA.

The general trend is a loss of freshwater tidal marsh occurring with the increased channel depth. The largest community shifts are seen under the 6-foot deepening scenario. In addition to changes in distributions of communities the results of the 6-foot deepening under 25 cm sea level rise, indicate significant structural and compositional change in the ELEM0 dominated community along the Front, Middle and Little Back rivers. This compositional change is indicated by a loss in species diversity. With the 6-foot deepening there is a loss of salt-sensitive subdominants like GALTI and SAGLT. Other areas of compositional change are seen along the Back River in the more saline communities. This area shows a loss in subdominant ASTTE, which is a mildly salt-tolerant species. A quick view of the Wetland/Marsh Impact Evaluation table in Appendix C does not tell the full story of pore water salinity impacts associated with deepening. The Ecological Community maps and Ecological Community Shift maps in Appendix C provide a clearer picture of what is happening in the areas of greatest concern: Middle, Little Back, and Back rivers.

Sensitivity Analysis #2B: Sensitivity Analysis #2B includes five model runs each with a different channel depth: existing conditions (42-ft depth), 44-ft, 45-ft, 46-ft and 48-ft depths. The input conditions for the runs are pore water salinity of the marsh based on average/typical river flow and a 50 cm sea level rise. The evaluation period is 1 March to 1 October 1997.

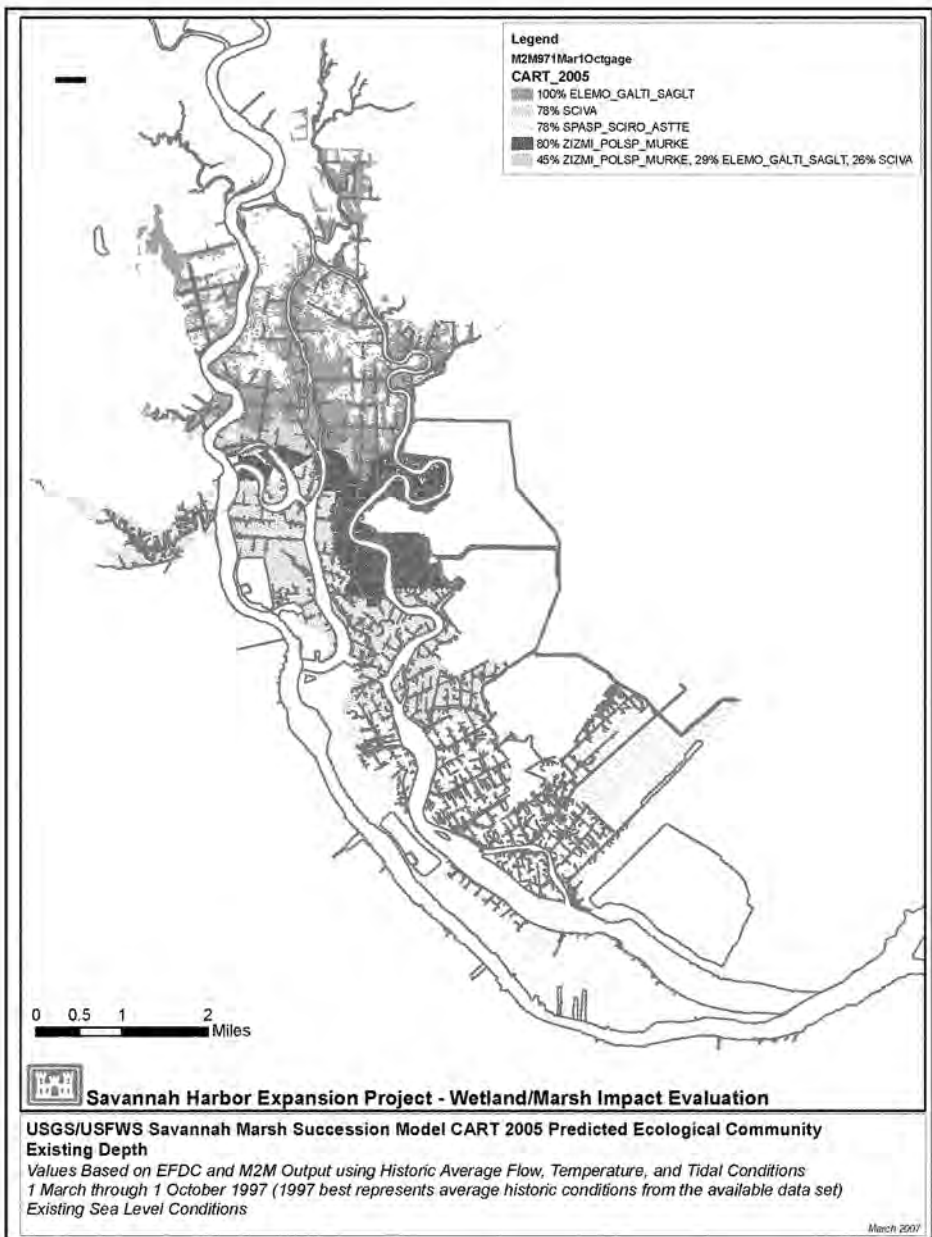
Ecological Community Change maps in Appendix D show shifts in marsh vegetation communities throughout the estuary associated with pore water salinity changes from channel deepening. The impacts with deepening just an additional 2 ft, extend above Steamboat River on the Front and Middle rivers. The largest change in vegetation communities are in the ELEM0_GALTI_SAGLT community along the Front, Middle, and Back rivers north of Steamboat River. In these locations there is an increased presence of ZIZMI_POLSP and SCIVA. Other large changes are seen in the SCIVA dominated community along the Back River and lower Middle River near New Cut and in the ZIZMI_POLSP_MURKE dominated communities along the Front, Middle and Back rivers. Areas of the SCIVA community along the Back and lower Middle River are replaced in dominance by the brackish community species of SPASP and SCIRO. Areas of the ZIZMI_POLSP_MURKE dominate community along the Front Middle and Back Rivers are replaced by SCIVA.

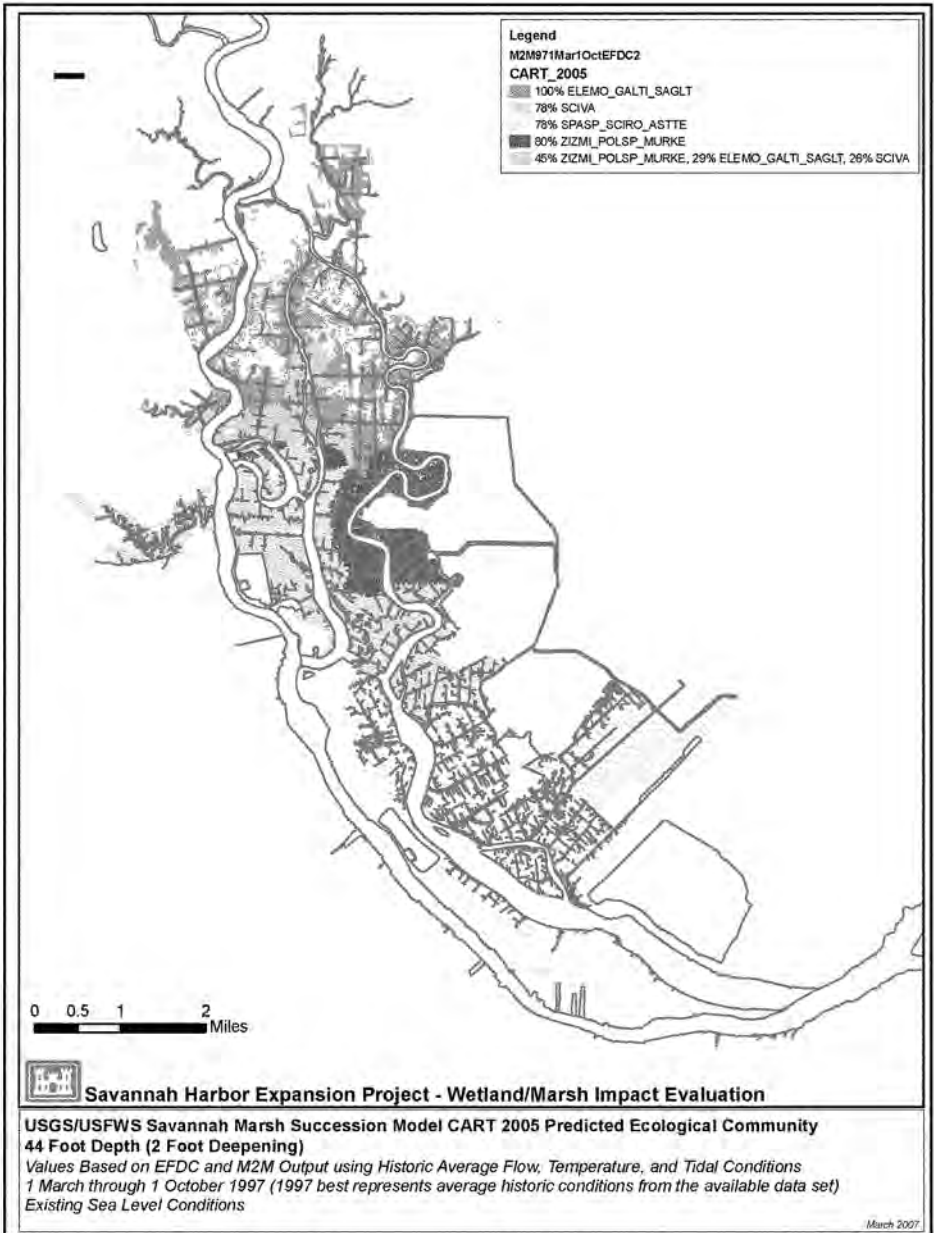
The general trend is a loss of freshwater tidal marsh occurring with the increased channel depth. The largest community shifts are seen under the 6-foot deepening scenario. In addition to changes in distributions of communities the results of the 2-, 3-, 4- and 6-foot deepening with 50 cm sea level rise, indicate significant structural and compositional change in the *E. montevidensis* dominated community along the Front, Middle and Little Back rivers. This compositional change is indicated by a loss in species diversity. Under deepening with 50 cm sea level rise there is a loss of salt-sensitive subdominants like GALTI and SAGLT. Other areas of compositional change are seen along the Back River in the most saline communities. This area shows a loss in subdominant ASTTE, which is a mildly salt-tolerant species. A quick view of the Wetland/Marsh Impact Evaluation table in Appendix D does not tell the full story of pore water salinity impacts to freshwater marsh communities with deepening. The Ecological Community maps and Ecological Community Shift maps in Appendix D provide a clearer picture of what is happening in the areas of greatest concern: Middle, Little Back, and Back rivers.

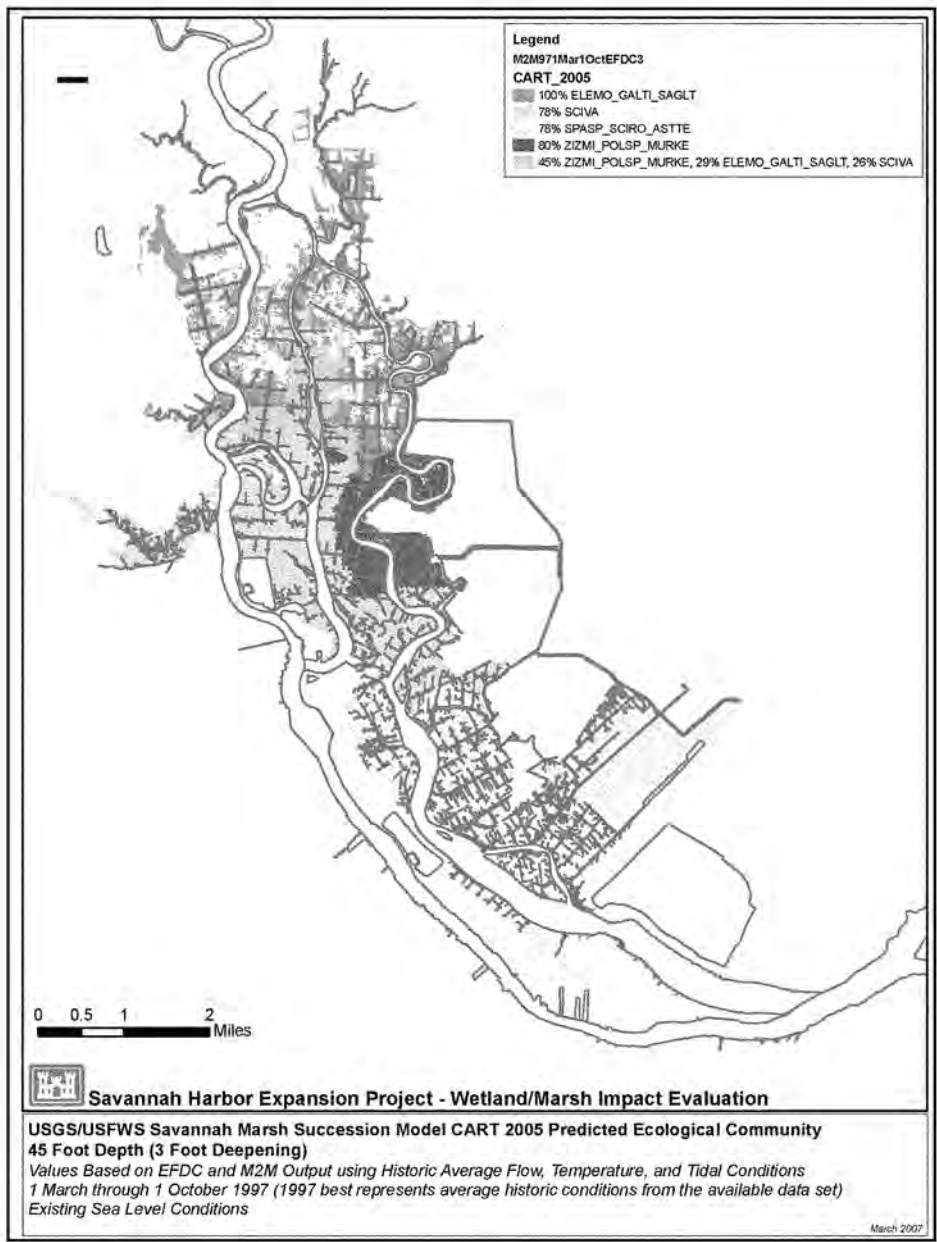
Conclusion:

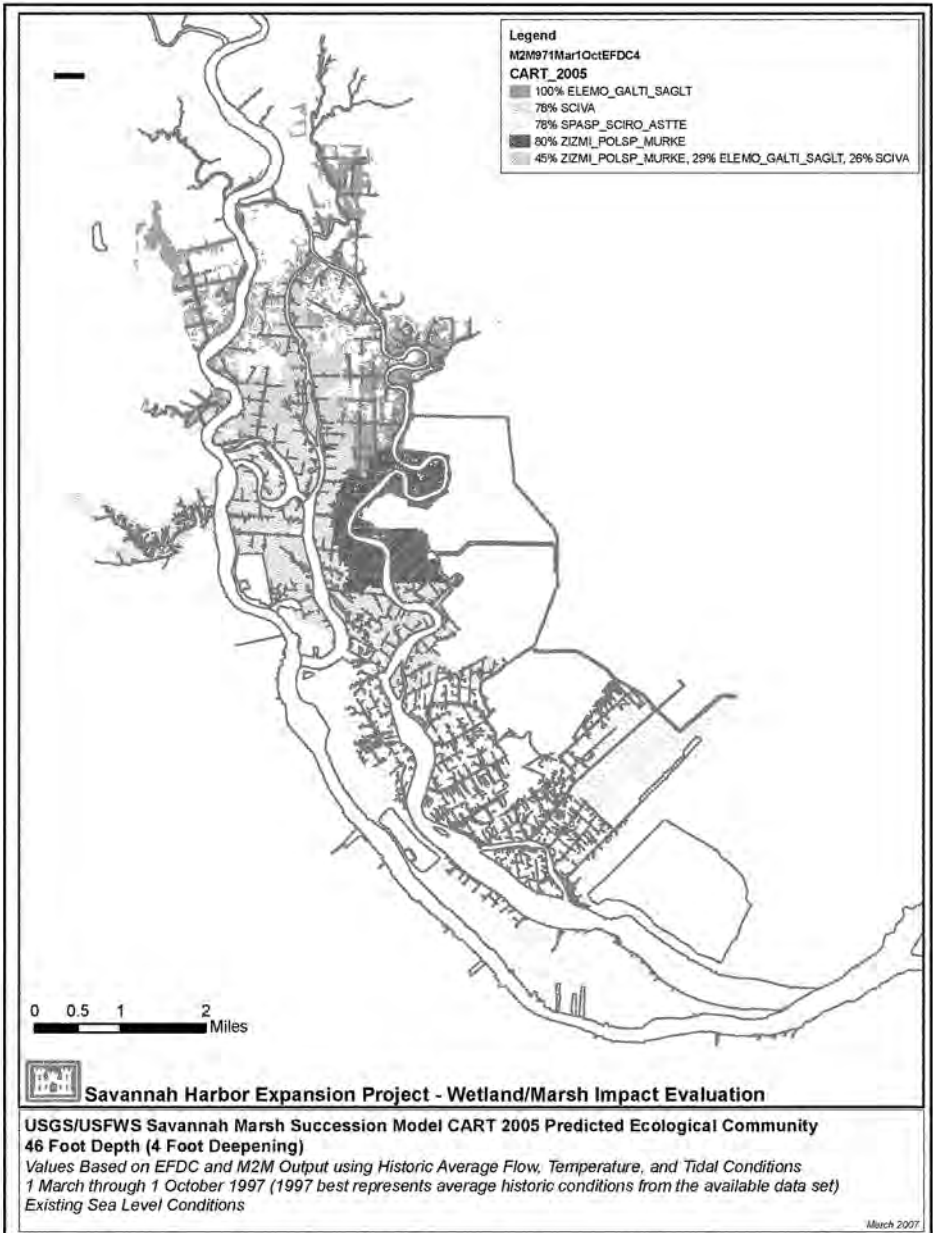
The MSM modeling predicts that there will be impacts on the freshwater marsh vegetation communities with each deepening. The level of impact depends directly on the proposed depth of the navigation channel. The trends indicate that as the navigation channel is deepened salinity intrudes further and further upstream resulting in a shift to more salt tolerant species. Rising sea levels results in salt tolerant species propagating even further upstream.

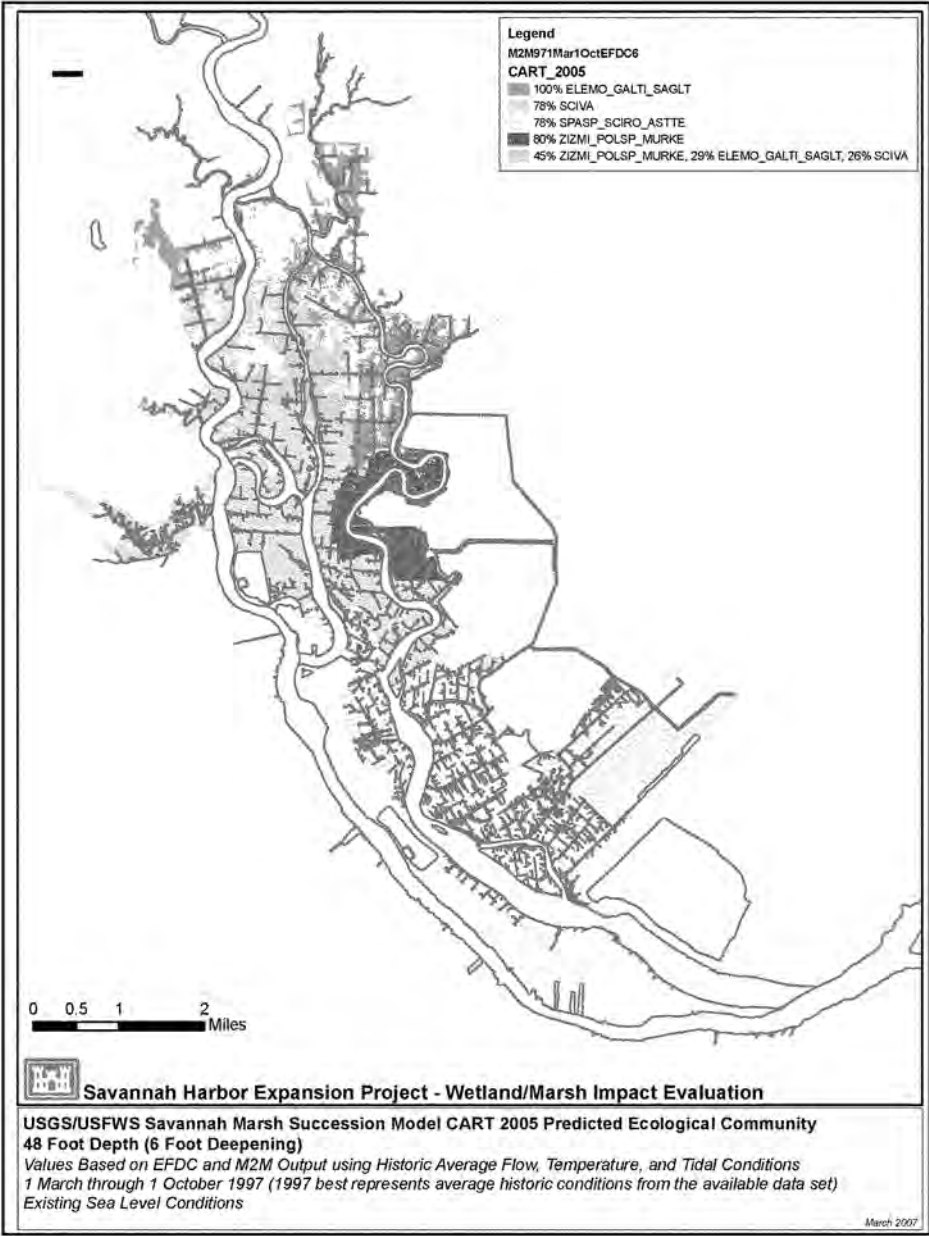
APPENDIX A
BASIC EVALUATION
ECOLOGICAL COMMUNITY MAPS &
ECOLOGICAL COMMUNITY SHIFT MAPS

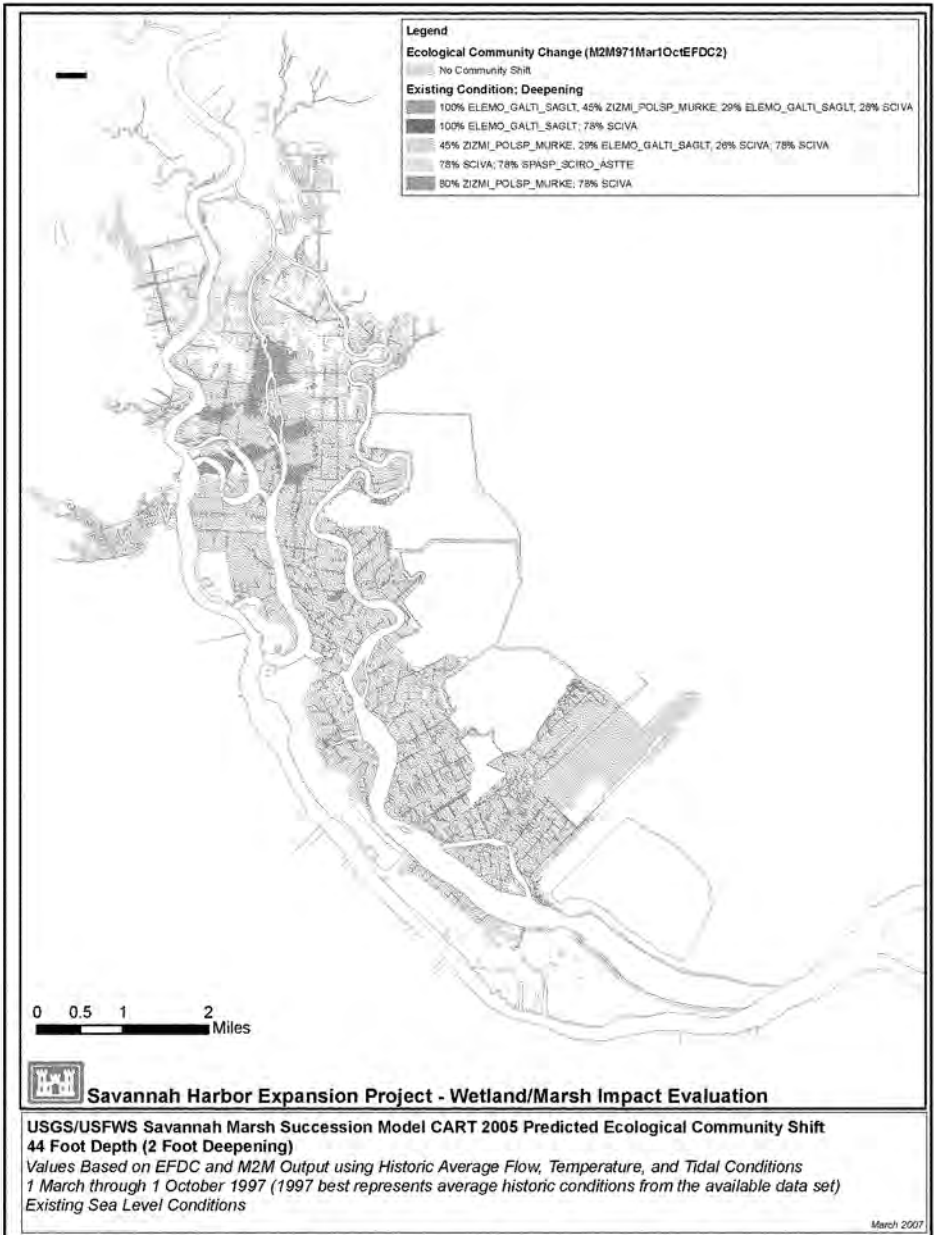


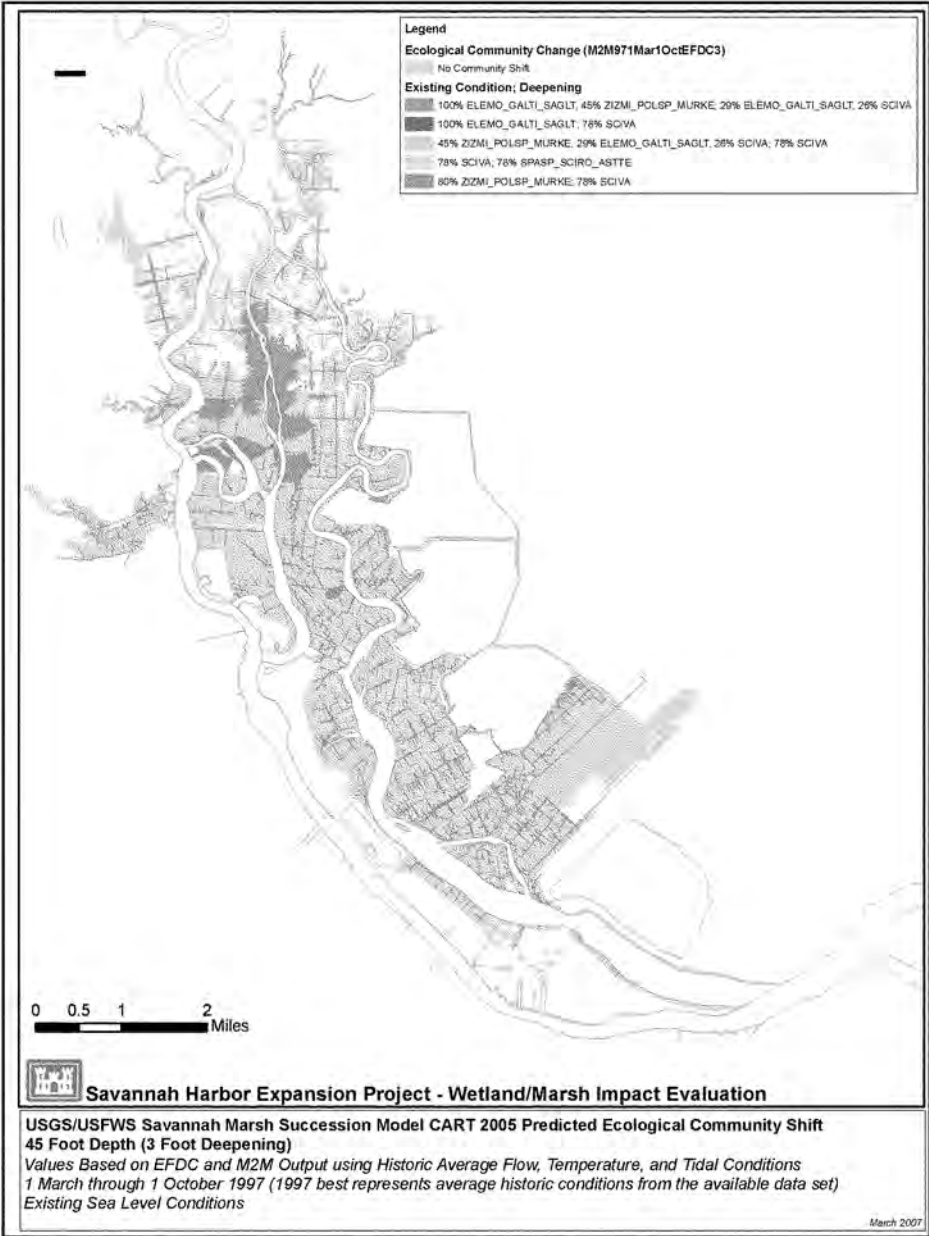


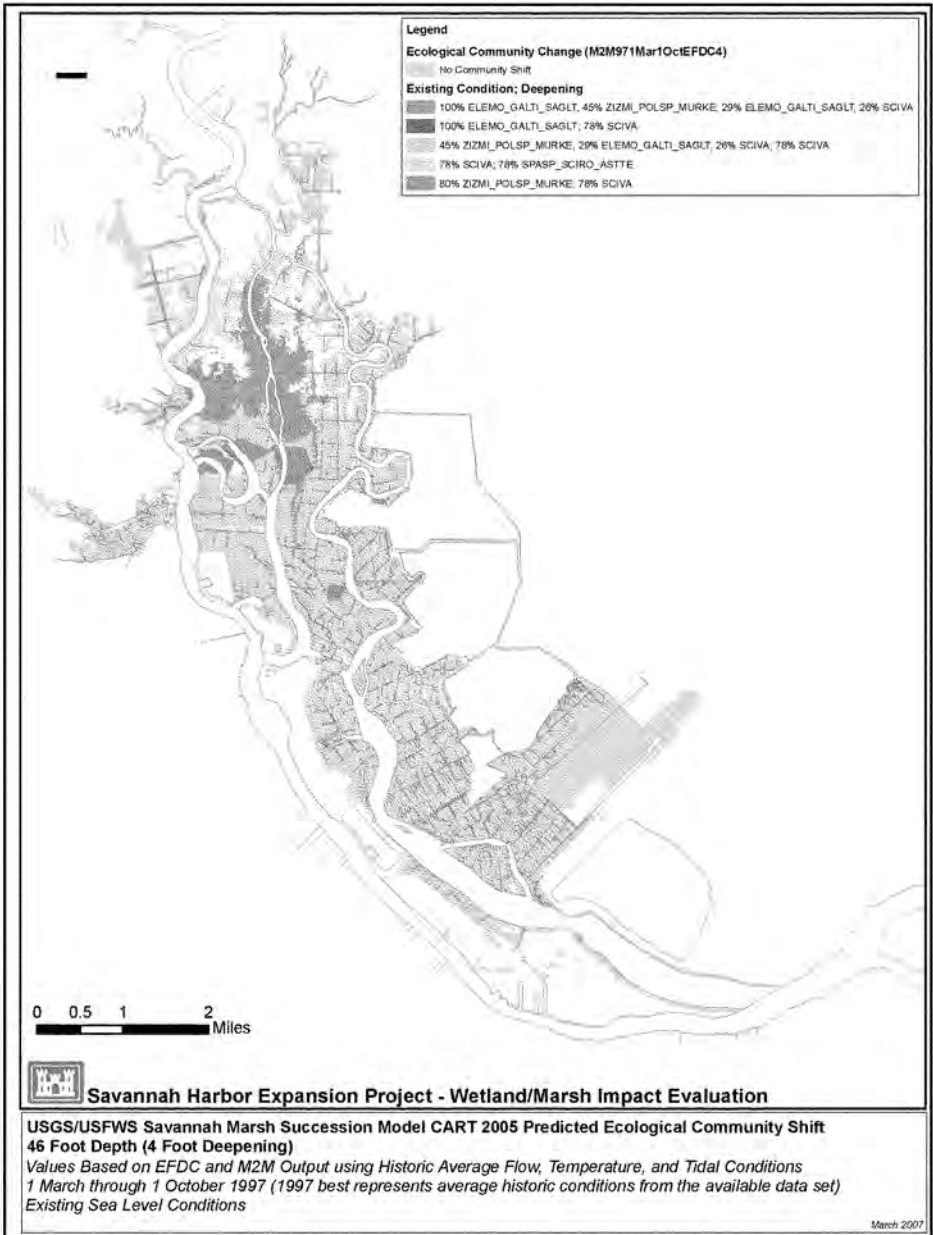


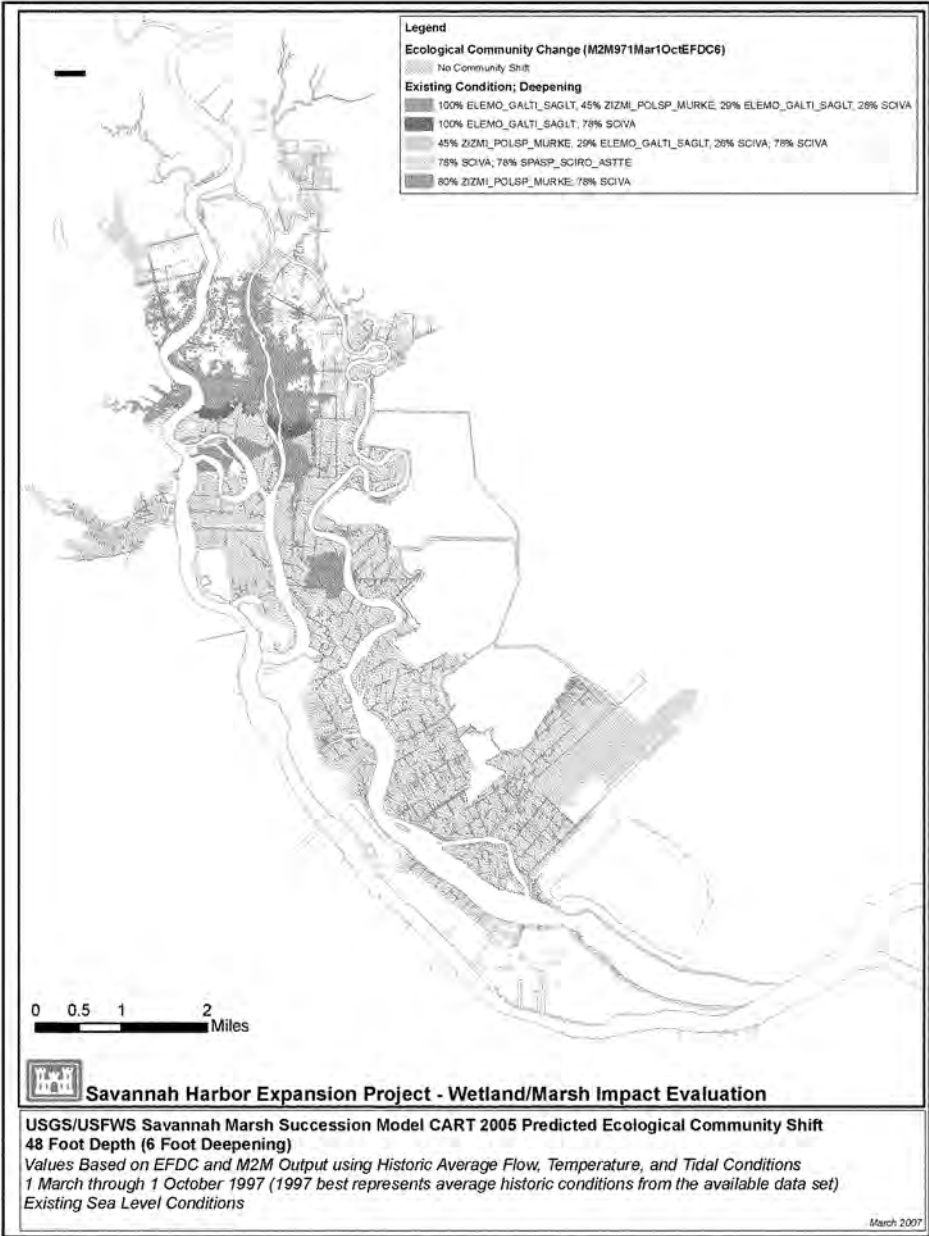












Savannah Harbor Expansion Project
USGS/USFWS MSM
Wetland/Marsh Impact Evaluation
Predicted Vegetation Community Shifts

Community CART2005	No Deepening Average Flow Associated Acreages	44 ft Deepening Average Flow Associated Acreages	Net Change (net negative), net positive
100% Elemo_Galti_Saglt	2231	1950	(280)
80% Zizmi_Polsp	959	814	(145)
45% Zizmi_Polsp, 29% Elemo_Galti_Saglt, 26% Sciva	232	499	266
78% Sciva	2215	2183	(32)
78% Spasp_Sciro_Astte	3209	3400	191
TOTAL	8847	8847	

Community CART2005	No Deepening Average Flow Associated Acreages	45 ft Deepening Average Flow Associated Acreages	Net Change (net negative), net positive
100% Elemo_Galti_Saglt	2231	1746	(485)
80% Zizmi_Polsp	959	748	(211)
45% Zizmi_Polsp, 29% Elemo_Galti_Saglt, 26% Sciva	232	659	427
78% Sciva	2215	2193	(22)
78% Spasp_Sciro_Astte	3209	3501	291
TOTAL	8847	8847	

Community CART2005	No Deepening Average Flow Associated Acreages	46 ft Deepening Average Flow Associated Acreages	Net Change (net negative), net positive
100% Elemo_Galti_Saglt	2231	1510	(721)
80% Zizmi_Polsp	959	715	(244)
45% Zizmi_Polsp, 29% Elemo_Galti_Saglt, 26% Sciva	232	812	579
78% Sciva	2215	2179	(36)
78% Spasp_Sciro_Astte	3209	3631	422
TOTAL	8847	8847	

Community CART2005	No Deepening Average Flow Associated Acreages	48 ft Deepening Average Flow Associated Acreages	Net Change (net negative), net positive
100% Elemo_Galti_Saglt	2231	1176	(1055)
80% Zizmi_Polsp	959	579	(380)
45% Zizmi_Polsp, 29% Elemo_Galti_Saglt, 26% Sciva	232	979	747
78% Sciva	2215	2238	23
78% Spasp_Sciro_Astte	3209	3874	665
TOTAL	8847	8847	

* Values Based on EPDC and M2M Marsh Pore Water Salinity Input for Historic Average Flow, Temperature, and Tidal Conditions

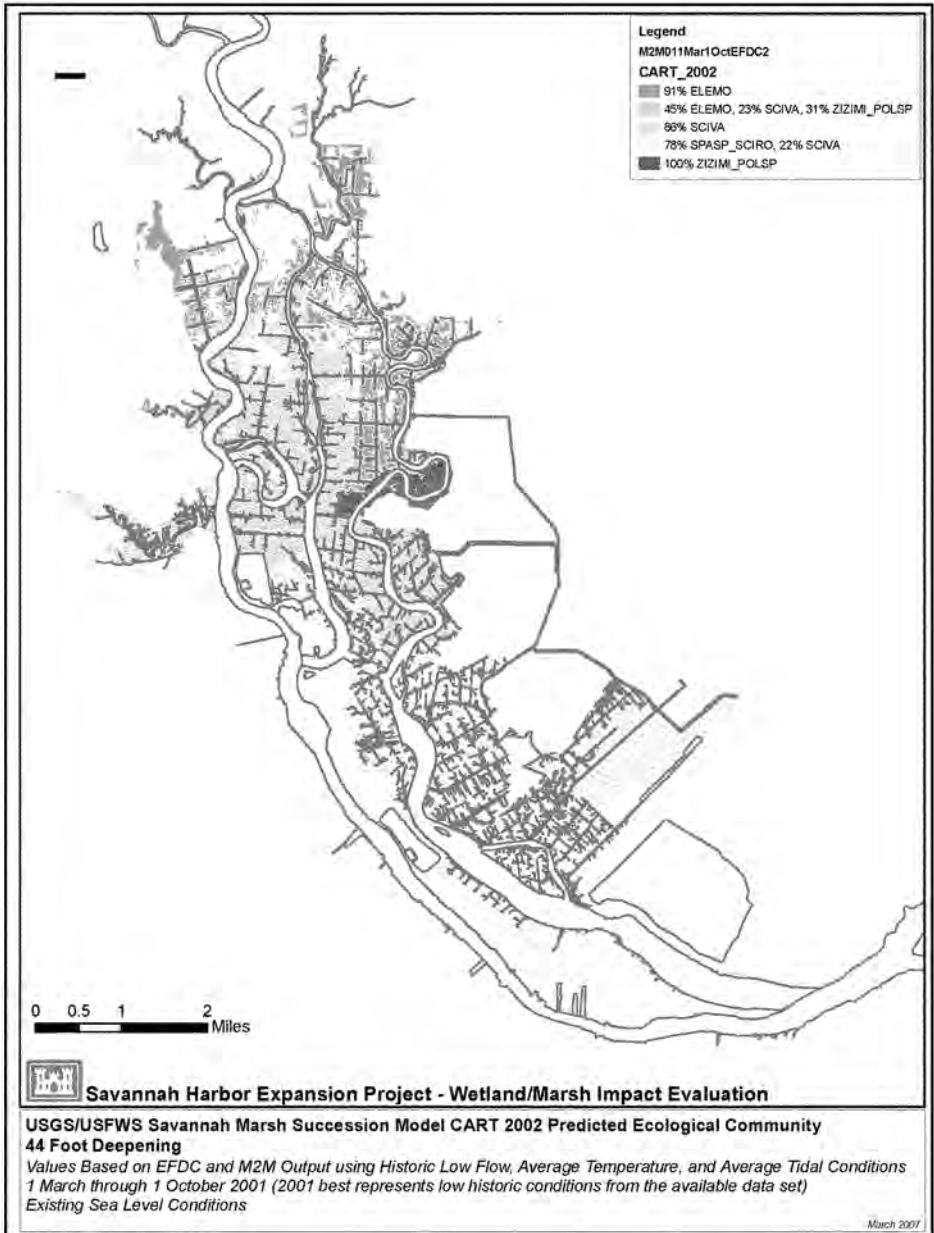
† March through 1 October 1997 (1997 best represents average historic conditions from the available data set)

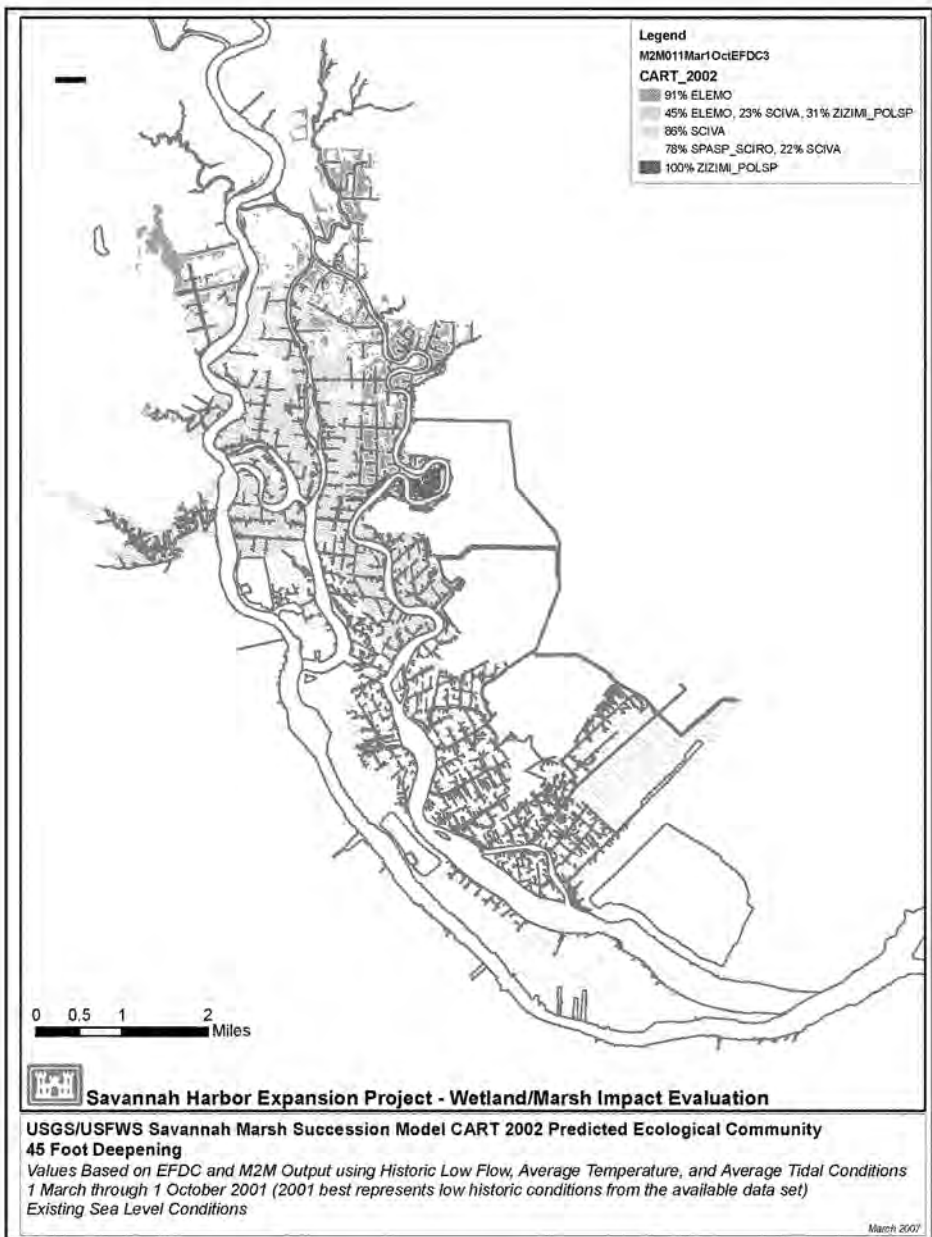
Existing Sea Level Conditions

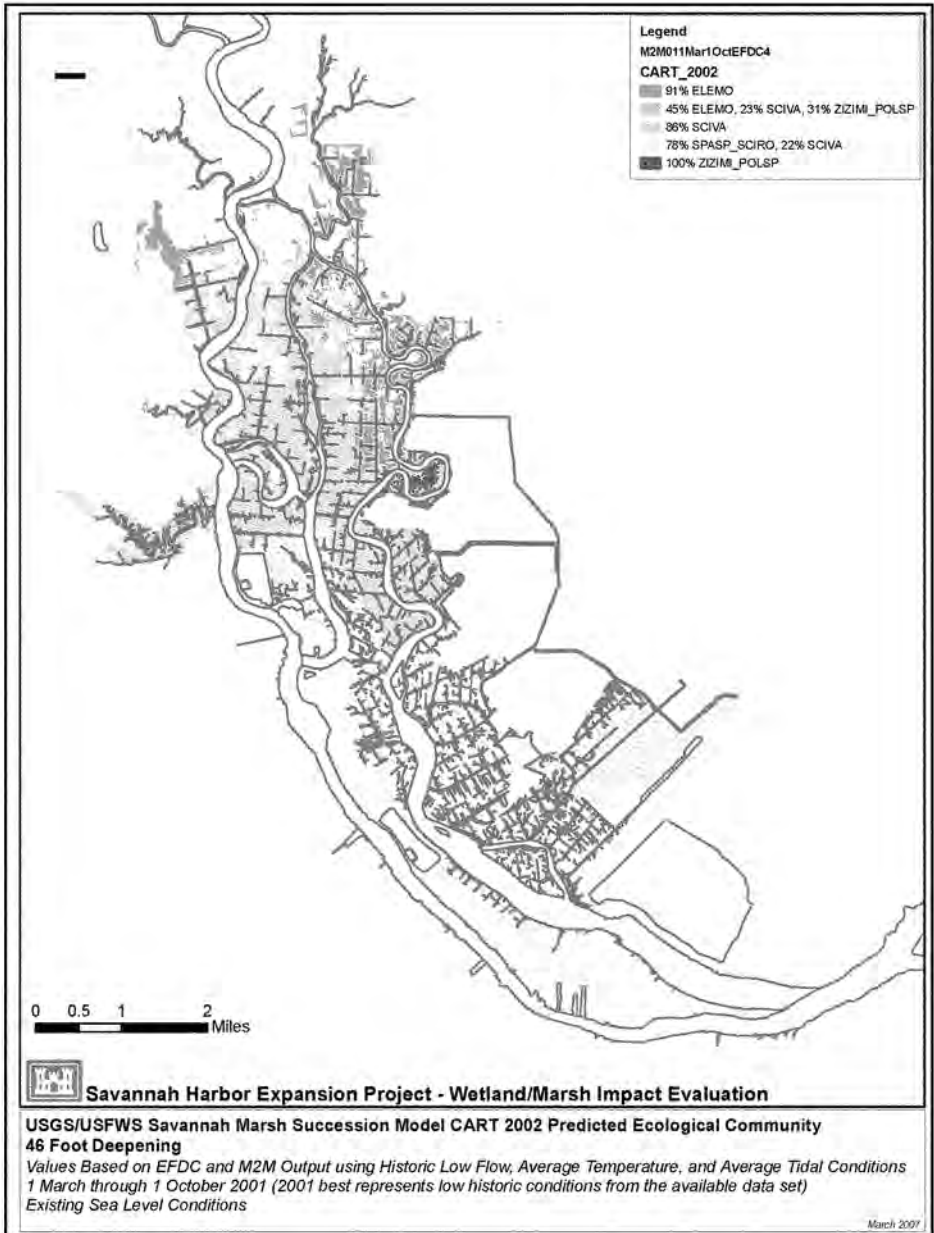


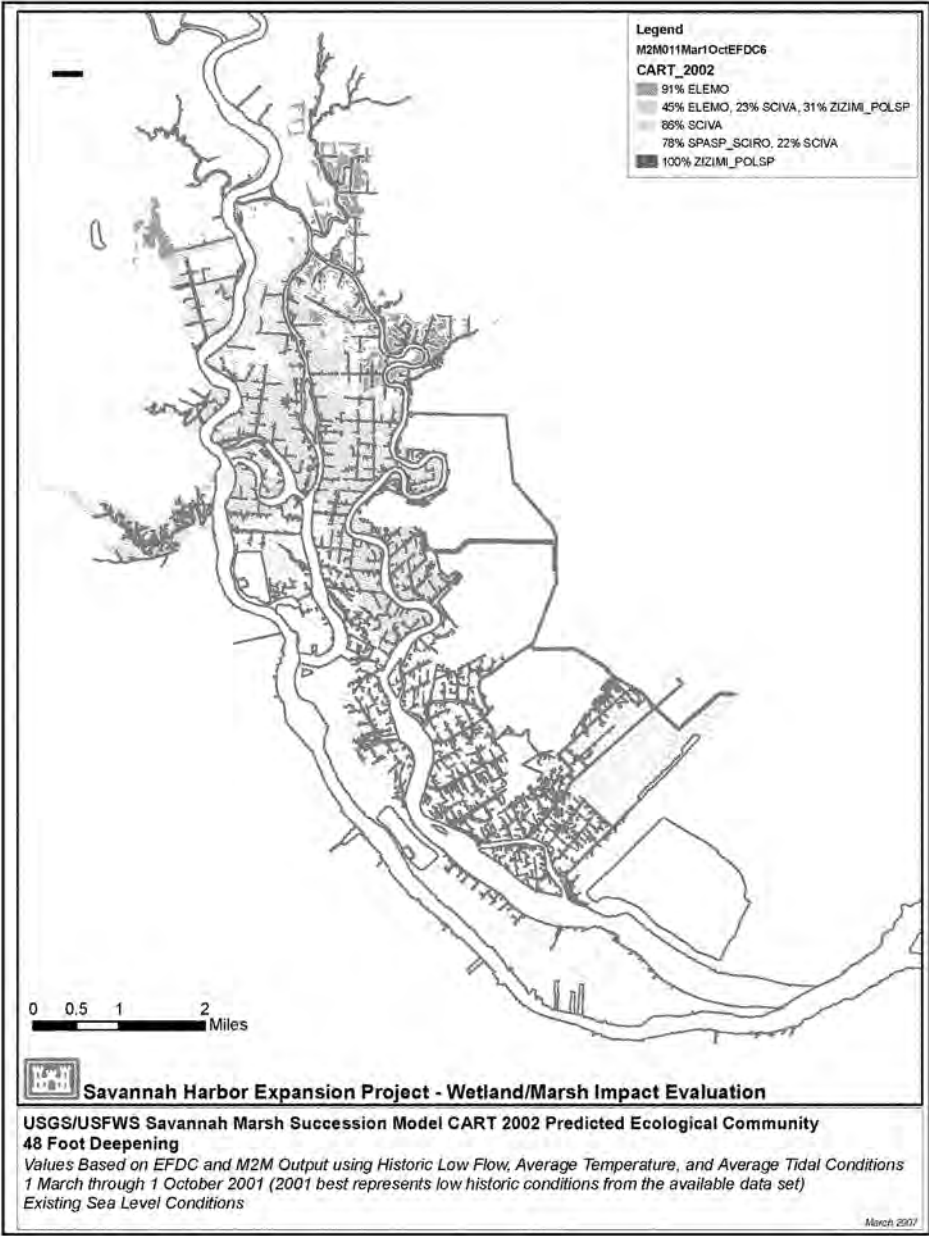
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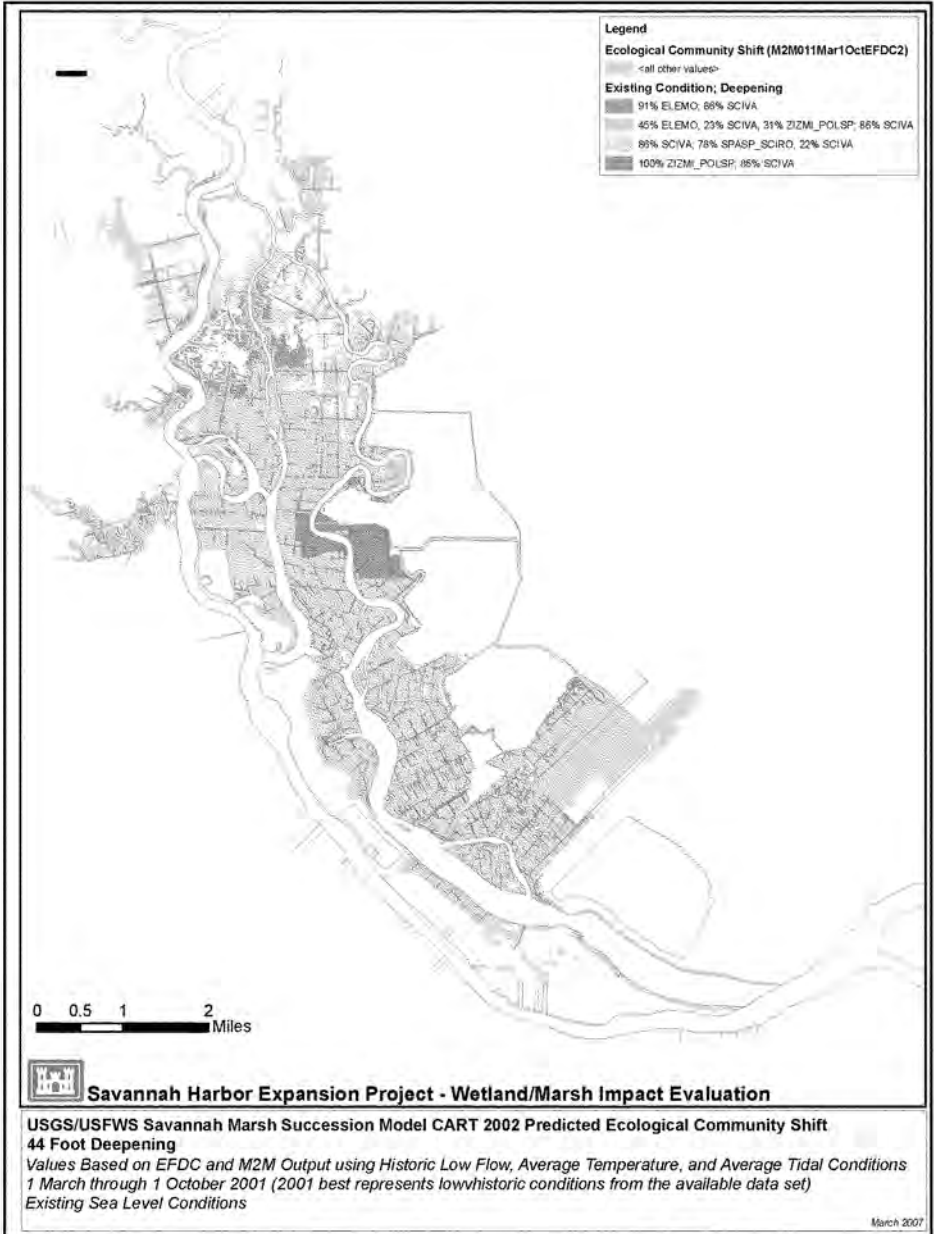
APPENDIX B
SENSITIVITY ANYSIS #1
ECOLOGICAL COMMUNITY MAPS &
ECOLOGICAL COMMUNITY SHIFT MAPS

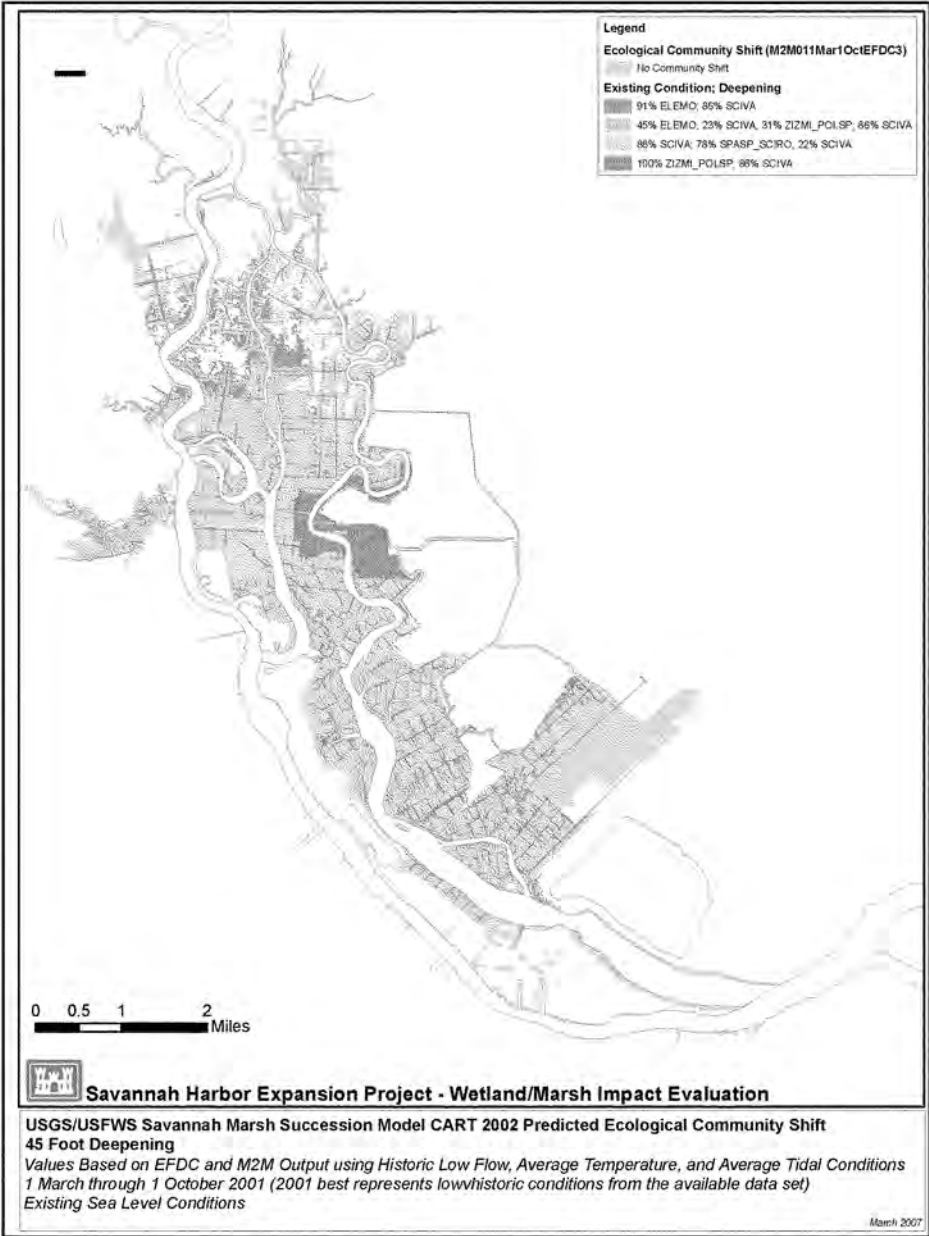


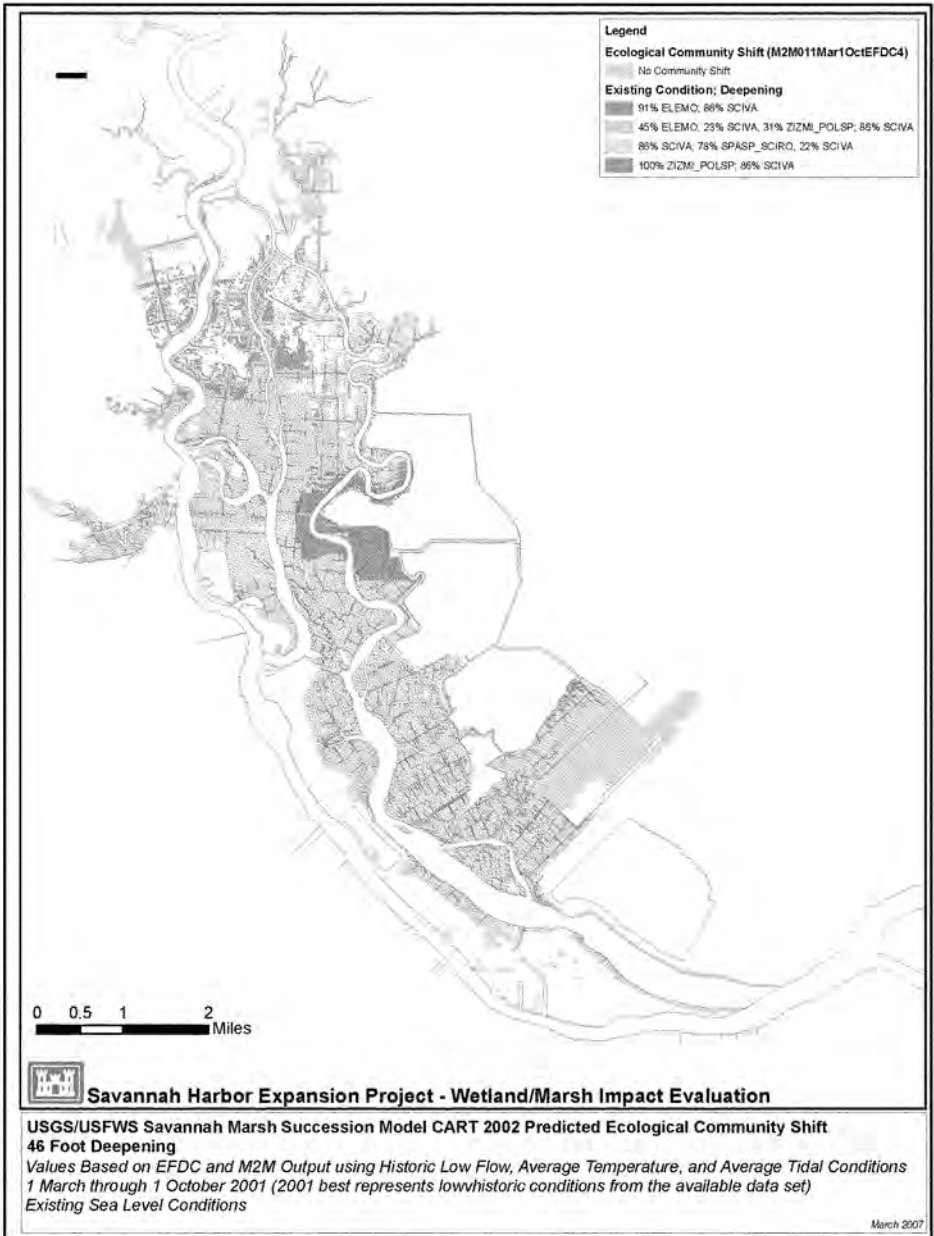


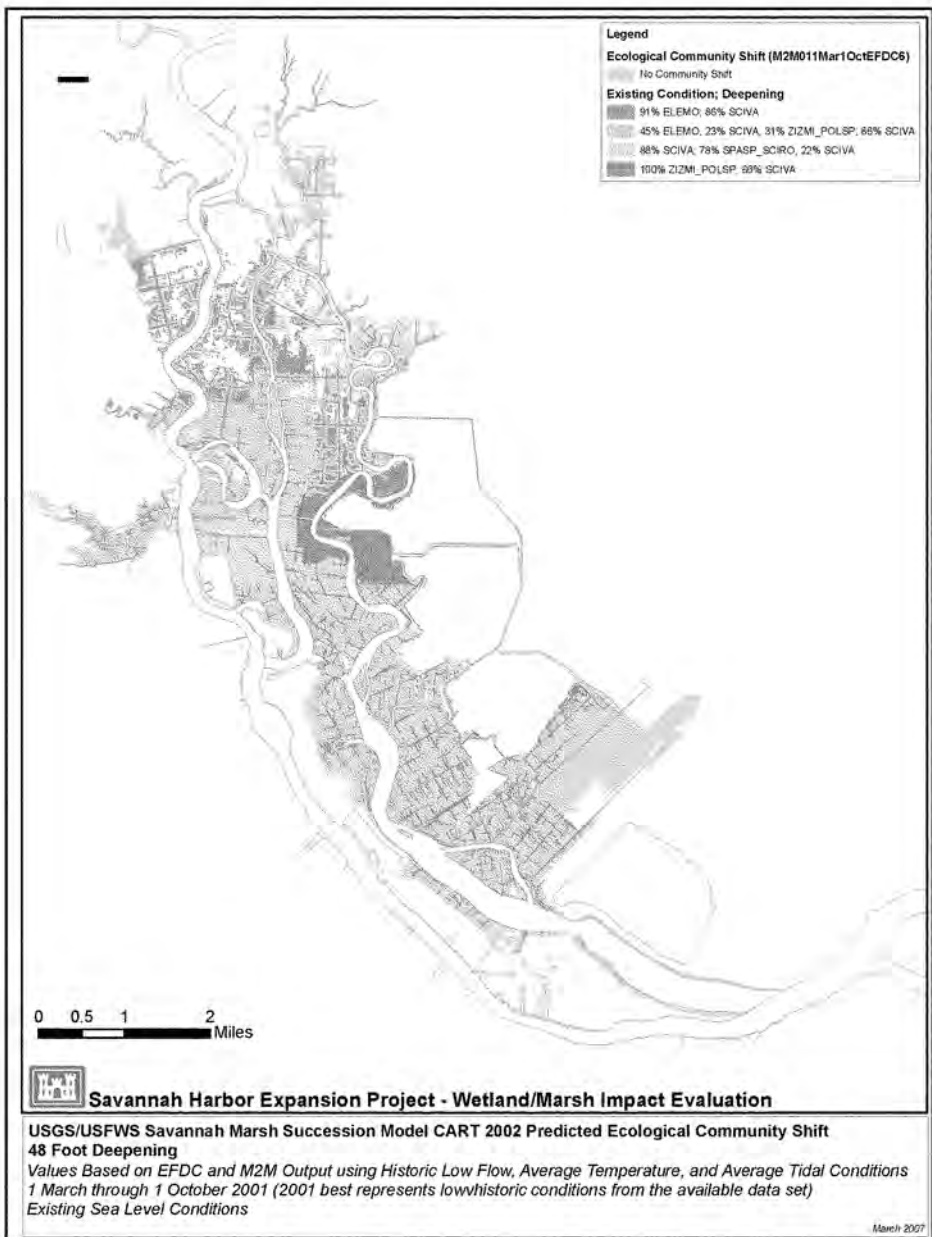












Savannah Harbor Expansion Project
USGS/USFWS MSM Wetland/Marsh Impact Evaluation
Predicted Vegetation Community Shifts

Community CART2002	No Deepening Low Flow Associated Acreages	44 ft Deepening Low Flow Associated Acreages	Net Change (net negative), net positive
91% Elemo	868	614	(254)
100% Zizmi_Polsp	476	144	(332)
45% Elemo, 23% Sciva, 31% Zizmi_Polsp	1069	781	(288)
86% Sciva	2390	3062	672
78% Spasp_Sciro, 22% Sciva	4043	4245	202
TOTAL	7978	8847	

Community CART2002	No Deepening Low Flow Associated Acreages	45 ft Deepening Low Flow Associated Acreages	Net Change (net negative), net positive
91% Elemo	868	549	(319)
100% Zizmi_Polsp	476	80	(396)
45% Elemo, 23% Sciva, 31% Zizmi_Polsp	1069	673	(396)
86% Sciva	2390	3211	821
78% Spasp_Sciro, 22% Sciva	4043	4333	290
TOTAL	8847	8847	

Community CART2002	No Deepening Low Flow Associated Acreages	46 ft Deepening Low Flow Associated Acreages	Net Change (net negative), net positive
91% Elemo	868	493	(375)
100% Zizmi_Polsp	476	48	(428)
45% Elemo, 23% Sciva, 31% Zizmi_Polsp	1069	610	(459)
86% Sciva	2390	3275	885
78% Spasp_Sciro, 22% Sciva	4043	4420	377
TOTAL	8847	8847	

Community CART2002	No Deepening Low Flow Associated Acreages	48 ft Deepening Low Flow Associated Acreages	Net Change (net negative), net positive
91% Elemo	868	365	(503)
100% Zizmi_Polsp	476	0	(476)
45% Elemo, 23% Sciva, 31% Zizmi_Polsp	1069	423	(646)
86% Sciva	2390	3482	1092
78% Spasp_Sciro, 22% Sciva	4043	4576	532
TOTAL	8847	8847	

* Values Based on EFDC and M2M Marsh Pore Water Salinity Input for Historic Low Flow, Average Temperature, and Tidal Conditions.

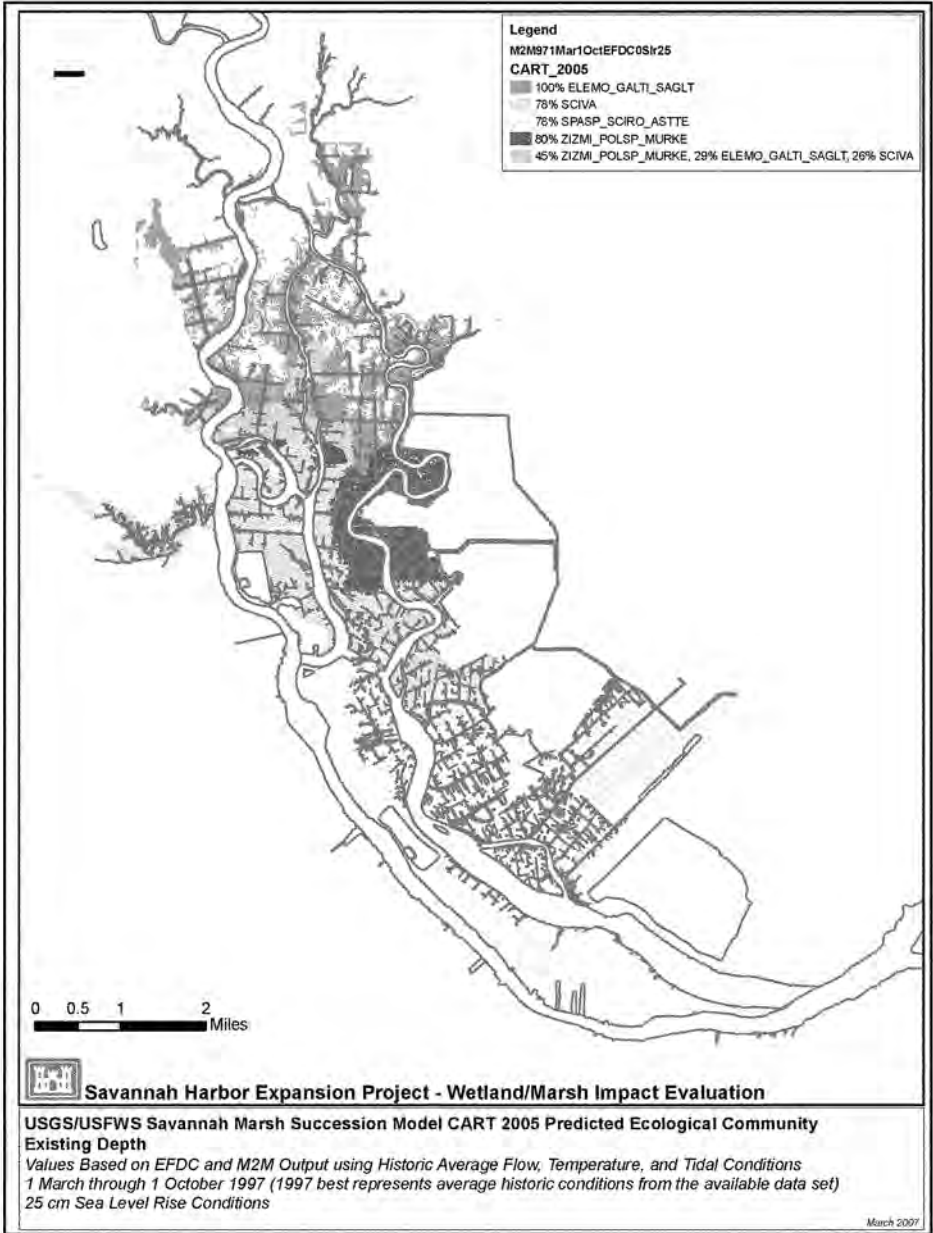
† March through 1 October 2001 (2001 best represents low historic conditions from the available data set)

Existing Sea Level Conditions

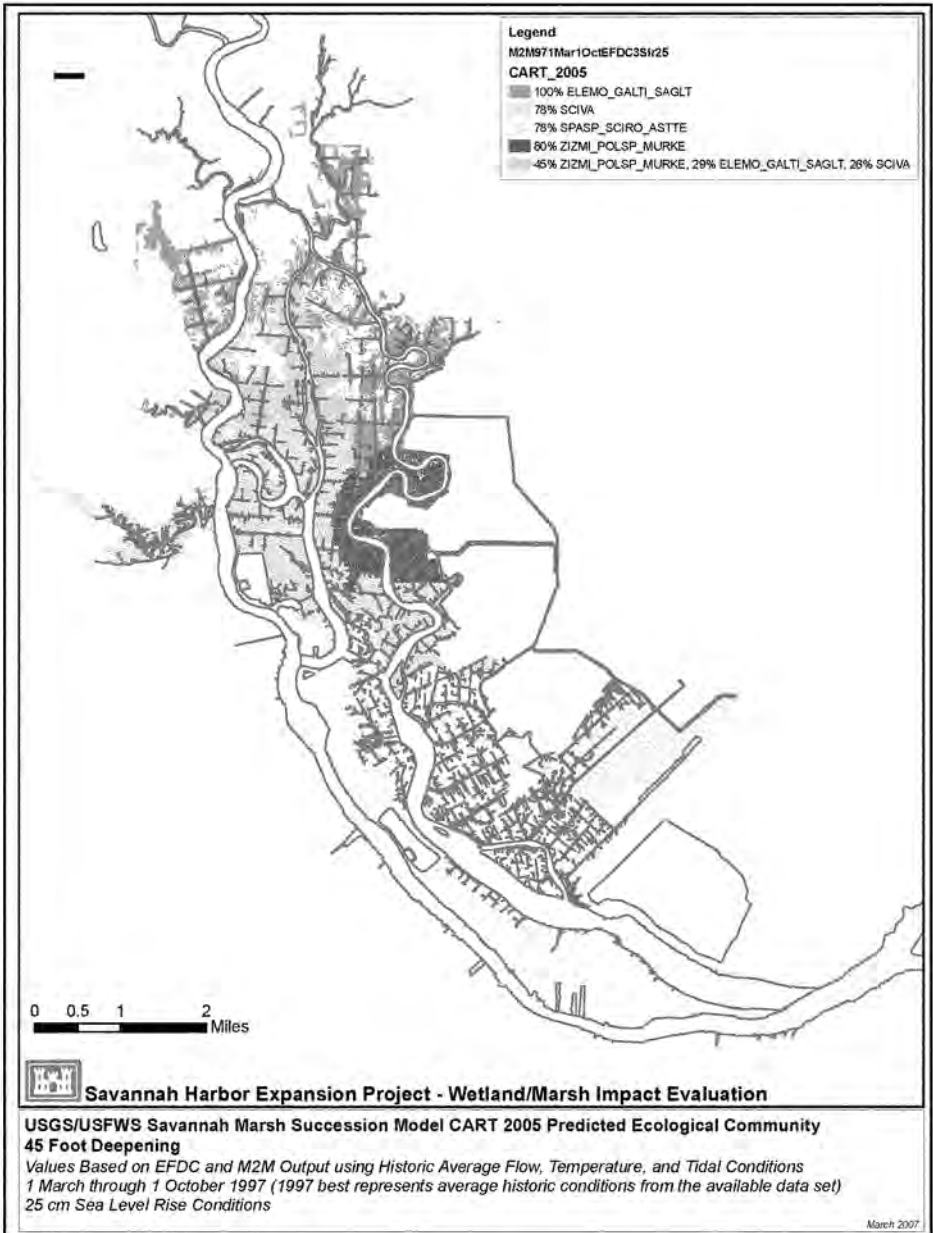


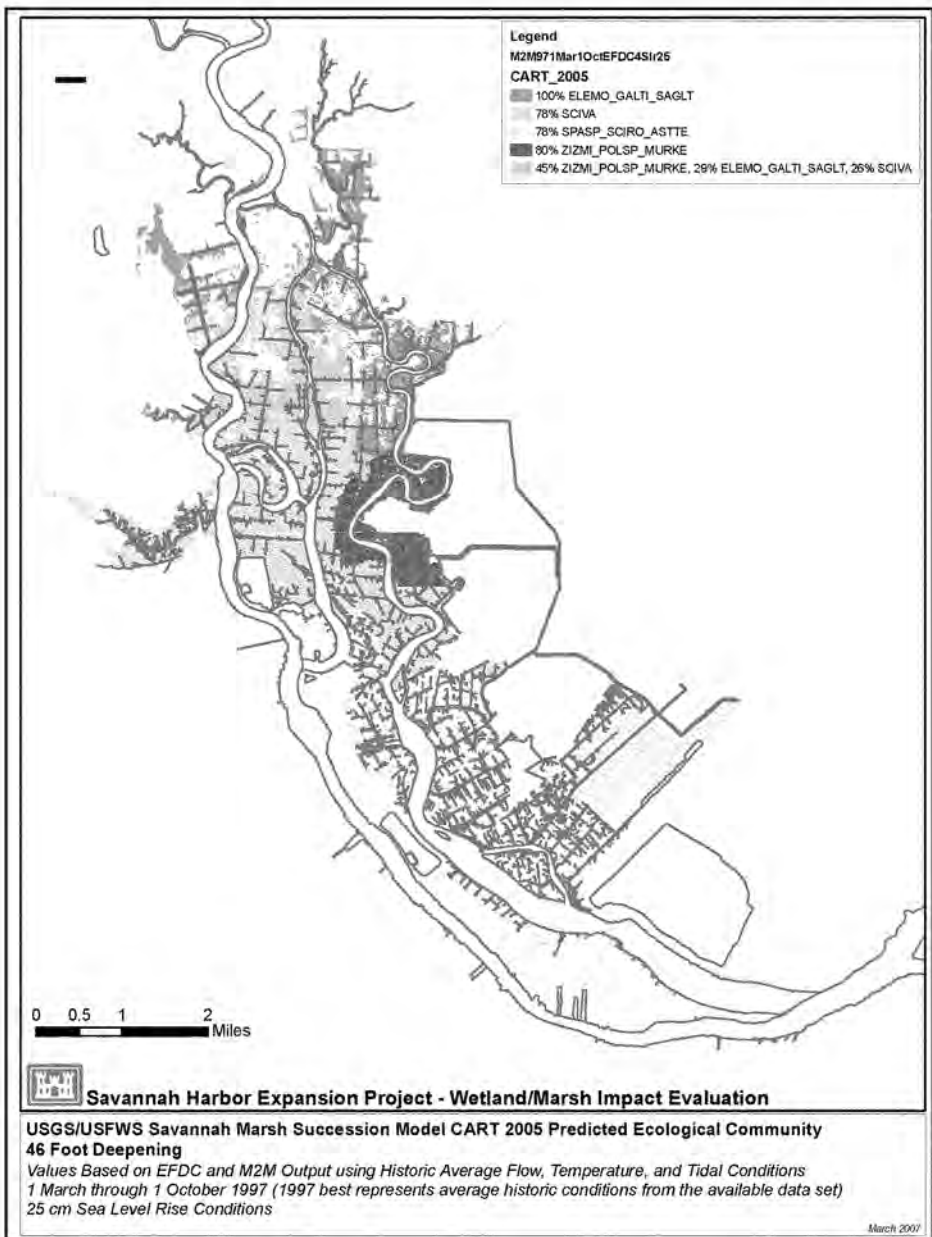
March 2007

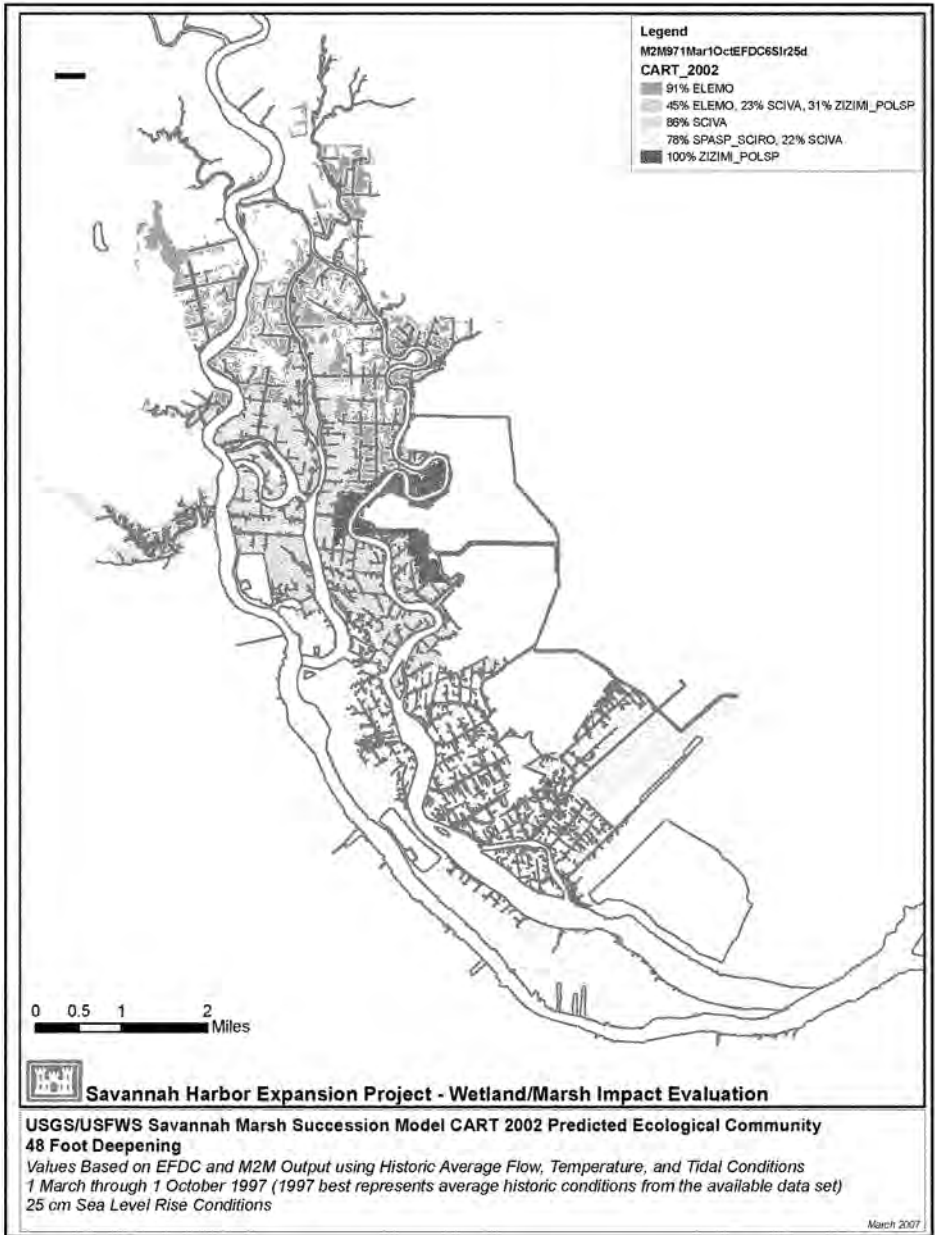
APPENDIX C
SENSITIVITY ANALYSIS #2A
ECOLOGICAL COMMUNITY MAPS &
ECOLOGICAL COMMUNITY SHIFT MAPS

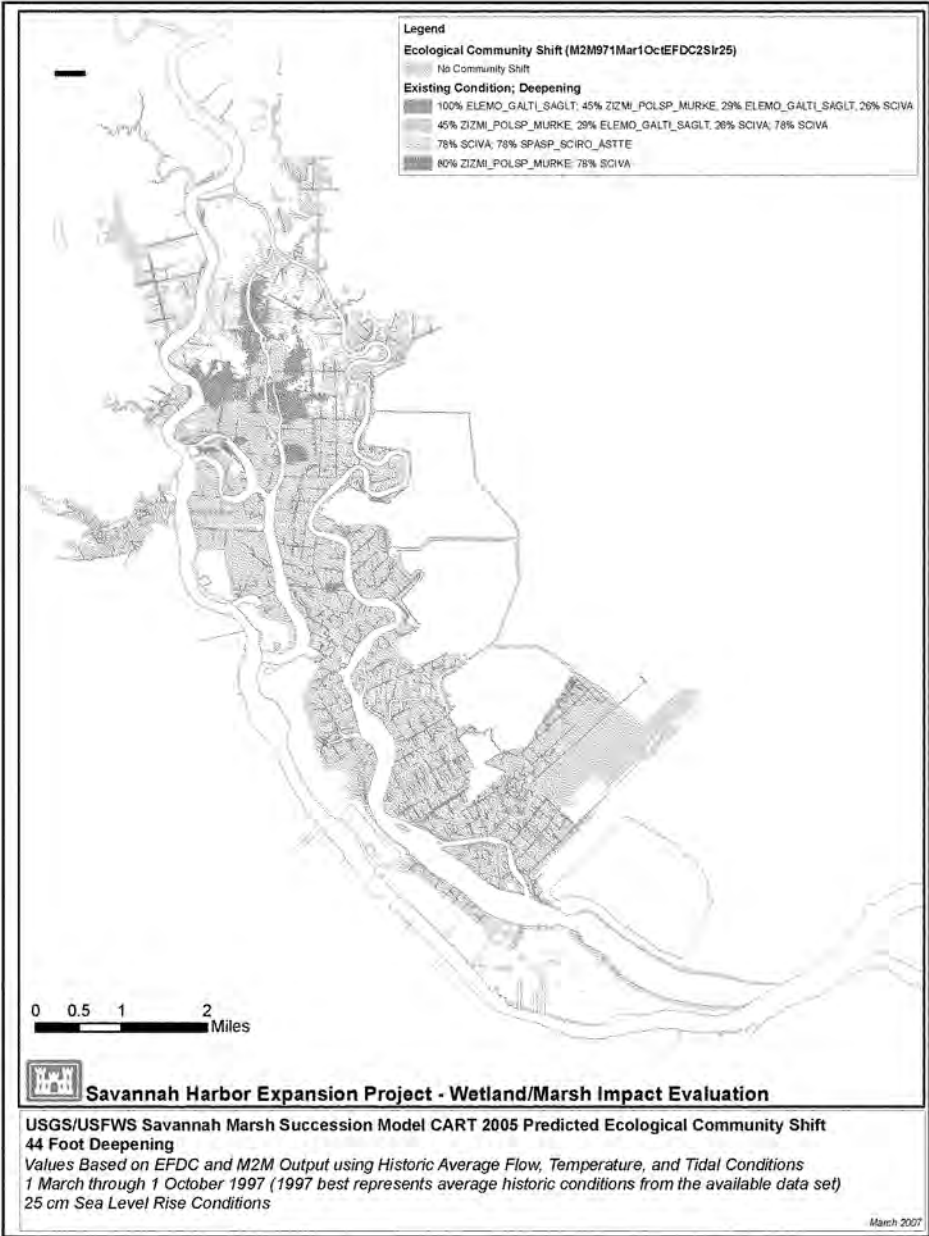


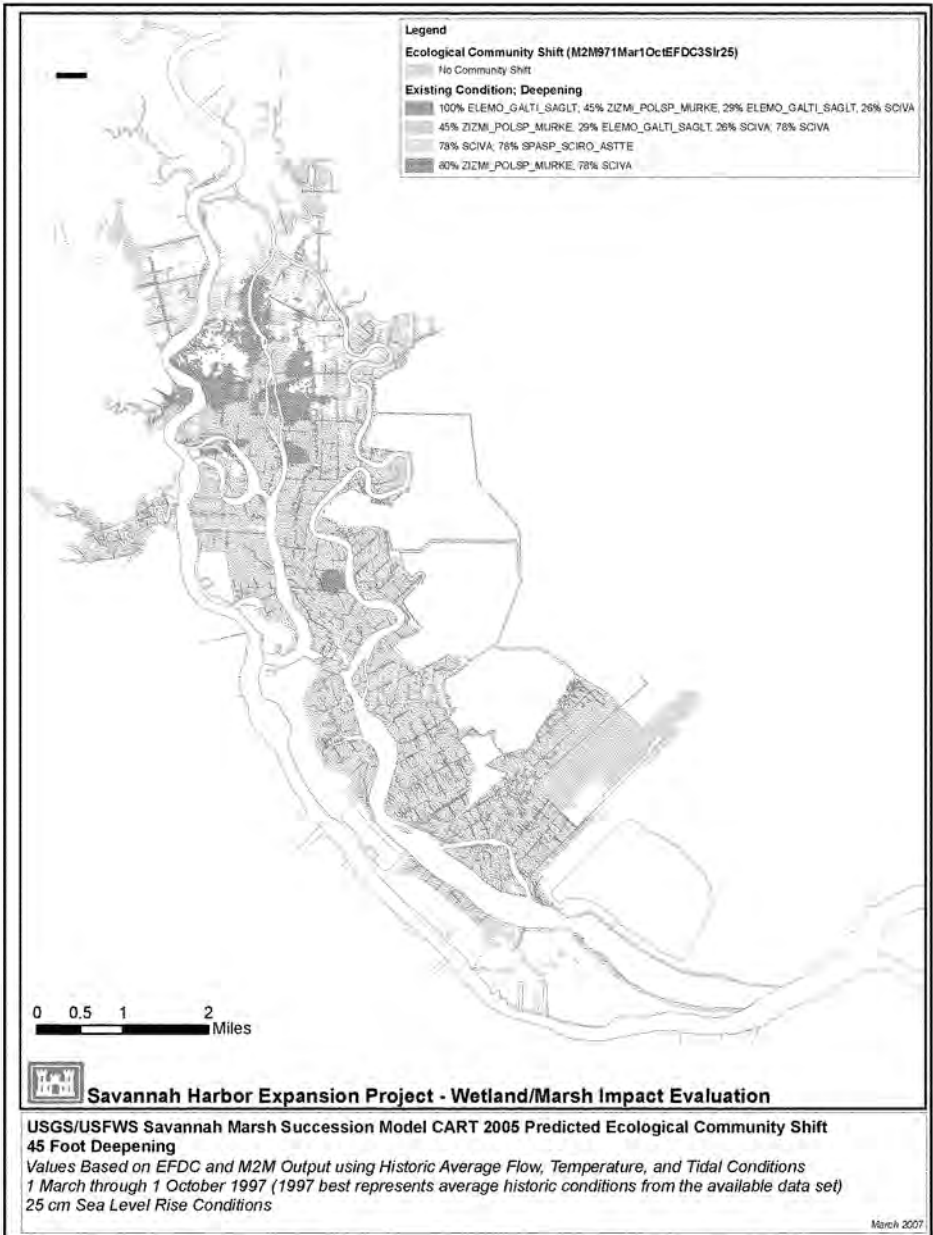


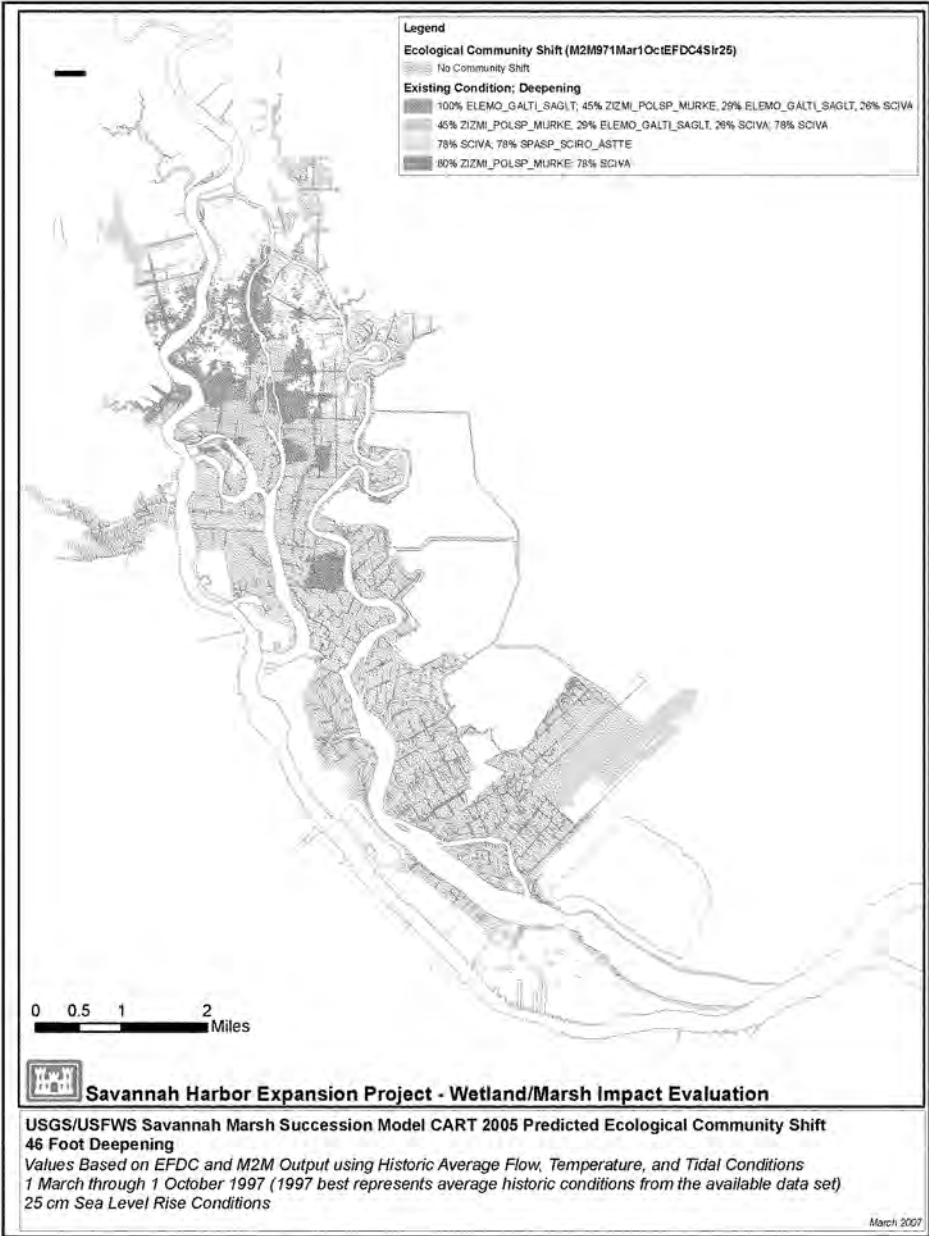


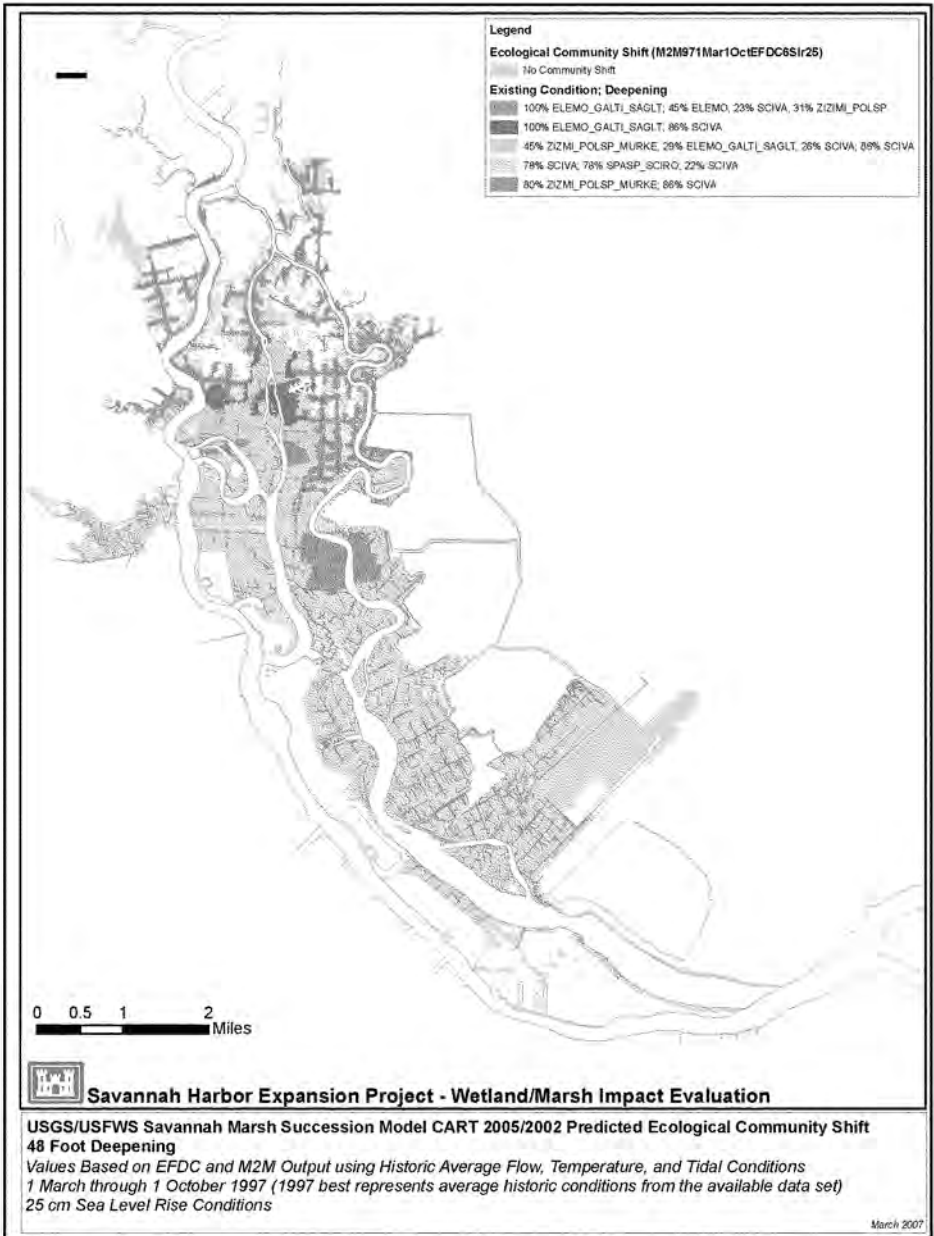












Savannah Harbor Expansion Project
USGS/USFWS MSM Wetland/Marsh Impact Evaluation
Predicted Vegetation Community Shifts

Community CART2005	No Deepening 25 cm Sea Level Rise Associated Acreages	44 ft Deepening 25 cm Sea Level Rise Associated Acreages	Net Change (net negative), net positive
100% Elemo_Galti_Saglt	2003	1527	(476)
80% Zizmi_Polsp	805	711	(94)
45% Zizmi_Polsp, 29% Elemo_Galti_Saglt, 26% Sciva	446	793	348
78% Sciva	2165	2149	(16)
78% Spasp_Sciro_Astte	3428	3666	238
TOTAL	8847	8847	

Community CART2005	No Deepening 25 cm Sea Level Rise Associated Acreages	45 ft Deepening 25 cm Sea Level Rise Associated Acreages	Net Change (net negative), net positive
100% Elemo_Galti_Saglt	2003	1374	(628)
80% Zizmi_Polsp	805	699	(106)
45% Zizmi_Polsp, 29% Elemo_Galti_Saglt, 26% Sciva	446	863	418
78% Sciva	2165	2168	3
78% Spasp_Sciro_Astte	3428	3772	343
TOTAL	8847	8847	

Community CART2005	No Deepening 25 cm Sea Level Rise Associated Acreages	46 ft Deepening 25 cm Sea Level Rise Associated Acreages	Net Change (net negative), net positive
100% Elemo_Galti_Saglt	2003	1159	(843)
80% Zizmi_Polsp	805	598	(207)
45% Zizmi_Polsp, 29% Elemo_Galti_Saglt, 26% Sciva	446	986	540
78% Sciva	2165	2214	50
78% Spasp_Sciro_Astte	3428	3889	461
TOTAL	8847	8847	

Community CART2005/2002	No Deepening 25 cm Sea Level Rise Associated Acreages	48 ft Deepening 25 cm Sea Level Rise Associated Acreages	Net Change (net negative), net positive
100% Elemo_Galti_Saglt/ 91% Elemo	2003	824	(1178)
80% Zizmi_Polsp/ 100% Zizmi_Polsp	805	317	(488)
45% Zizmi_Polsp, 29% Elemo_Galti_Saglt, 26% Sciva/ 45% Elemo, 23% Sciva, 31% Zizmi_Polsp	446	1017	571
78% Sciva/ 86% Sciva	2165	2799	634
78% Spasp_Sciro_Astte/ 78% Spasp_Sciro, 22% Sciva	3428	3889	461
TOTAL	8847	8847	

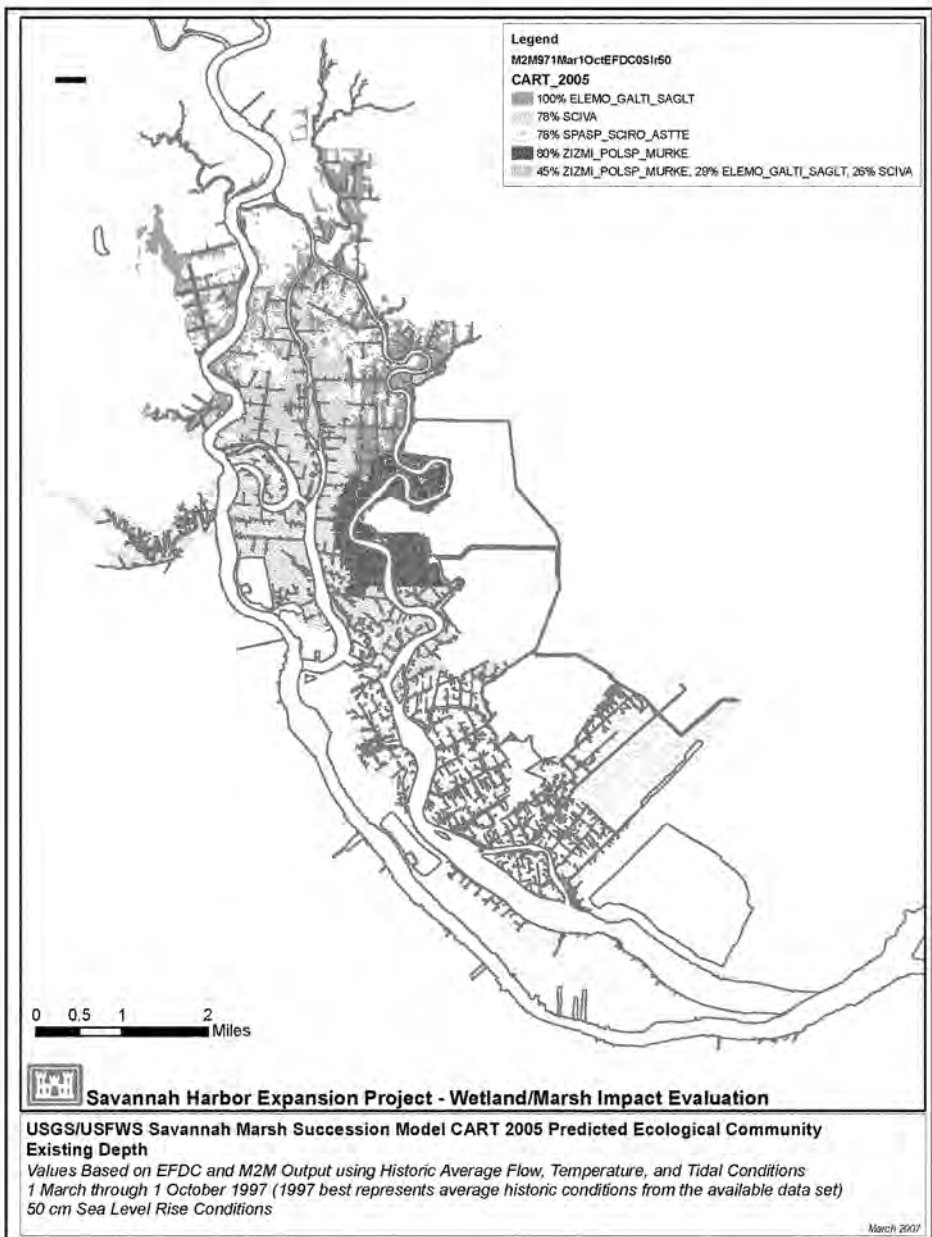
* Values Based on EFDC and MSM Marsh Pore Water Salinity Input for Historic Average Flow, Temperature, and Tidal Conditions

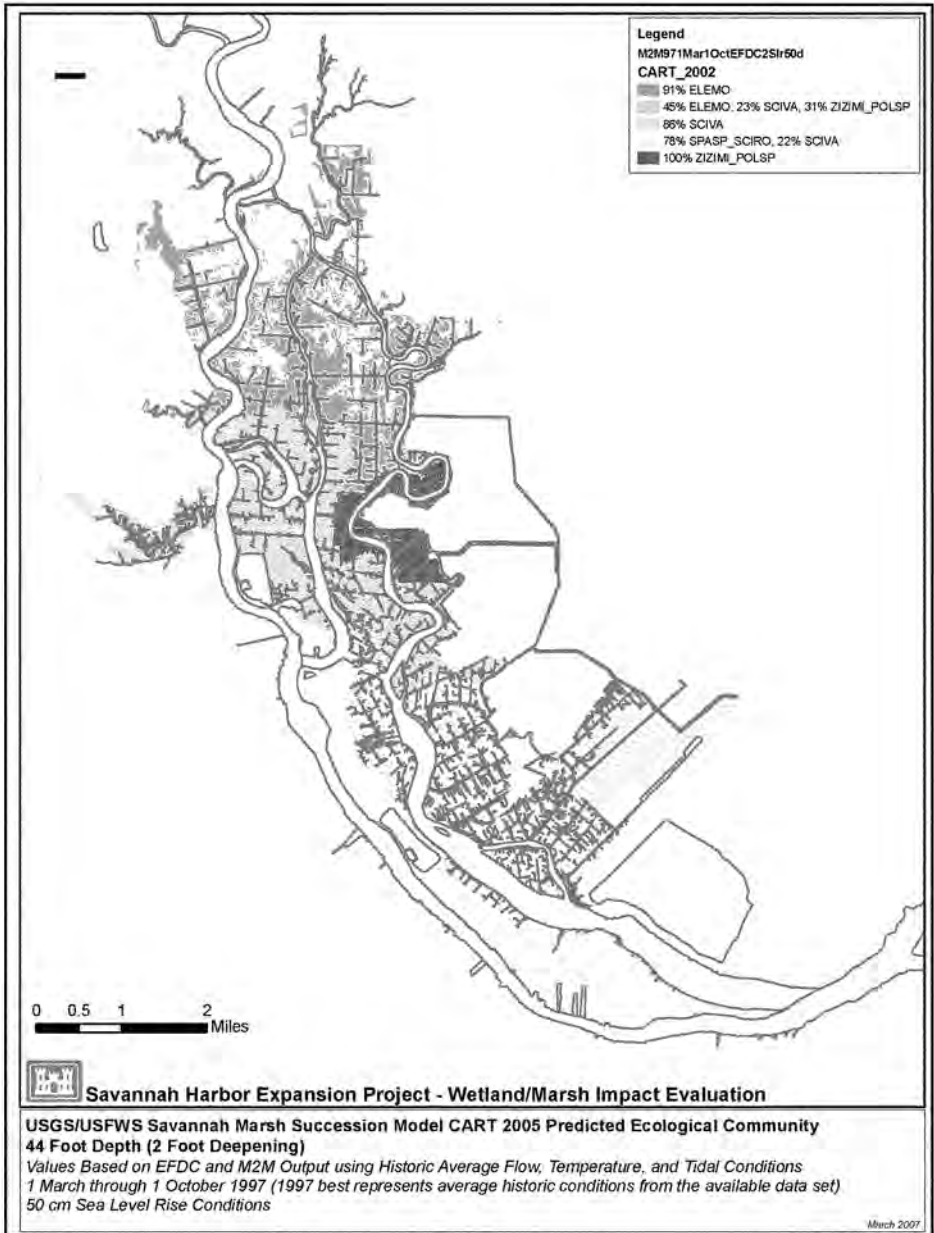
1 March through 1 October 1997 (1997 best represents average historic conditions from the available data set).

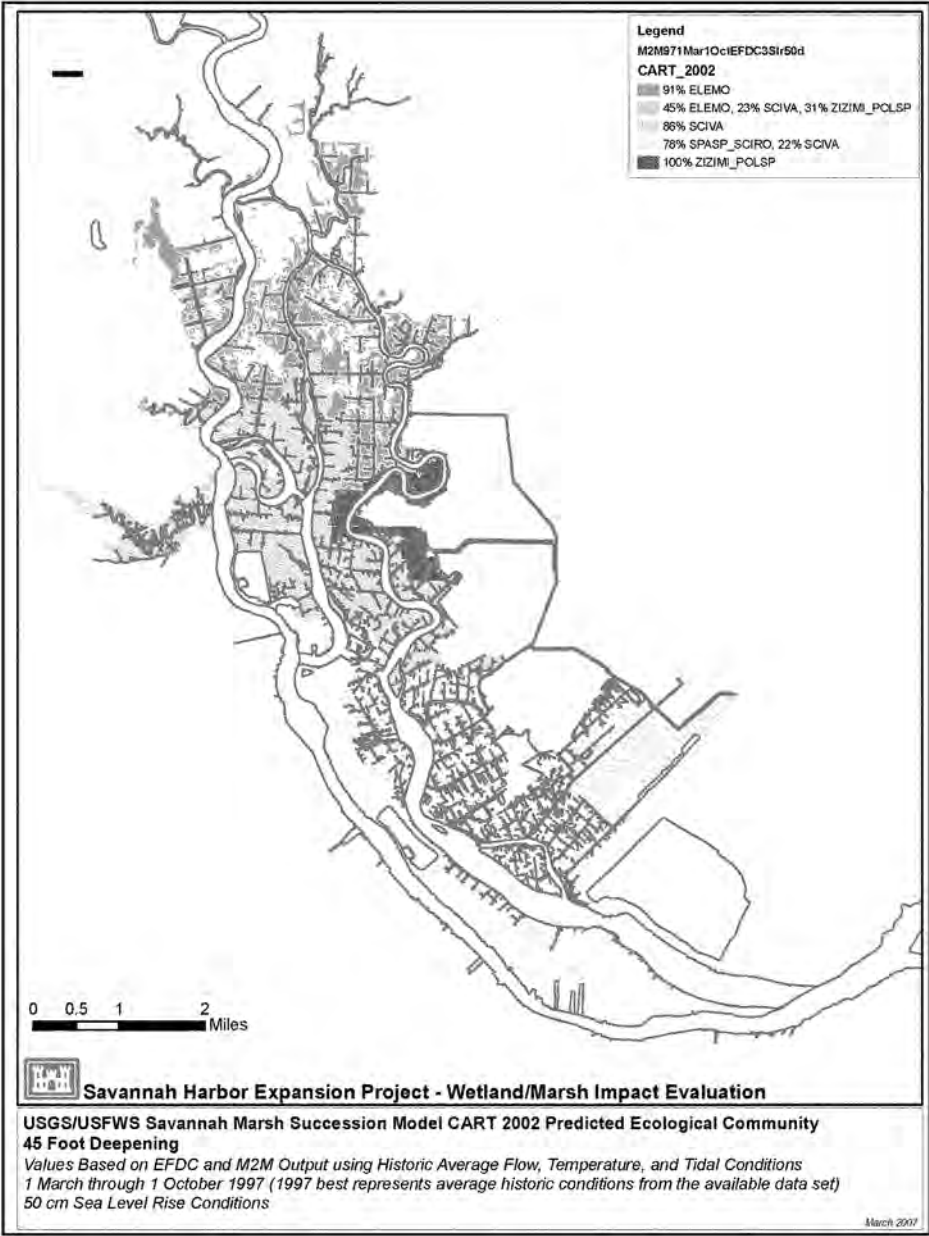
25 cm Sea Level Rise Conditions.

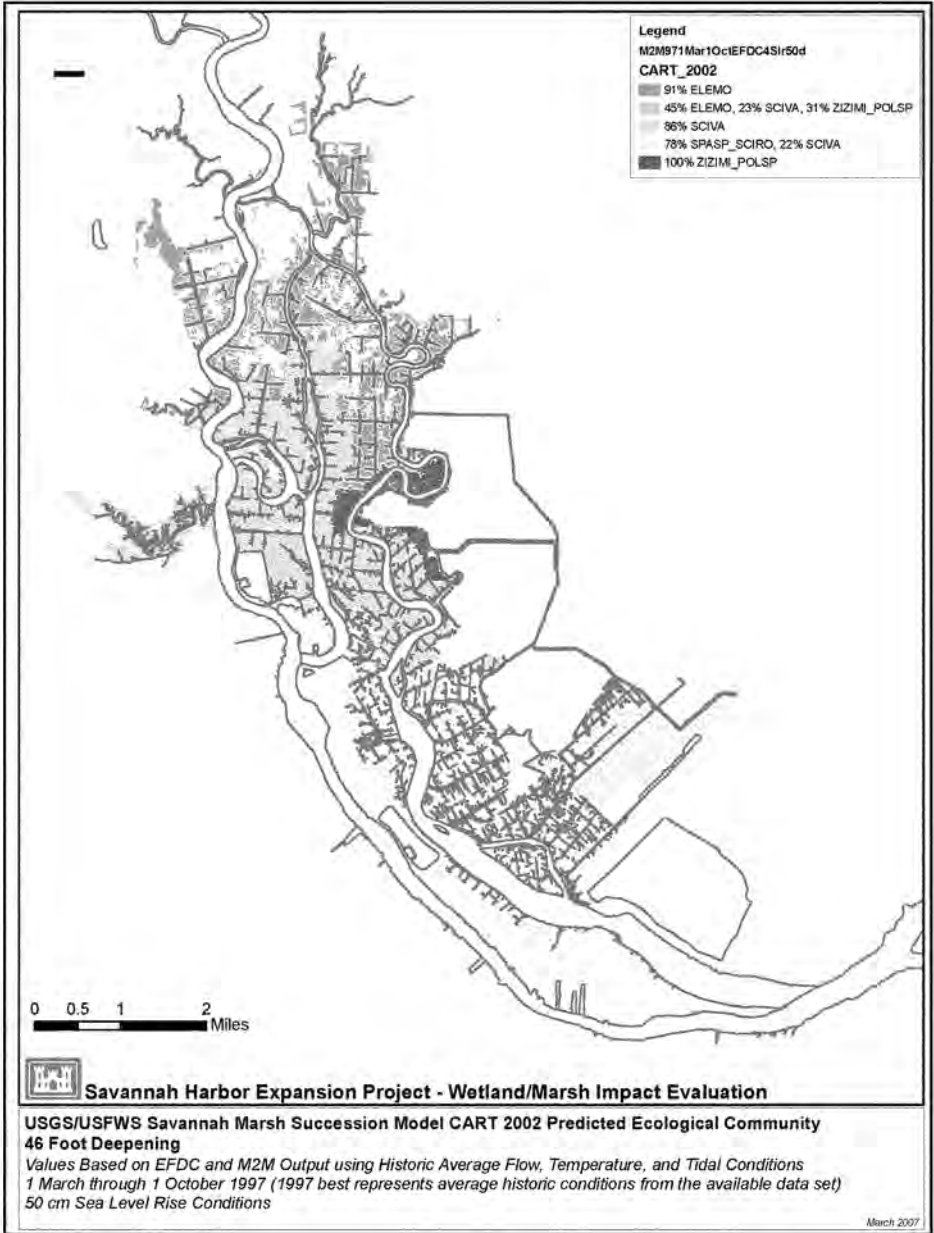
** 25 cm sea level rise conditions with 48 ft. deepening was modeled using the CART 2002 MSM due to predicted salinity increases showing similarities to drought conditions.

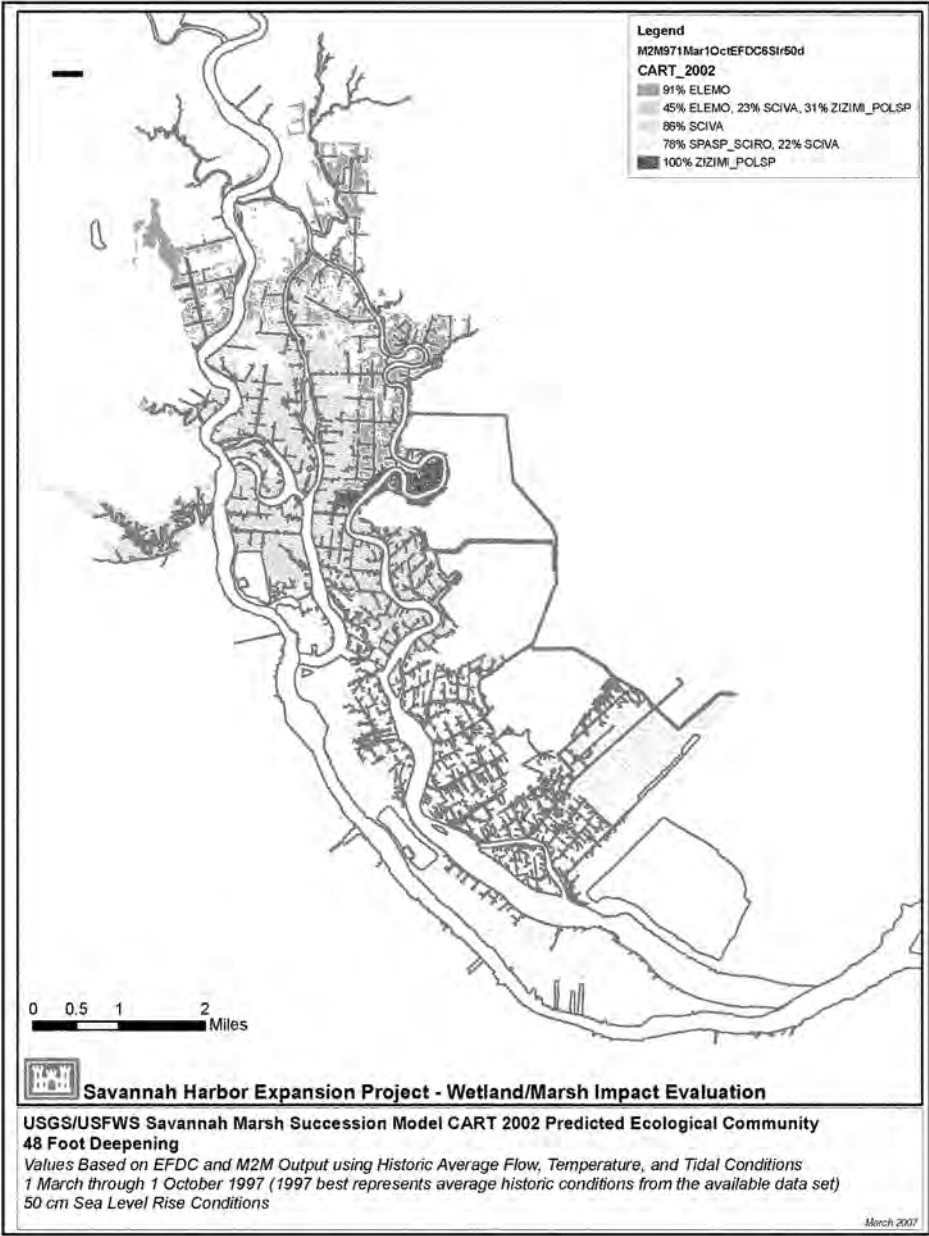
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SENSITIVITY ANALYSIS #2B
ECOLOGICAL COMMUNITY MAPS &
ECOLOGICAL COMMUNITY SHIFT MAPS

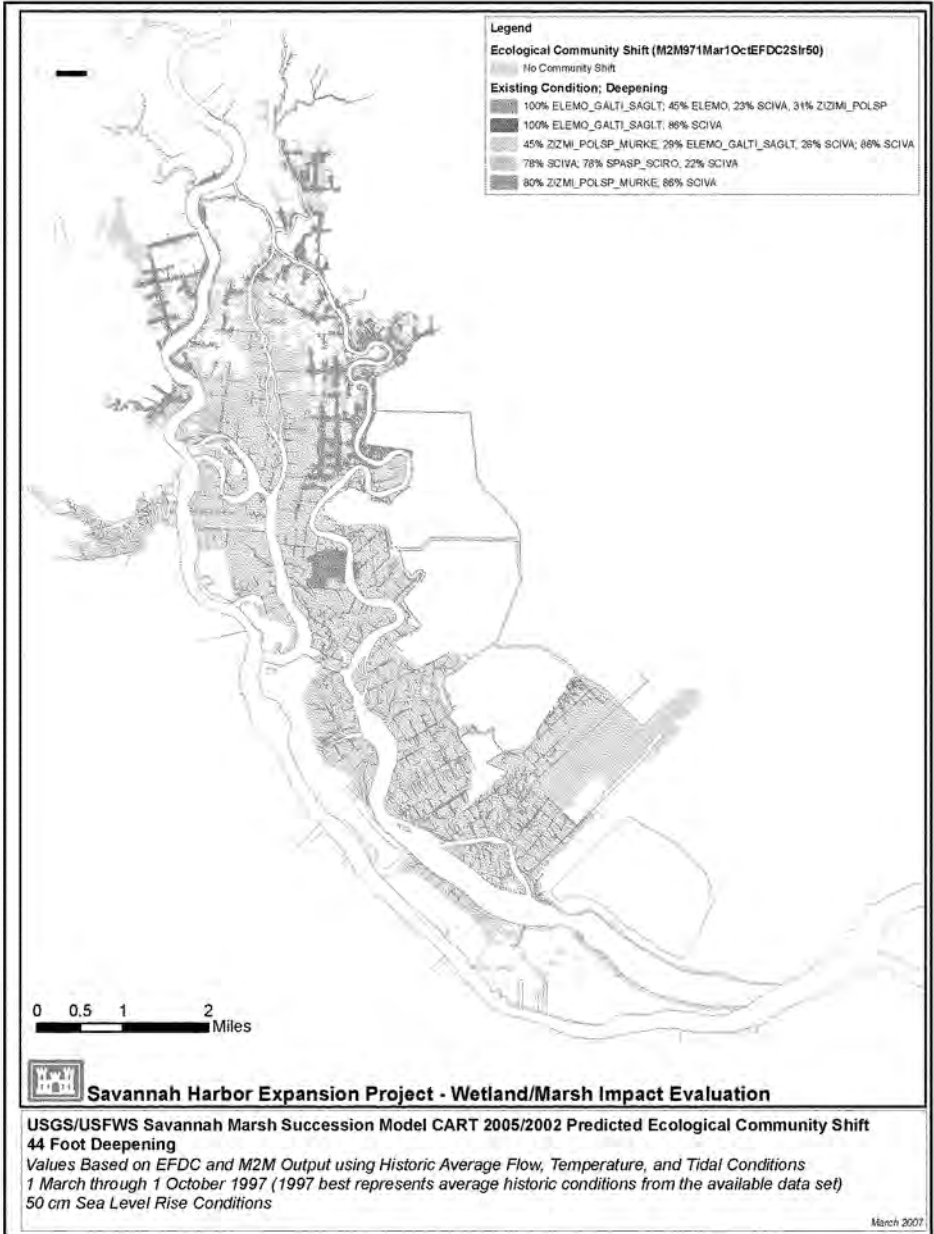


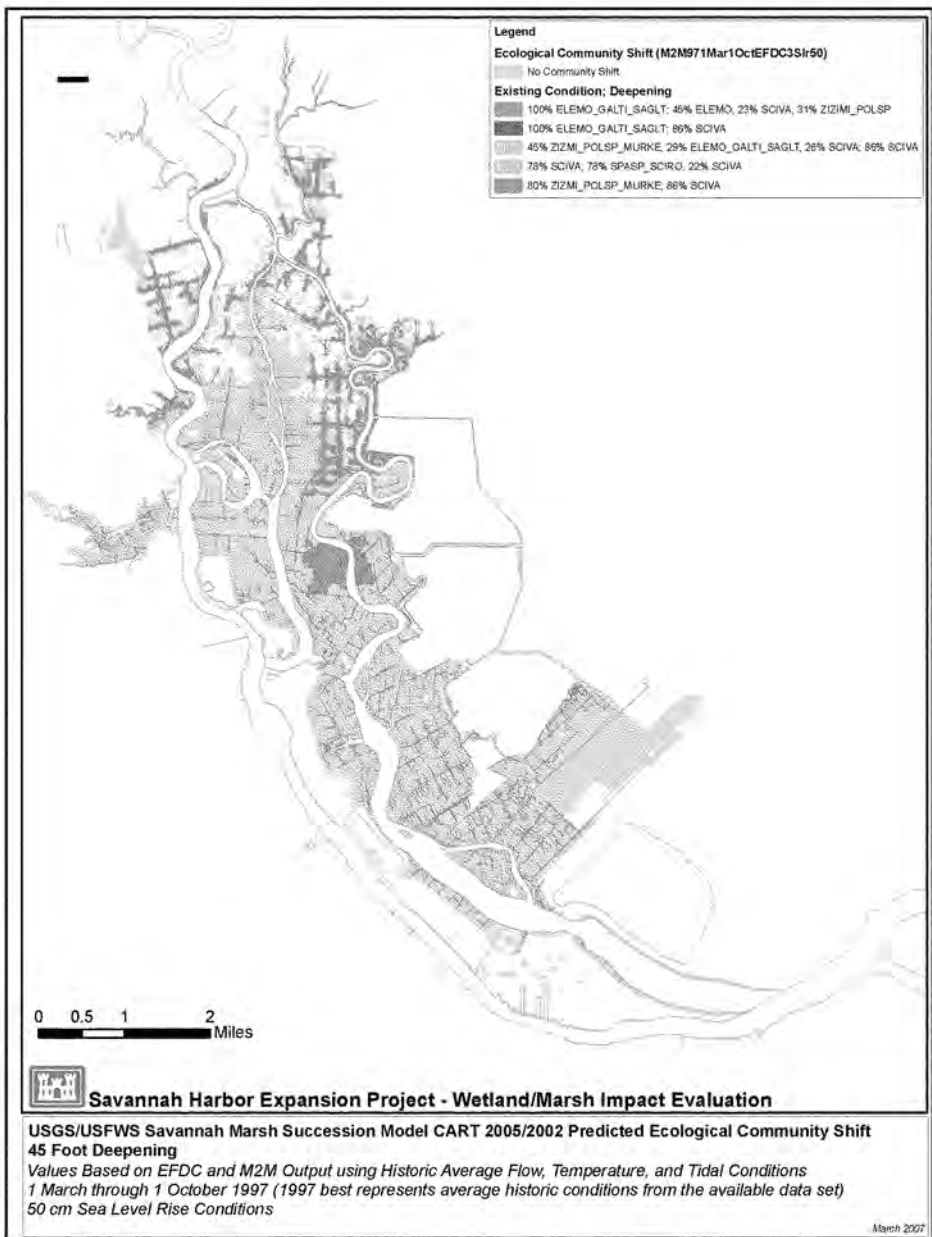


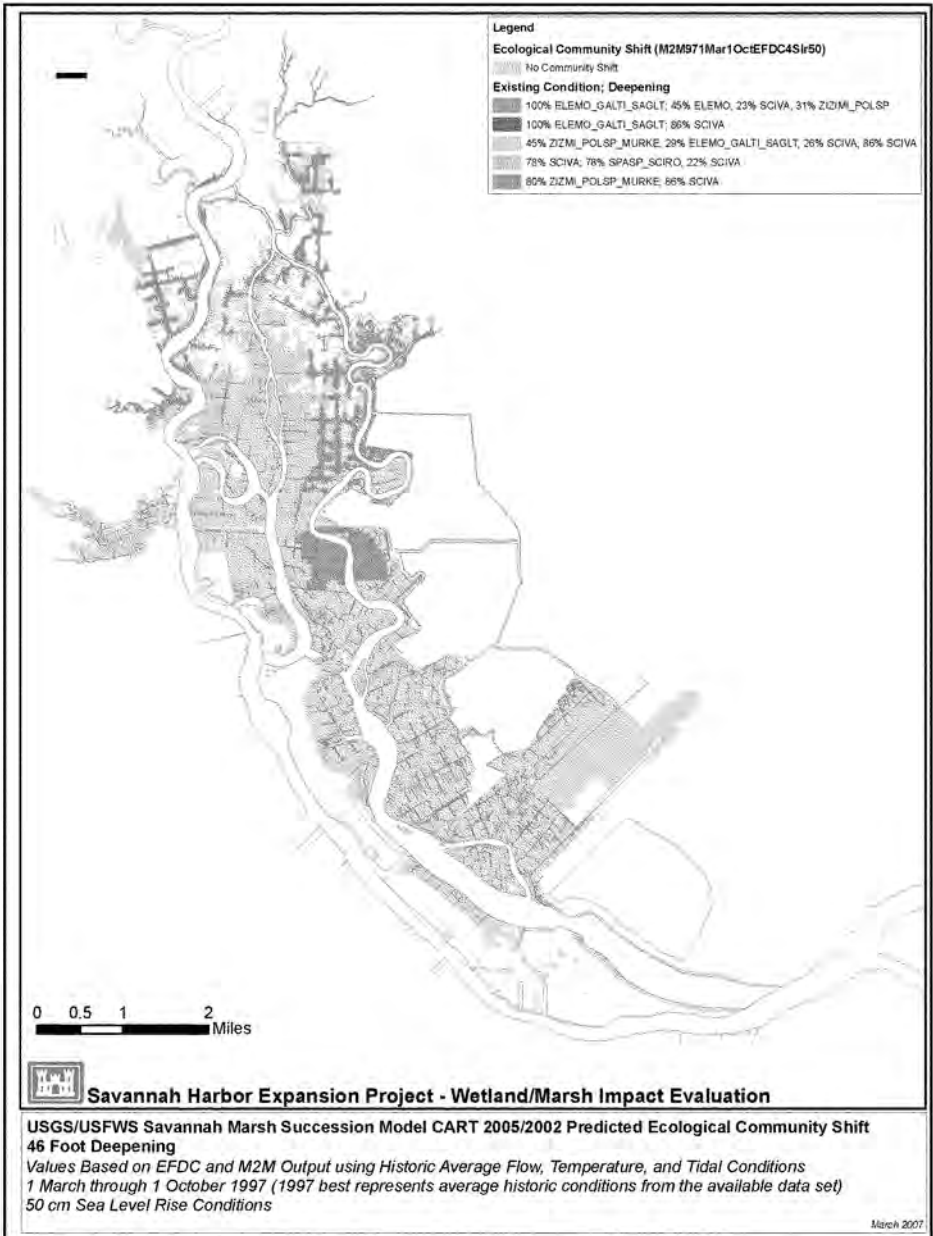


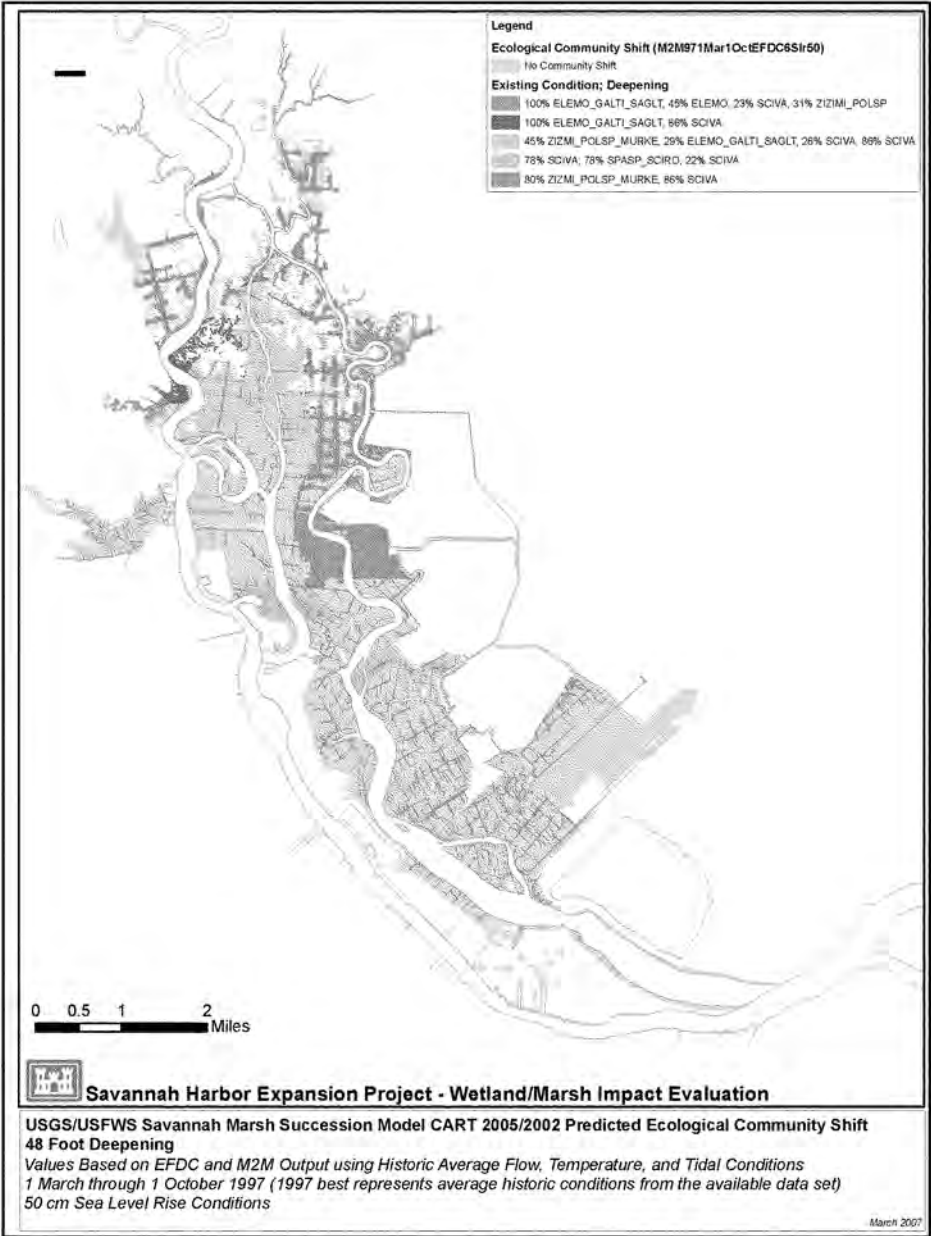












Savannah Harbor Expansion Project
USGS/USFWS MSM Wetland/Marsh Impact Evaluation
 Vegetation Community Shifts

Community CART2005/2002	Existing Depth 50 cm Sea Level Rise Associated Acreages	44 ft Depth 50 cm Sea Level Rise Associated Acreages	Net Change (net negative), net positive
100% Elemo_Galti_Saglt/ 91% Elemo	1519	975	(544)
80% Zizmi_Polsp/ 100% Zizmi_Polsp	702	457	(245)
45% Zizmi_Polsp, 29% Elemo_Galti_Saglt, 26% Sciva/ 45% Elemo,23% Sciva, 31% Zizmi_Polsp	788	1181	393
78% Sciva/ 86% Sciva	2114	2510	395
78% Spasp_Sciro_Astte/ 78% Spasp_Sciro, 22% Sciva	3723	3723	0
TOTAL	8847	8847	

Community CART2005/2002	Existing Depth 50 cm Sea Level Rise Associated Acreages	45 ft Depth 50 cm Sea Level Rise Associated Acreages	Net Change (net negative), net positive
100% Elemo_Galti_Saglt/ 91% Elemo	1519	883	(637)
80% Zizmi_Polsp/ 100% Zizmi_Polsp	702	359	(343)
45% Zizmi_Polsp, 29% Elemo_Galti_Saglt, 26% Sciva/ 45% Elemo,23% Sciva, 31% Zizmi_Polsp	788	1064	275
78% Sciva/ 86% Sciva	2114	2792	678
78% Spasp_Sciro_Astte/ 78% Spasp_Sciro, 22% Sciva	3723	3750	27
TOTAL	8847	8847	

Community CART2005/2002	Existing Depth 50 cm Sea Level Rise Associated Acreages	46 ft Depth 50 cm Sea Level Rise Associated Acreages	Net Change (net negative), net positive
100% Elemo_Galti_Saglt/ 91% Elemo	1519	785	(734)
80% Zizmi_Polsp/ 100% Zizmi_Polsp	702	255	(447)
45% Zizmi_Polsp, 29% Elemo_Galti_Saglt, 26% Sciva/ 45% Elemo,23% Sciva, 31% Zizmi_Polsp	788	972	184
78% Sciva/ 86% Sciva	2114	2985	870
78% Spasp_Sciro_Astte/ 78% Spasp_Sciro, 22% Sciva	3723	3850	127
TOTAL	8847	8847	

Community CART2005/2002	Existing Depth 50 cm Sea Level Rise Associated Acreages	48 ft Depth 50 cm Sea Level Rise Associated Acreages	Net Change (net negative), net positive
100% Elemo_Galti_Saglt/ 91% Elemo	1519	632	(887)
80% Zizmi_Polsp/ 100% Zizmi_Polsp	702	135	(567)
45% Zizmi_Polsp, 29% Elemo_Galti_Saglt, 26% Sciva/ 45% Elemo,23% Sciva, 31% Zizmi_Polsp	788	801	12
78% Sciva/ 86% Sciva	2114	3275	1161
78% Spasp_Sciro_Astte/ 78% Spasp_Sciro, 22% Sciva	3723	4004	282
TOTAL	8847	8847	

* Values Based EFDC and M2M Marsh Pore Water Salinity Input for Historic Average Flow, Temperature, and Tidal Conditions

1 March through 1 October 1997 (1997 best represents average historic conditions from the available data set)

50 cm Sea Level Rise Conditions

** 50 cm sea level rise conditions with deepening were modeled using the CART 2002 MSM due to predicted salinity increases showing similarities to drought conditions

FINAL

**IDENTIFICATION AND SCREENING LEVEL EVALUATION OF
MEASURES TO IMPROVE DISSOLVED OXYGEN IN THE SAVANNAH
RIVER ESTUARY**

**SAVANNAH HARBOR EXPANSION PROJECT
&
SAVANNAH HARBOR ECOSYSTEM RESTORATION STUDY
CHATHAM COUNTY, GEORGIA**

Prepared for:
United States Army Corps of Engineers
Savannah District
Savannah, Georgia

Prepared by:
MACTEC Engineering and Consulting, Inc.
3200 Town Point Drive
Suite 100
Kennesaw, Georgia 30144
Project Number: 6301-05-0001

Delivery Order: CV01
Contract No.: W91278-04-D-009

JUNE 2005

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GLOSSARY

ATS	Aero Transfer System
BOD	biochemical oxygen demand
BOD ₅	5-day biochemical oxygen demand
CBOD _U	carbonaceous ultimate biochemical oxygen demand
CFR	Code of Federal Regulations
CWA	Clean Water Act
DMR	discharge monitoring reports
DO	dissolved oxygen
EIS	Environmental Impact Statement
GADNR	Georgia Department of Natural Resources
GAEPD	Georgia Environmental Protection Division
IP	International Paper
ISO	In-situ Oxidation
kW-hr/ton	kilowatt hour per ton
LAS	Land application system
lbs O ₂ /hp-hr	pounds oxygen per horsepower-hour
lbs/day	pounds per day
m ³ /ton	cubic meter per ton
MACTEC	MACTEC Engineering and Consulting, Inc.
mg/L	milligrams per liter
MGD	million gallons per day
MP	management practices
NA	not applicable / not available
NBOD _U	nitrogenous ultimate biochemical oxygen demand
NEPA	National Environmental Policy Act
NH ₃	ammonia
NPDES	National Pollutant Discharge Elimination System
NPS	non-point source
O&M	operations and maintenance
O ₂	oxygen
°C	degree Celsius
PCS	Permit Compliance System
POTW	publicly owned treatment works
PS	point source
PSA	Pulsed swing adsorption
PSSO	Pressurized sidestream
RM	river mile
SOW	Statement of Work
TBOD _U	total ultimate biochemical oxygen demand
TMDL	Total Maximum Daily Load
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
UWR	Urban Water Reuse
WRDA	Water Resources Development Act
WWTP	wastewater treatment plant

*Identification and Screening Level Evaluation of Measures to Improve
Dissolved Oxygen in the Savannah River Estuary
USACE Savannah District
Savannah, Georgia*

*FINAL
June 2005
MACTEC Project 6301-05-0001
Contract No. W91278-04-D-0009, Delivery Order CY01*

Disclaimer

The following report contains references to specific products, vendors, and trade names. MACTEC used this information to provide examples of equipment that could be used to meet the objectives of the various alternatives presented. MACTEC is not recommending or endorsing a specific supplier or vendor.

EXECUTIVE SUMMARY

MACTEC Engineering and Consulting, Inc. (MACTEC) was contracted by the U.S. Army Corps of Engineers, (USACE) Savannah District to perform the **Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen (DO) in the Savannah River Estuary** under Contract Number: W91278-04-D-0009, Delivery Order: CV01.

The screening level evaluation was completed to address two phases, each with multiple steps (identified in the Scope of Work [SOW] provided by the USACE) and to identify potential DO improvement measures that may be suitable for application in the Savannah Harbor Estuary. The Steps for Phase I were based on potential load allocations as presented in the **Draft Total Maximum Daily Load (TMDL) for Dissolved Oxygen in Savannah Harbor River Basin: Chatham and Effingham Counties, Georgia** (Draft TMDL) (USEPA, 2004). Steps in Phase II were developed to identify DO improvement measures to mitigate for DO impacts from past and future deepening of Savannah Harbor.

Phase and Steps Completed for this Screening Level Evaluation			
Phase/ Step	Description	BOD Offset Required (lbs/day)	Supplemental DO Required (lbs/day)
Phase I			
Step 1	Current BOD loads / Current GA DO standard	290,250	
Step 2	Permitted BOD loads / Current GA DO standard	725,500	
Step 3	Current BOD loads / Recommended GA DO standard	68,250	
Step 4	Permitted BOD loads / Recommended GA DO standard	503,500	
Phase II			
Step 1	0.2 mg/L DO improvement in the Harbor		72,818
Step 2	0.4 mg/L DO improvement in the Harbor		145,636
Step 3	0.6 mg/L DO improvement in the Harbor		218,455
Step 4	0.8 mg/L DO improvement in the Harbor		291,273

These criteria were developed using two critical simplifying assumptions from data obtained in the Draft TMDL.

- 1 pound (lb) ultimate biochemical oxygen demand (BOD) discharged equates to 1 lb DO consumed.
- 0.1 mg/L supplemental oxygen increase in the harbor equates to 36,409 lbs/day BOD reduction or supplemental DO.

Results from the preliminary screening of potential technologies show injection of molecular oxygen to be the most cost-effective means for achieving incremental DO improvements in Savannah Harbor.

1.0 INTRODUCTION

MACTEC Engineering and Consulting, Inc. (MACTEC) was contracted by the U.S. Army Corps of Engineers, Savannah District (USACE) under Contract Number: W91278-04-D-0009, Purchase Request Number: W33SJG-4357-9959, Delivery Order: CV01 to conduct the **Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen (DO) in the Savannah River Estuary**. The screening level evaluation was completed to address two phases each with multiple steps (identified in the Scope of Work [SOW] provided by the USACE [Appendix A]) and to identify potential DO improvement measures that may be suitable for application in the Savannah Harbor Estuary. This report presents the results of the evaluation.

1.1 BACKGROUND

The Savannah River Basin is located along in the eastern portion of Georgia and southwestern South Carolina, and has a drainage area of 10,577 square miles. The Savannah River defines the state boundary between Georgia and South Carolina and ultimately flows into the Atlantic Ocean. The headwaters of the Savannah River originate in the Blue Ridge Province in Georgia, North Carolina, and South Carolina. The Savannah River Basin contains parts of the Piedmont and Coastal Plain physiographic provinces of the southeastern United States (GADNR, 2005).

The harbor is on Georgia's Section 303(d) list for waters that do not comply with water quality standards for DO. The Savannah Harbor from Fort Pulaski (River Mile [RM] 0) to Seaboard Coastline Railway Bridge (RM 27.4) is identified on the State of Georgia's 2002 Section 303(d) List as impaired for DO. Figure 1.1 shows the location of the DO impaired stream segment from RM 0 to RM 27.4. Water bodies on the 303(d) list require a Total Maximum Daily Load (TMDL) evaluation be conducted to estimate the allowable site-specific loading of the constituent for which the water body is listed.

In August 2004, the U.S. Environmental Protection Agency (USEPA) Region 4 released the **Draft Total Maximum Daily Load (TMDL) for Dissolved Oxygen in Savannah Harbor River Basin: Chatham and Effingham Counties, Georgia** for the harbor (Draft TMDL) (USEPA, 2004). To support the designated uses in the Harbor and to meet the current Georgia DO standard, the Draft TMDL calls for elimination of all point source waste loads exerted on the harbor, plus the addition of 90,000 pounds per day (lbs/day) of oxygen to the harbor system during warmer periods of the summer (mid-July through mid-

September [critical season]) and during periods of critical low flows in the Savannah River (critical flow) (critical season and critical flow are referenced herein as critical conditions). The Draft TMDL indicated that the waste load from point source discharges within the harbor placed a 99,000 lbs/day oxygen demand on the system, while the load from upriver point source discharges exerts an additional 100,000 lbs/day oxygen demand in the harbor. These combined loads equate to roughly a 0.55 milligram per liter (mg/L) contribution to the DO deficit in the critical harbor segment. Since the current Georgia DO standard was disapproved by USEPA, USEPA recommended an alternate DO standard in the Draft TMDL. Three-dimensional hydrodynamic and water quality modeling (Harbor Model) performed by the USEPA in support of TMDL activities identified a portion of the listed segment as being the critical segment (Figure 1.2). Additionally, modeling indicated that during critical conditions and with current point and non-point source biochemical oxygen demand (BOD) loads (as measured in the 1997 and 1999 data collection efforts) (USEPA, 2004), the recommended DO standards will not be met during critical conditions in the critical segment. Therefore, the Alternate TMDL (based on the EPA-recommended DO standard) consisted of a 30 percent reduction in the current point source waste load to the harbor (a reduction of about 68,250 lbs/day total ultimate BOD [TBOD_U] allowing a remaining load of 132,000 lbs/day TBOD_U).

Concurrent to development of the TMDL for the harbor, the USACE is investigating the feasibility of further expanding and deepening the Harbor. The Savannah Harbor Expansion Project is evaluating deepening the navigation channel in Savannah Harbor to allow passage of larger ships. The Georgia Ports Authority examined the economic justification for a deepening project under the authority of Section 203 of the Water Resources Development Act of 1996 (USACE, 2005). They prepared a feasibility report that resulted in a conditional Congressional authorization of the project. Although the economic feasibility of the project was identified, Congress stipulated that (1) the Secretary of the Army, in consultation with affected Federal State of Georgia, State of South Carolina, regional, and local entities, reviews and approves an EIS that examines the effects of project depth alternatives ranging from 42 feet through 48 feet, and a selected plan for navigation with an associated mitigation plan; and (2) that the Secretary of the Interior, the Secretary of Commerce, the Administrator of the USEPA, and the Secretary of the Army approve the selected plan and determine that the associated mitigation plan adequately addresses the potential environmental impacts of the project.

To identify ways to improve DO in the harbor over present conditions, the USACE and the City of Savannah are jointly conducting the Savannah Harbor Ecosystem Restoration Study. This study is also considering alternatives to improve DO levels in the harbor.

As components of both the Savannah Harbor Expansion Project and the Savannah Harbor Ecosystem Restoration Study, this study identifies and conducts a screening level evaluation of potential measures designed to improve DO in the Savannah River Estuary during critical conditions.

1.1.1 Regulatory History

The State of Georgia assesses waterbodies for compliance with water quality standards established for their designated uses as required by the Federal Clean Water Act (CWA) and implementing regulations in the Code of Federal Regulations 40CFR130. Assessed waterbodies are placed into three categories, supporting, partially supporting, or not supporting their designated uses, depending on water quality assessment results. These waterbodies are found on Georgia's 305(b) list as required by that section of the CWA that defines the assessment process. Some of the 305(b) partially and not supporting waterbodies assigned to Georgia's 303(d) list, also named after that section of the CWA. Waterbodies on the 303(d) list are required to have a TMDL evaluation for the constituent(s) causing exceedance of the water quality standard. The TMDL process establishes the allowable pollutant loadings or other quantifiable parameters for a waterbody based on the relationship between pollutant sources and instream water quality conditions. This allows water quality-based controls to be developed to reduce or mitigate pollution and to restore and maintain water quality.

The Department of Natural Resources (GADNR) Environmental Protection Division (GAEPD) water use classification for the Savannah Harbor segment of the Savannah River (i.e. from the Seaboard Coast Railroad Bridge [RM 27.4] to Fort Pulaski [RM 0]) is designated as coastal fishing. The Coastal Fishing DO criteria are minimum instantaneous concentrations applicable throughout the water column as follows:

- No less than 3.0 mg/L in June, July, August, September, and October;
- No less than 3.5 mg/L in May and November; and
- No less than 4.0 mg/L in the remaining months (USEPA, 2004).

Upon review, USEPA Region 4 disapproved the GAEPD DO criteria for the Savannah Harbor segment on the basis that the 3 mg/L DO the criterion during the critical summertime conditions, is not adequately

protective of aquatic life in the upper part of the water column and is overprotective of aquatic life in the lower parts of the water column. However, until such time that replacement criteria are adopted, the existing state criteria (even though disapproved by USEPA) remain in effect.

Certain waters of the State, including Savannah Harbor, may have conditions where DO is naturally less than the numeric criteria specified in the rules and therefore cannot meet these DO criteria unless naturally occurring loads are reduced or such naturally low DO streams are artificially oxygenated. This is addressed in Georgia's Rules and Regulations for Water Quality Control, Chapter 391-3-6-.03(7): Natural Water Quality.

It is recognized that certain natural waters of the State may have a quality that will not be within the general or specific requirements contained herein. These circumstances do not constitute violations of water quality standards. This is especially the case for the criteria for dissolved oxygen, temperature, pH and fecal coliform. NPDES permits and Best Management Practices will be the primary mechanisms for ensuring that the discharges will not create a harmful situation. (GAEPD, 2005)

USEPA DO criteria are used to address these naturally occurring low DO situations. Alternative USEPA limits are defined as 90 percent of the naturally occurring DO concentration at critical conditions.

Where natural conditions alone create DO concentrations less than 110 percent of the applicable criteria means or minima or both, the minimum acceptable concentration is 90 percent of the naturally occurring concentration.

Accordingly, if the naturally occurring DO concentration exceeds the Georgia Department of Natural Resources (GADNR), Environmental Protection Division (GAEPD) numeric limits at critical conditions, then the GAEPD numeric limits apply. If naturally occurring DO is less than the GAEPD numeric limits, then the 90 percent of the natural DO will become the minimum allowable. Based on the Draft TMDL report low natural DO is a limiting factor for Savannah Harbor DO criteria (USEPA, 2004).

1.2 USEPA DRAFT TMDL

In August of 2004, the USEPA released the draft TMDL report (USEPA, 2004) that provided allowable BOD loads for the Savannah River system. Additionally, the Draft TMDL recommended a new DO standard for the harbor/estuary that would replace the current Georgia DO standard. The recommended criteria combines the features of traditional water quality criteria with a new biological framework, one that integrates exposure to low DO over time rather than averaging DO exposure conditions into one

single value (USEPA, 2004). The USEPA recommended DO criteria for Savannah Harbor are expressed as follows:

- One-day water column average DO = 2.3 mg/L
- Seven-day water column average DO = 3.0 mg/L
- Thirty-day water column average DO = 3.55 mg/L

The Virginian Province Saltwater Criteria, which served as the basis for USEPA's criteria recommendation for the Savannah Harbor, proposes a 30-day water column average of 4.8 as protective of aquatic life. Natural conditions water quality modeling of the Savannah Harbor in the Draft TMDL for DO indicated that the 30-day average DO of the Savannah Harbor under natural conditions in the critical segment was 3.95 mg/L due to the deepened physical configuration of Savannah Harbor and the high water temperatures experienced in the water column during the summer (greater than 30 degrees Celsius [°C] for 30 days or longer).

As noted previously, GAEPD has established a 10 percent reduction below the natural minimum DO condition as the criteria for naturally low DO waters. Applying this policy to USEPA's recommendation for a site-specific criterion for the Harbor, a recommended 30-day water column average for protection of the aquatic life use is 3.55 mg/L or 90-percent of 3.95 mg/L (instead of the Virginian Province 30-day-average criterion of 4.8 mg/L).

USEPA's Draft TMDL also determined the natural DO conditions of the Harbor expressed as a 1-day water column average and a 7-day water column average. The 1-day water column "natural condition" is 3.5 mg/L and the 7-day water column "natural condition" is 3.6 mg/L. The Virginian Province criterion documentation demonstrates that aquatic species are protected at a 1-day water column average of 2.3 mg/L and a 7-day water column average of 3.0 mg/L. USEPA's recommended DO criteria for the Savannah Harbor adopted the Virginian Province criteria for the 1 day and 7 day water column averages (USEPA, 2004).

As part of the Savannah Harbor Expansion Project and a Tier II, Environmental Impact Statement (EIS) in accordance with the National Environmental Policy Act (NEPA), is currently being developed. As part of the EIS, the effect of the deep-draft navigation channel on the system's ability to recover from point and non-point source waste loads is under investigation. As part of the deepening project activities, a Section 203 study in conjunction with the Water Resources Development Act (WRDA) examined the

economic justification for the deepening project (USACE, 2005). With this first phase of the project completed, the deepening project was determined to be economically feasible and stipulated two conditions. The first condition required that the Secretary of the Army, in consultation with the affected Federal, State of Georgia, State of South Carolina, regional, and local entities, review and approve a Tier II EIS that includes an analysis of the impacts of project depth alternatives ranging from 42 feet through 48 feet; and a selected plan for navigation and an associated mitigation plan as required under federal law (33 U.S.C. 2283(a)). The second condition stipulated that the Secretary of the Commerce, the Administrator of the USEPA, and the Secretary of the Army approve the selected plan that adequately addresses the potential environmental impacts of the project.

1.3 OBJECTIVE

The objective of the **Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen (DO) in the Savannah River Estuary** is to identify and conduct a screening level evaluation of potential measures that could improve DO in the Savannah River Estuary. This analysis includes an assessment of the engineering feasibility and cost effectiveness of potential improvement measures, as well as an initial identification of potential implementation problems. This effort is directed toward both the portion of the harbor (critical segment) and the time of year (critical season) that were identified in the Draft TMDL as having recurring low levels of DO. The analysis will allow the USACE to consider alternate methods of improving DO from present levels and to identify methods for incremental DO improvement for both the Savannah Harbor Expansion Project and the Savannah Harbor Ecosystem Restoration Study.

1.4 METHODOLOGY

This study was conducted in two phases, each with multiple steps. For Phase I, these steps were developed to address the current and recommended DO standards and the current and potential BOD loading scenarios presented in the Draft TMDL and included considerations for non-point BOD sources of DO demands.

- Phase I, Step 1 considered measures that would potentially allow the harbor to comply with the present Georgia DO standard and provided potential options for addressing the excess total ultimate BOD (TBOD_U) load of 290,250 pounds per day (lbs/day) from current BOD_U loads from point sources (99,000 lbs/day from the Harbor area dischargers and 75 percent of the 135,000 lbs/day [101,250 lbs/day]

from the upstream river dischargers) and a portion of the load coming from non-point sources (90,000 lbs/day).

- Phase I, Step 2 considered measures that would allow the harbor to comply with the present Georgia DO standard and provided potential options for addressing a total BOD_{U} load of 725,500 lbs/day from the National Pollutant Discharge Elimination System (NPDES) permitted loads (367,000 lbs/day from the Harbor area dischargers and 75 percent of the 358,000 lbs/day [268,500 lbs/day] from the upstream river dischargers) and a portion of the load from non-point sources (90,000 lbs/day).
- Phase I, Step 3 considered measures to improve DO levels in the harbor to meet the revised DO standard recommended in the Draft TMDL. This step addressed the current BOD_{U} loads and measures that equated to an approximate 30 percent reduction in the current BOD_{U} loads (68,250 lbs/day) from point source dischargers.
- Phase I, Step 4 considered measures that would allow the harbor to comply with the recommended DO standard and considered the effects of the excess NPDES permitted BOD_{U} load of 503,500 lbs per day.

Phase II consisted of assessing potential measures to improve DO levels in the harbor by 0.2 mg/L increments to a maximum increase of 0.8 mg/L and are related to DO impacts that may be caused by future deepening of the harbor. Thus, this phase develops four potential design alternatives to improve DO, the first capable of improving DO levels by 0.2 mg/L, the second improving DO levels by 0.4 mg/L, the third improving DO levels by 0.6 mg/L, and the fourth improving DO levels by 0.8 mg/L. Phase II assumed that the DO levels in the harbor meet the recommended DO standard presented in the Draft TMDL.

Table 1.1 presents a summary of Phase I and II BOD load reductions. For this screening level evaluation, one pound of $TBOD_{\text{U}}$ equates to one pound of supplemental DO required, thus equal amounts of oxygen are applied to fully satisfy the theoretical $TBOD_{\text{U}}$ loads discharged. This simplifying assumption inherently over estimates the amount of supplemental oxygen required. Point source BOD loads and flows are based on information contained in the Draft TMDL (USEPA, 2004) and the USEPA EnviroFacts Database (USEPA, 2005). For Phase II, the required incremental DO increase was estimated using a relationship taken from the Draft TMDL in which 0.55 mg/L of critical DO deficit equates the 200,250 lbs of BOD from all the point source dischargers combined. Using this deficit-load relationship, the supplemental DO needed for each 0.2 mg/L of DO improvement equates to 72,818 lbs of added oxygen required. Of course, these simplifying deficit load assumptions are subject to refinement once the final TMDL water quality model is made available by USEPA for general use.

2.0 ASSESSMENT OF DISSOLVED OXYGEN DEFICIT FROM POINT SOURCE AND NON-POINT DISCHARGE

2.1 ASSESSMENT OF POINT SOURCE DISCHARGERS

According to the Draft TMDL, the NPDES permitted cumulative oxygen-demanding substance load for facilities authorized to discharge into the Harbor (Harbor Dischargers), expressed as $TBOD_{U_0}$, is 367,000 lbs/day. Of this authorized 367,000 lbs/day, facilities were cumulatively discharging approximately 99,000 lbs/day of $TBOD_{U_0}$ in the summer of 1999. This 99,000 lbs/day is known as the "existing" load; the load authorized by point-source NPDES permits (i.e., the 367,000 lbs/day) is known as the "permitted" load.

Loadings of oxygen-demanding substances from sources upstream of the Harbor (Upstream Dischargers), below Thurmond Dam, also impact the Harbor DO levels and are taken into account in the Draft TMDL. The majority of these dischargers are located in the Augusta, Georgia area. The total loading of oxygen-demanding substances for the upstream sources authorized by point-source NPDES permit is 358,000 lbs/day $TBOD_{U_0}$ (permitted load). The total loading of existing oxygen-demanding substances discharged in the summer of 1999 was 135,000 lbs/day (existing load). Approximately 75 percent or 101,250 lbs/day of the oxygen-demanding substances discharged in the Augusta area reach the upstream portion of the Harbor according to the Draft TMDL (USEPA, 2004).

As part of the assessment of point source dischargers, the dischargers listed in the Draft TMDL from the Harbor and the Upstream areas were tabulated. Permit loads as presented in the Draft TMDL were verified using the USEPA Database, EnviroFacts (USEPA, 2005).

According to the Draft TMDL, "Oxygen-demanding loads from City of Savannah municipal storm water, and heat loads from the three Savannah Electric power facilities were evaluated in the model and shown to have no measurable impact on the DO levels in the critical areas of concern" (USEPA, 2004).

Notably, the current Draft TMDL does not provide separate explicit allocations for those stormwater dischargers subject to a general NPDES permit.

2.2 ASSESSMENT OF NON-POINT SOURCE DISCHARGE

The non-NPDES loadings of oxygen-demanding substances are from natural background sources including detritus transported in the stream, detritus from marsh areas flowing directly into the Harbor, and tidally-transported detritus from the ocean. The Draft TMDL describes natural background oxygen demanding substance loads as follows.

- Marsh 150,000 lbs/day
- Upstream 85,000 lbs/day
- Ocean CBOD_L = 6 mg/L;
Ammonia = 0.1 mg/L

The Draft TMDL identified the critical segment of the Savannah Harbor system as the segment of the Harbor with the lowest daily DO average. This segment is an approximate four mile segment of the Savannah Harbor from RM 9.3 to RM 14.3 (Figure 1.2). This segment is the primary focus of the DO improvement technologies and is also a segment proposed to be further deepened. In order to identify screening level evaluation measures for technologies, the river system was divided into an upstream zone referring to the Augusta area (Upstream Area) and the harbor area referring to the critical segment (Critical Harbor Area). Next non point discharge was identified as natural background oxygen demanding substances (marsh, upstream, ocean and stormwater).

2.3 RANKING OF TOP FIVE POINT SOURCE DISCHARGERS

In order to summarize the effect that point source dischargers have in the Savannah Harbor, a list was compiled using information from the Draft TMDL Table I and Appendix D (of that document), respectively that included harbor and upstream point source dischargers. For each discharger as available, the permitted flow, BOD (load or discharge concentration), and ammonia-nitrogen (load or concentration) capacities were obtained from the Draft TMDL tables and/or the USEPA EnviroFacts Data Warehouse Water Discharge Permits (PCS) Database. The resulting compilation is presented in Appendix B. The top five dischargers with the largest permitted loads are presented in Table 2.1. These “top five” dischargers with the greatest permitted BOD loading were (in order of greatest to least) International Paper – Savannah Mill (IP Savannah), International Paper – Augusta Mill (IP Augusta), Georgia Pacific, Weyerhaeuser, and the City of Savannah President Street wastewater treatment plant (WWTP). Though these dischargers were identified as the top five based on permit conditions, they may not necessarily cause the “top five” impacts to the DO deficit due to:

- Actual BOD loadings may be substantially less than permit limits.
- Other dischargers with lower permit limits may have a current load that exceeds the current load of one of the identified “top five” dischargers.
- Degradation rates of BOD loads vary greatly between types of effluents and were not considered in this evaluation. However, a discharge with a lower BOD and a relatively rapid BOD decay rate may cause more impact in the critical segment than a higher BOD discharge with a slower BOD decay rate, and
- This analysis assumes that 1-pound of BOD loading from any point source discharge will have an equal effect on DO deficit in the critical area. This may not be true because the BOD decay rates differ between discharges and their location with respect to the critical area differs. More detailed analyses with an accepted three-dimensional hydrodynamic and water quality model of the river and harbor should be performed before decisions are made regarding a specific DO improvement.

2.3.1 Next Two Traditional Steps for BOD Reduction - Top Five Dischargers

A request for information from the identified “top five” permitted dischargers was sent on January 31, 2005 requesting information on treatment processes currently being used and potential upgrades under consideration to potentially meet the allocations proposed in the Draft TMDL (Appendix C).

MACTEC reviewed GAEPD permit files for permit applications, wastewater treatment process diagrams, and other relevant information. This investigation provided information such as permit limits, wastewater generation diagrams, and discharge monitoring reports (DMRs). However, specific information on the design or processes of the wastewater treatment facilities for each discharger was not obtained.

As part of the public comments submitted to USEPA on the Draft TMDL, the IP Savannah and Augusta Mills (through their Corporate Environment office) provided estimated costs required to reduce existing loads from their two mills by 30 percent. “Both IP mills would have to significantly reconfigure their wastewater treatment system to achieve the improved removal efficiencies. This action could only be achieved at a significant capital cost to each mill. Using standard engineering assumptions, the estimates to increase BOD removal efficiency at the Augusta and Savannah Mills, respectively, are \$28,275,000 and \$37,492,000.” The type of treatment measures and design were not specified (Appendix C).

The City of Savannah President Street WWTP is currently implementing an urban water reuse program. Urban water reuse programs are used to irrigate large open areas such as golf courses, industrial parks, recreational parks, etc. Wastewater treatment standards for reuse water are more stringent than wastewater treated to secondary treatment standards and generally require advanced treatment such as

membrane filtration. At this time a portion of the flow from the President Street WWTP, is treated to reuse standards and is used to irrigate two major golf courses. Irrigation is typically needed during the DO critical season for the harbor and would reduce flows and loading from the President Street WWTP. Increasing reuse demand would potentially allow further reduction in BOD loading to the Harbor during the summer and is currently under investigation by City officials (<http://www.ci.savannah.ga.us/cityweb/webdatabase.nsf>). MACTEC requested additional information from the City to use in the various design scenarios (Appendix C).

Although source-specific information was not obtained, several typical approaches to reducing BOD loads from point sources are available for consideration and include technologies and management/operations such as:

- Membrane filtration of effluents
- Oxidation technologies
- Constructed wetlands treatment (polishing)
- Additional storage with intermittent controlled releases based on receiving water conditions
- Changes in water management within a facility that results in waste stream generation reductions and thereby reduces the total flow and BOD load discharged
- Land application of treated effluent
- Seepage lagoons
- Water conservation education for the community to reduce flows to the municipal WWTP
- Technologies that result in delignification of effluents allowing faster degradation of carbon sources.

From a DO improvement perspective alone, the Draft TMDL modeling by USEPA shows that total elimination of all point source discharges in both the Savannah and Augusta areas, would improve the critical harbor DO by only 0.55 mg/L.

Independent of this present DO improvement screening study, USEPA Region 4 is presently considering the potential for treatment improvement at the paper industry facilities. No information was available from USEPA for this report.

3.0 DISSOLVED OXYGEN IMPROVEMENT TECHNOLOGY ASSESSMENT

This section presents the screening level evaluation of DO improvement measures designed to improve DO levels in the harbor during critical summer months. The screening was divided into two levels of screening to assess the viability of a given alternative. These alternatives for DO improvements for the Savannah Harbor were organized by technology or process. The tabulated information is provided as Tables 3.1 and 3.2 and includes information on the Level I & II - Assessment of Dissolved Oxygen Technology, respectively.

3.1 LEVEL I ASSESSMENT

Level I screening of DO improvement alternatives involved listing reasonable, available technologies to increase DO concentrations in surface waters and evaluating the technical feasibility of each alternative based on potential effectiveness and applicability with current site conditions. Twenty improvement technologies were initially identified as potential solutions. Those technologies include:

- Membrane Filtration of Effluents
- Cascade Aerator
- CleanFlo-Natural Inversion
- Coarse Bubble Diffuser
- Fine Bubble Diffuser
- Linde-Soaker Hose
- Mechanical Surface Aerators
- Rolling Maintenance Shutdown during Critical Season
- Increased Releases from Upstream Reservoirs
- ECO2-SuperOxygenation (Speece Cone)
- Fine Bubble Diffuser using High Purity Oxygen
- Hydroflo-Aero Transfer System
- Praxair-In-Situ Oxygenation
- Sidestream Pressurized Oxygenation
- U-Tube Oxygenation
- Venturi Oxygenation
- Aquatic Treatment Systems
- Constructed Wetland Treatment Systems
- Discharge Collection Network With Supplemental Oxygen Injection
- Inflatable Weir
- Land Treatment Systems/Water Reuse
- Mechanical Pumps
- Seaward Pipeline with Timed Tidal Discharge
- Storage and Controlled Discharge System
- Tidal Gate

These technologies are listed in Table 3.1 and fall into the following categories:

- Advanced Treatment
- Aeration
- Management
- Oxygen Injection
- Physical Modifications

The technologies were classified as potentially effective for implementing in the harbor system and/or at the location of a point source discharge. The first screening level took into account site-specific conditions and requirements for either upstream or harbor implementation. Screening of the identified technologies considered the shipping channel traffic, the zone of influence, applicability to moving or stagnant water, power needs, required space for application of technology, and the ability to effectively dissolve oxygen into water.

Aeration/Oxygenation Technology Comparison – Types of oxygenators were evaluated on their ability to provide large quantities of oxygen to surface water bodies. The specific design goals for oxygenation technologies included:

- High oxygen absorption efficiency
- Low unit energy consumption kilowatt hour per ton of DO (kW-hr/ton DO)
- Side stream superoxygenation (50 to 100 mg/L) at reasonable capital cost

Aeration (with air) and superoxygenation (using commercial “pure” oxygen) technologies dissolve oxygen into the water. It may appear counterintuitive to utilize commercial oxygen when air is available from the atmosphere for free. However, the use of commercial oxygen may prove to be more economical than air. For instance, dissolving oxygen from air into water involves considerable capital and operating costs. Some adverse effects are also associated with the use of air which are negated using commercial oxygen (Speece, 2005-Appendix D). The use of air in contact with water under more than ambient pressure, on the other hand, may result in supersaturation of the water column with dissolved nitrogen gas, potentially adversely impacting fish. Air as the oxygen source also restricts the maximum DO concentration achievable, and therefore increases the aeration required to achieve a given daily oxygen supplementation mass rate. In addition, the use of air necessitates almost an order of magnitude greater energy expenditure per ton of DO dissolved into solution when compared to commercial oxygen use.

Commercial oxygen can also be dissolved even in stratified water columns and generally becomes more economically competitive when the target dissolved oxygen requirement exceeds 4 to 5 mg/L (Speece, 2005-Appendix D).

Technologies that require large amounts of River surface area or submerged River bed area were generally eliminated. These types of area-extensive technologies would likely interfere with routine maintenance dredging and future Harbor expansion projects. Also, velocities in the river may be great enough that some of these large area technologies would not be able to withstand the dynamic forces and may be swept away. Technologies eliminated for these reasons include: Cascade aerators, CleanFlo – Natural Inversion Technology, coarse and fine bubble diffusers, soaker hose technologies, and mechanical surface aerators.

Management Options - Application of employing increased releases from upstream reservoirs was eliminated based on modeling runs completed by the USEPA observing only local increases in DO by the increased DO levels at the dam and no noticeable increase in DO at Clio, RM 61 (USEPA, 2003). Also, during critical flows, the potential for release from the upstream reservoirs may be severely limited by drought conditions and the required water volumes needed to substantially increase flows in the critical segment may not be available.

3.2 LEVEL II ASSESSMENT

The Level I screening evaluation eliminated those technologies which if implemented would not feasibly achieve the desired BOD reduction improvement goals or the TMDL DO requirements for the critical segment of Savannah Harbor or did not have convincing evidence for current application. Based on the results of the Level I screening evaluation, the following alternatives were retained for further consideration:

3.2.1 Membrane Filtration

Membrane filtration is a tertiary treatment applied to wastewater treatment processes which removes residual sedimentary particles and particulate organics from treated wastewater. Site specific wastewater characterization (total dissolved solids, total suspended solids, nitrates, sulfates, dissolved organic carbon, etc.) is needed to design membrane filtration systems in order to predict potential performance and

relative costs. Membrane filtration systems have been employed at publicly owned treatment works (POTWs) (Zenon, 2005).

3.2.2 ECO_2 Speece Cone

The Speece Cone oxygenation device uses water pumps to move large quantities of water or treated effluent into a cone shaped device. High purity oxygen is injected into the center of the cone. The high velocity downflow of water inside the cone creates a "bubble swarm" which increases the concentration of oxygen absorbed into the water. Upon exiting the Speece Cone, the high DO water may be injected back into the harbor at various depths (minimum 10 feet to greater than 50 feet) to increase DO concentrations. The Speece Cone has been implemented at a variety of locations including lakes and river water bodies. Case studies include East Bay Municipal District at Comanche Reservoir, CA, Newman Lake Homeowners Association at Newman Lake, WA, and Alabama Power at Logan Martin Dam, GA. In comparison to a U-Tube, the main advantage of a Speece cone is that no deep excavation costs would be required for the Savannah Harbor because the approximate 50 foot depth and associated water pressure of the harbor can be utilized for achieving superoxygenation of the returned flow.

3.2.3 Deep U-Tube

The U-Tube technology requires installation generally into an excavation approximately 150 to 200 feet in depth. A large pipe is fitted into the hole, and water is pumped down the length of the pipe. High purity oxygen is injected into the bottom of the pipe as the water travels downward. The velocity of descent exceeds the bubble rise velocity, which creates a long contact time and results in a high transfer rate of oxygen to the water stream. As the water travels to greater depths, the pressure increases, which also increases the absorption of oxygen into the water. The superoxygenated water rises through a middle pipe, where it is discharged (at varying depths) into the receiving surface water being oxygenated. This deep U-Tube application is being demonstrated at the Stockton Deep Water River Channel near San Joaquin River at the mouth of the San Francisco Bay in California (Civil Engineering News, 2005).

3.2.4 Pressurized Side Stream Oxygenation (PSSO)

The PSSO system uses industrial water pumps to move water at high pressure through a series of looping pipes. The length of the pipe increases residence/contact time (approximately 100 seconds) and backflow valves increase water pressure. High purity oxygen is injected into the influent stream of water. Oxygen absorption into the water is driven by the high residence time and high pressure. High DO water is then

discharged and dispensed into the critical segment at depth. The PSSO systems require large tracts of land to accommodate the length of piping necessary to achieve the desired residence time under high pressure.

3.2.5 HydroFlo Aero Transfer System

HydroFlo technology withdraws a side stream of water into which high purity oxygen is injected, then directed through equipment in which the oxygen absorption takes place, and sent back into the harbor. The HydroFlo system utilizes a proprietary Aero Transfer System (ATS) to inject high purity oxygen into the water. The HydroFlo system is able to achieve high transfer efficiencies with low power consumption requirements. The superoxygenated water would be discharged into varying depths of the water body to increase DO concentrations at critical depths.

3.2.6 Praxair In-situ Oxidation (ISO)

The Praxair ISO system uses a surface mounted aerator with an impellor and high purity oxygen injection. The oxygen is injected into the surface water, where an impellor mixes the oxygen into the water body. This movement also pushes the oxygenated water downward and away from the aerator. The system requires low energy input per ton of oxygen dissolved and has good oxygen transfer efficiency (>90%). However, the Praxair system is limited in coverage to the area that can be oxygenated by a single unit, requiring several units be located within close proximity. Because these are floating aerators, they are not the best solution for the Savannah Harbor, as they would potentially interfere with right-of-way water traffic but may be considered for off stream storage pond aeration.

3.2.7 Venturi Injection

Venturi injection nozzles have been developed in which water is passed through a section of pipe into which high purity oxygen is injected. The high velocity water through the venturi nozzle increases the amount of oxygen absorbed. The residence time within the Venturi is very short even though the bubbles are tiny and a high gas/water interface, thus the brief contact time precludes efficient absorption. Vendors utilizing the Venturi aspiration principle to achieve absorption of purity oxygen include Air Products, Mazzei, and Linde.

3.2.8 Rolling Maintenance Shutdown during Critical Months

Many of the manufacturing facilities discharging to the Savannah River both upstream near Augusta and within the harbor area conduct periodic planned maintenance shutdowns of their facilities. These maintenance shutdowns generally take some or all of the production lines off-line to clean, test, and repair major equipment. These shutdowns are scheduled in advance and may last from several days to a week or more depending on the requirements of the facility. As such, it may be feasible to organize the industrial point source dischargers along the Savannah River to coordinate these shutdowns to occur during the DO critical season to minimize treated effluent flow discharged to the river during the critical season. As possible, these industries along the middle and lower reaches of the Savannah River/Harbor may be able to coordinate a maintenance shutdown to occur at staggered intervals maximizing the length of time and the load reductions to the system during summer critical conditions.

Some of the constraints that may be applicable to this management scenario include:

- Coordination and agreement among dischargers along the river/harbor,
- Maintenance requirements may not be required by a facility during the applicable critical season, or hot weather shutdowns may not be feasible from a health and safety perspective for maintenance workers.
- Contingencies for emergency shutdowns and completing other maintenance activities during this period thereby eliminating a need for another shutdown, and
- Actual BOD load during shutdowns is not known (and may not be substantially different from normal discharges) and would require further investigation.

3.2.9 Urban Water Reuse Plan

Urban water reuse (UWR) is a type of land application utilizing highly treated municipal effluent as an irrigation source. Two golf courses in the Savannah area are currently being irrigated by UWR effluent from the President Street WWTP. Potentially, this program could be expanded to provide irrigation for parks, recreational areas, office parks, and other open areas to reduce the total load to the Harbor. Demand for reuse water is at a maximum during the critical summer period when rainfall is limited creating a complimentary situation. Also, in the cooler months when demand is low, flows in the Savannah should be sufficient to allow the facility to discharge according to limits specified in their NPDES permit. GAEPD rules have specific water quality limits for effluents used for UWR.

3.2.10 Constructed Wetlands

Constructed wetlands are man-made systems that imitate the functions of natural wetland systems. Constructed wetlands often perform better for treatment than natural wetlands of equal area because the constructed system is specifically managed and controlled for treatment effectiveness. Emergent plants provide significant amounts of reactive surface area for microbial activity that can further degrade BOD. Additionally, depending on the design, a constructed wetland may provide habitat for wildlife. Constructed wetlands have the potential for treating moderate to high organic loads with a BOD effluent characteristic of 5 to 40 mg/L (Reed, 1995).

3.2.11 Oxidation/Partial-mix Aerated Pond

Oxygen in an aerated pond is supplied mainly through mechanical or diffused aeration. Aerated ponds are generally 6-20 feet in depth with detention times of 3-10 days. The main advantage of aerated ponds is that they require less land area in comparison to systems without aeration technology. However, as the size of ponds increase capital and operations and maintenance (O&M) costs significantly increase. Aerated ponds that may have application in the Savannah Harbor area would be polishing ponds to provide further reduction of BOD from the treated wastewater collected and to provide additional storage of treated effluents during the DO critical period for subsequent release.

The four Savannah area discharges blended together in an aerobic¹ effluent storage pond would have a CBOD decay rate of about 0.033/day (base e, 20°C – volume weighted average decay rate) based on the Savannah Harbor Wastewater Characterization Study (LAW, 2000) effluent characterization study. Adjusting this rate to 30°C (expected effluent temperature during the critical season) this decay rate would be about 0.052/day.

The percent (%) reduction of CBOD_t as a function of storage time is as follows:

<u>Days Storage</u>	<u>% CBOD_t reduction</u>
1	2.5
10	21
30	40
60	48
90	50

¹ Aeration/Oxygenation of the storage pond would be added as necessary to maintain aerobic conditions throughout the storage pond contents.

The August IP effluent in aerobic¹ storage would decay at about 0.036/day (base e, 20°C). At 30°C this rate would increase to about 0.057/day.

The percent (%) decay at CBOD_{LT} in storage would be as follows:

<u>Days Storage</u>	<u>% CBOD_{LT}</u>
1	3
10	22
30	41
60	49
90	50

¹Aeration/Oxygenation of the storage pond would be added as necessary to maintain aerobic conditions throughout the storage pond contents.

3.2.12 Discharge Collection Network with Supplemental Oxygen Injection

Pipelines may be constructed to convey treated effluent from selected facilities to a centralized storage lagoon. High purity supplemental oxygen may be injected into the pipe network to maintain aerobic conditions and provide for further degradation of BOD during conveyance. A collection system would connect the discharge collection lines into one main terminal. The discharge collection network would be used in conjunction with a seaward pipeline scenario in the Savannah area (Section 3.2.13) or with the effluent storage and controlled discharge scenario (Section 3.2.14).

3.2.13 Savannah Area Seaward Pipeline with Timed Tidal Discharge

This approach utilizes a pipeline to discharge Savannah area treated effluent from the centralized storage lagoon (Section 3.2.14) downstream (seaward) of the DO critical segment. Discharges from this system would be timed so that releases are coordinated with outgoing tides to maximize seaward transport and dispersion. As part of this alternative, the centralized storage lagoon would need a minimum 12 hours detention time to be able to time the release to occur on outgoing tides. Supplemental oxygen may also be injected in the pipeline to superoxygenate the discharge before release.

3.2.14 Storage and Controlled Discharge Pond

Storage and controlled discharge ponds would be operated and constructed in addition to the discharge collection pipe network (Section 3.2.12). Rather than discharging at a seaward location, the storage ponds would be designed to store treated effluents during the critical season for post-critical-season

release. Controlled discharge ponds have long retention times (in this case up to 90 days), and the effluent is discharged (at varying rates) to coincide with instream river conditions. A variation of the controlled discharge pond is a hydrograph controlled release lagoon. The pond discharge is matched to periods of high flow in the receiving stream, using the stream hydrograph as the control (Reed, 1995). Typical storage areas needed for corresponding flows are estimated below.

Facility Name	NPDES ID	Full Permit Flow ^a (MGD)	Assumed Flow (MGD)	Pond Area (Acres) (assume 9 feet deep)					
				12-HRS Retention		30-Day Retention		60-Day Retention	
				Surface	Total*	Surface	Total*	Surface	Total*
International Paper (Savannah)	GA0001988	38.00	30.00	5	9	307	340	614	650
International Paper (Augusta)	GA0002801	40.00	40.00	7	12	409	453	819	867
Fort James Paper (GA Pacific)	GA0046973	33.00	33.00	6	10	338	374	675	715
Weyerhaeuser-Port Wentworth	GA0002798	22.00	20.00	3	6	205	227	409	433
President Street	GA0025348	27.00	10.00	2	3	102	113	205	217

Facility Name	NPDES ID	Actual Flow ^a (MGD)	Assumed Flow (MGD)	Pond Area (Acres) (assume 9 feet deep)					
				12-HRS Retention		30-Day Retention		60-Day Retention	
				Surface	Total*	Surface	Total*	Surface	Total*
International Paper (Augusta)	GA0002801	30.00	30.00	5	9	307	340	614	650
International Paper (Savannah)	GA0001988	28.00	28.00	5	8	287	317	573	607
Fort James Paper (GA Pacific)	GA0046973	19.00	19.00	3	6	194	215	389	412
Weyerhaeuser-Port Wentworth	GA0002798	11.75	11.75	2	4	120	133	240	255
President Street	GA0025348	25.83	25.83	4	8	264	293	529	560

* Total area includes berm footprint.

Those alternatives that were considered applicable for the Savannah Harbor area were passed to the next screening process and were further evaluated based on the criteria listed below.

3.3 LEVEL II ASSESSMENT OF LIMITATIONS

The overall objective of the Level II screening is to identify appropriate, effective and economical alternatives capable of achieving the required improvement. The detailed screening of potential remedies consisted of ranking the various DO improvement alternatives according to the following criteria:

- Performance/Effectiveness – Addresses the degree to which the alternative will achieve the improvement measure (i.e. increase Harbor DO during critical conditions).
- Reliability – Addresses the ability of the alternative to consistently maintain effectiveness and operate continuously.
- Oxygen (O₂) Transfer Efficiency – Addresses the degree to which the technology is capable of transferring oxygen into the water stream.
- Unit Energy per ton DO – Addresses the energy required to introduce one ton of DO.
- DO Concentration – Addresses the DO output concentration that may be achieved by a given technology.
- Capital and Added Operation and Maintenance Cost – Addresses the cost of implementing each alternative.
- Physical/Logistical – Addresses the location for installation of each alternative.
- Seasonal Application – Addresses the application of each alternative on a seasonal or annual operating basis.

The second screening evaluation, Level II, considered the individual characteristics in a more detailed analysis. Each technology is evaluated and ranked for each characteristic and a numerical ranking is assigned. These rankings were assigned based on the overall achievement of the project goals and objectives for DO improvement.

For the technologies under consideration, each criterion listed above was assigned a qualitative ranking factor based on a 3-point rating scale (3 = good; 2 = fair; 1 = poor). The ranking for each alternative was tallied and totals were compared to facilitate selection of applicable technologies. The results of the

improvement technology screening evaluations are summarized in Table 3.2 and Table 3.3. Criteria for assigning a numerical value to a given characteristics are as follows:

- **Harbor Improvements Oxygen Injection Performance/Effectiveness**
 - 3 – low maintenance; high oxygen transfer efficiency (>90%); high production of oxygen per horsepower hour (>10 lbs O₂/hp-hr); high sidestream O₂ concentration (>50 mg/l); and low capital cost.
 - 2 – moderate maintenance; medium oxygen transfer efficiency (60-90%); medium production of oxygen per horse power hour (6-9 lbs O₂/hp-hr); medium sidestream O₂ concentration (10-50 mg/l); and medium capital cost.
 - 1 - high maintenance; low oxygen transfer efficiency (<60%); low production of oxygen per horse power hour (<6 lbs O₂/hp-hr); low sidestream O₂ concentration (<10 mg/l); and high capital cost
- **Harbor Improvements Physical Performance/Effectiveness**
 - 3 – most applicable to DO improvement goals; low maintenance; and low capital cost.
 - 2 – somewhat applicable to DO improvement goals; moderate maintenance; and medium capital cost.
 - 1 – further research needed to assess DO improvement goals; high maintenance; and high capital cost
- **Point Source Performance/Effectiveness**
 - 3 – most benefit to DO improvement goals; low maintenance; and high BOD reduction (250,000 to 500,000 lbs/day); low capital costs; no area constraints; and most effective during summer critical season.
 - 2 – moderate benefit to DO improvement goals; moderate maintenance; and medium BOD reduction (100,000 to 250,000 lbs/day); medium capital costs; some area constraints; and most effective during summer critical season.
 - 1 – further research needed to assess DO improvement goals; high maintenance; and low BOD reduction (<100,000 lbs/day); high capital costs; area constraints; and limited seasonal application.

Although the ranking is somewhat subjective, the process provides a structured format to assess alternatives for elimination, and often a clear-cut alternative emerges. The results of the Level II Assessment of Limitations for Alternatives are summarized in Table 3.2 and 3.3.

In summary, the top three oxygen injection technologies ranked from greatest to least are: Speece Cone, U-Tube, and Sidestream Pressurized Oxygenation. Each of the physical treatment options ranked equally. The inflatable weir, the tidal gate technology, and the mechanical pumps may apply to control salt water intrusion and/or provide for increased mixing as the harbor is deepened but more research is needed to be able to evaluate the potential effectiveness for DO improvements with these options.

The top three point source technologies ranked from greatest to least are: the seaward pipeline with timed tidal discharge, storage and controlled discharge pond, and rolling maintenance shutdowns during critical months.

4.0 CONCEPTUAL DESIGN ALTERNATIVES

Brief descriptions of the conceptual designs retained for further evaluation are presented in the following subsection with a discussion of application of selected technologies.

4.1 MAXIMUM TECHNOLOGY CAPABILITIES

The following section breaks each technology into a specific range of BOD loadings it is capable of meeting per single application.

4.1.1 0 to 100,000 lbs/day

Rolling Maintenance Shutdowns for BOD Load Management (2 weeks assumption per facility) -

The Rolling Maintenance Shutdown Program is a management practice (MP) that is potentially applicable for certain manufacturing facilities in Augusta and Savannah. It is not applicable for municipal WWTW or POTWs or for facilities that do not require scheduled periodic shutdowns for maintenance. Each summer from late July to early September, the major dischargers could coordinate maintenance activities allowing a period of time with reduced loadings. Facility shutdowns could be timed so that shutdowns would follow one another reducing the overall load during the critical season. For this study and to develop the application of this scenario, an assumption that each discharger would require 2 weeks to complete maintenance activities at their facility and that there is a total BOD load reduction of approximately 50 percent during a scheduled shutdown period was used. For example (in a given year), of the four applicable top five facilities, IP Savannah does not require extensive maintenance activities and therefore does not schedule a maintenance shutdown, the remaining three manufacturing facilities will require a brief period to shutdown part of the manufacturing process to replace and repair equipment and agree to conduct these activities during the DO critical season. Total BOD reductions within the 0 to 100,000 lbs/day range potentially provide total BOD reductions of: Weyerhaeuser ~15,000 lbs/day (end of July); Georgia Pacific ~21,700 lbs/day (first 2 weeks in August), and IP Augusta, ~67,500 lbs/day (last part of August). Using data from the top five ranked facilities and the assumptions previously stated, this alternative may provide a BOD loading reduction ranging from 15,000 to 67,500 lbs BOD/day.

Speece Cone Oxygenation - A single Speece Cone is capable of introducing approximately 10,000 to 12,000 lbs O₂/day, but multiple cones may be used to supply more than 10,000 to 12,000 lbs O₂/day. The Speece Cone could be mounted on the shore alongside the river channel. No more than 4 mounted cones

are recommended in one location (supplying approximately 40,000 to 50,000 lbs/day) though multiple groups may be applicable for the Harbor. A mobile barge arrangement capable of traveling to an area predicted to have critical low DO levels may have up to 8 cones supplying approximately 80,000 to 96,000 lbs/day. The discharge stream of the cones would be directed to a particular water depth to allow for best oxygen transfer into the varying depths in the harbor. The land requirements for an oxygenation station should be more preferably referred as dock requirements. The Speece Cone principal is to operate under the maximum hydrostatic head available i.e. in the bottom of the harbor. Therefore it is preferably located where it has access to the full depth of the harbor and this will probably be off the edge of a dock where the harbor depth is maximum. Each cone is 12 ft in diameter and about 15 ft high. Each cone has a 50 HP pump that withdraws water from the depth of the harbor and moves it through the cone. If liquid commercial oxygen is utilized, then a storage tank of approximately 6 ft diameter by 40 ft high would hold 7 days supply. Access to the site by a LOX tanker truck would be required. If mobile Speece cone units were considered, two complete units fit on a standard fifty foot barge. Mixing would be provided mainly by tidal action. The superoxygenated discharge would be horizontally directed perpendicular to the dock and would be transported over 0.5 miles away. Depending on the output of the tidal mixing model, if additional transport of the superoxygenated discharge was desired, a 10 HP low tip speed, 6 ft diameter mixer could be located at the cone discharge to supplement the tidal mixing.

Storage and Controlled Discharge Pond - Phase 1, Steps 1 and 2 require a 100 percent reduction of the current load or the permitted BOD loads, respectively. Storage and controlled discharge ponds would consist of earthen ponds constructed to periodically store treated wastewater effluent from large facilities discharging to the Savannah River and Harbor. These ponds may be designed to hold effluents for varying lengths of time and be engineered to allow discharge under various scenarios such as on outgoing tides, based on the river/harbor hydrograph, etc. The availability of land is directly proportional to the costs for this technology. Dredged sediment storage facilities may be potential areas available for such storage. Available areas for storage options in the Augusta region as well as storage capacities at each point source are unknown at this time to be considered as an alternative. Storing Weyhaeuser or President Street WWTP discharge would divert approximately 30,000 lbs BOD/day from the critical segment.

Supplemental Oxygen Injection (with Pipeline Alternative) - Supplemental Oxygen Injection involves a mixture of high purity oxygen injected into an extended discharge pipeline. Injection technologies are available for O_2 injection at the pipe inlet or O_2 injection at incremental lengths in the pipeline to maintain aerobic conditions within the entire length of the pipeline. Oxygen injection in a pipeline creates a

plug-flow reactor which will also allow further degradation of BOD loadings. The hydraulic residence time is determined by the length of the pipe and the flow velocity. Because most proposed pipelines are less than 15 miles, complex organics are not expected to further degrade in the pipe system. Preliminary designs predict a 10 mile segment may be superoxygenated feasibly with approximately 80,000 lbs/day (provided by Mazzei, 2005 – Appendix E)

Urban Water Reuse Plan - Municipal discharges may be reduced by the implementation or expansion of urban water reuse programs. The City of Savannah President Street facility has implemented an urban water reuse program. Wastewater treated to urban water reuse standards is used to irrigate two golf courses in the Savannah Area. Potentially, this program could be expanded to provide irrigation for parks, recreational areas, office parks, and other open areas to reduce the total load to the Harbor on a seasonal basis. Demand for reuse water is at a maximum during the critical summer period when rainfall is limited. Also, in the cooler months when irrigation demand is low, flows in the Savannah should be sufficient to allow the facility to discharge according to limits specified in their NPDES permit.

Currently, the City of Savannah has identified several areas where expansion may be feasible. Cost and material estimates for implementing the water reuse expansion program are not known at this time. Expansion of the reuse program for the City of Savannah would decrease the volume of effluent that may otherwise require another reduction alternative. Also, other municipalities or POTWs located along the Savannah River may be able to implement reuse programs (depending on the availability of customers to accept the water) reducing the overall loading of BOD during the critical summer months.

4.1.2 100,000 to 300,000 lbs/day

Discharge Collection Network (Single 36" Pipeline) - A 36 inch diameter pipeline from the IP – Savannah facility on Hutchinson Island could be constructed to carry treated effluent wastewater east toward an existing dredge resource location where a temporary storage pond would be constructed. The discharge network would follow a direct route to the dredge resource location, including a segment traveling under the Back River channel. This would route some (~267,500 lbs/day) of BOD loadings to a storage and controlled discharge system or to a point well past the DO critical segment through a seaward discharge pipeline with tide-coordinated discharge. Rerouting IP Savannah's discharge to temporary storage ponds would involve approximately 7,500 feet of pipe. Rerouting IP Savannah's discharge toward a seaward discharge point #1, would involve approximately 54,000 feet of pipe.

Rolling Maintenance Shutdowns (2 weeks per facility) - The Rolling Shutdown Program management practice (MP) is applicable for this scenario.

Storage and Controlled Discharge Pond - Phase I, Steps 1 and 2 require a 100 percent reduction of the current load or the permitted BOD loads, respectively. Storage and controlled discharge ponds would consist of earthen ponds constructed to seasonally store treated wastewater effluent from facilities otherwise discharging to the Savannah River and Harbor. These ponds may be designed to hold effluents for varying lengths of time and be engineered to allow discharge under various scenarios such as on outgoing tides, based on the river/harbor hydrograph, etc. The availability of land is directly proportional to the costs for this technology. Dredged sediment storage facilities may be potential areas available for such storage. Depending on the retention time preferred, storing IP Savannah's discharge alone would divert approximately 267,500 lbs BOD per day from the critical segment. Twelve hour retention would require approximately 5 acres, 30-days retention approximately 307 acres, and 60-days retention approximately 614 acres of area assuming a pond depth of 9 feet.

Facility Name	Pond Acreage ft (assume 9 feet deep)		
	12-HRS Retention	30-Day Retention	60-Day Retention
International Paper (Savannah) 30 MGD	5.1	307	614

4.1.3 300,000 to 500,000 lbs/day

Discharge Collection Network (3 - 36" Pipelines) - Three 36 inch diameter pipelines each from Weyerhaeuser, IP Savannah, and the President Street facilities could be constructed to convey treated wastewater effluent east toward a centralized storage lagoon (from a converted existing dredge resource site). The discharge network would follow a direct route to the dredge resource location, including segments traveling under the river channel. This could potentially route approximately 327,500 lbs/day of BOD loadings to a centralized storage lagoon. Discharges from the centralized storage lagoon may be made using a controlled discharge or a seaward discharge pipeline with timed tidal discharge. Rerouting the three closest dischargers to a temporary storage pond would involve approximately 36,500 feet of pipe for Weyerhaeuser, approximately 7,500 feet of pipe for IP Savannah, and approximately 10,800 feet of pipe for President Street WWTP.

Storage and Controlled Discharge Pond – Utilizing the storage and controlled discharge pond is applicable for this scenario.

Facility Name	Pond Acreage ft (assume 9 feet deep)		
	12-Hrs Retention	30-Day Retention	60-Day Retention
International Paper (Savannah) 30 MGD	10	614	1228
Weyerhaeuser-Port Wentworth 20 MGD			
President Street 10 MGD			

4.1.4 500,000 to 750,000 lbs/day

No single technology is available to meet or exceed a 500,000 lbs/day requirement. Only a combination of the above listed technologies can achieve this range of oxygen addition or BOD offset. For example, routing BOD loadings to a storage pond and multiple Speece cones along the Harbor are considered combinations of technologies.

4.2 DEVELOPMENTAL CONCEPTUAL DESIGN ALTERNATIVES PHASE I

In general, constructing a pipeline to convey the point source discharges to the ocean is a high capital cost but an effective solution that could be utilized year round. The cost of such a pipeline is directly proportional to its length so considering shorter pipelines is a more feasible solution. The technologies available for oxygen injection are more cost effective for providing oxygen in the range of 0-300,000 lbs/day if 90 days of O&M is required for 20 years. As oxygen supply requirements exceed this range other technologies may prove more feasible thus pipelines and effluent storage systems could be considered. The direct oxygen injection is most feasible for treating background BOD loads. In concept, one or two injection systems could compensate for non-point source BOD loads of 90,000 lbs/day. Management practices like scheduled maintenance shut downs are potentially the least expensive BOD reducing measure. However, total elimination of all point sources in the Savannah and Augusta areas would only decrease the loading by 234,000 lbs/days and, thereby, increase the critical DO deficit in the harbor by only 0.55 mg/L.

4.2.1 Phase I, Step 1, (~290,250 lbs/day Reduction)

- critical season (assumed 90 days)

Options for Phase I, Step 1 require an elimination of 99,000 lbs/day BOD from Harbor point source dischargers and 135,000 lbs/day BOD (equating to 101,250 lbs/day in the Harbor) from upstream point source dischargers. This step also requires removal or improvement alternatives for an additional 90,000 lbs/day BOD loading from non-point source loads.

Concept I Alternative 1A – Harbor Injection Technology (29 Speece Cones)

In order to provide 290,250 lbs/day of oxygen to the critical segment of the harbor, 29 Speece cones could provide up to 290,000 lbs/day of oxygen for the critical season. This alternative could be used to further increase DO levels in the Harbor at any period in the seasonal cycle.

Concept I Alternative 1B – Harbor Injection Technology (29 Speece Cones with scheduled maintenance shut downs)

A similar conceptual design (Concept I-1B) would use Speece cones in combination with scheduled maintenance shut downs in four of the top five dischargers. This could reduce the need for Speece cones to operate the entire 90 days. Utilizing a shutdown scenario should reduce the supplemental oxygen requirements, thereby lessening the number of days that all the Speece cones need to be operated and the total annual O&M costs.

Concept I Alternative 1C – Discharge Collection Network

Another design to provide a similar level of DO improvement is a discharge collection network in conjunction with either storage, a controlled discharge pond, or a seaward discharge pipeline with timed tidal discharge (Concept I-1C). A discharge collection network could be installed connecting one of the top five dischargers resulting in a potential reduction of BOD loading of up to 327,000 lbs/day (more than needed for this phase and step) and would be capable of transferring a combined total of 30 million gallons per day to a centralized storage lagoon during the critical season. The discharge collection network could be injected with pure oxygen to maintain aerobic conditions. The centralized storage lagoon (consisting of an earthen berm) could be constructed to hold up to 60 days of effluent flow and

would require approximately 650 acres of land. The 60-day retention time would provide time for additional degradation of BOD in the treated effluent. The discharge collection network and storage pond could potentially eliminate most of the 367,000 lbs/day BOD from Harbor point source dischargers.

4.2.2 Phase I, Step 2, (~725,500 lbs/day Reduction)

- critical season (assumed 90 days)

Options for Phase I, Step 2 require an elimination of 367,000 lbs/day BOD from Harbor point source dischargers and 358,000 lbs/day BOD from upstream point source dischargers (equating to 268,500 lbs/day in the Harbor) and an additional 90,000 lbs/day BOD loading removal for non-point source loads.

Concept 1 Alternative 2A – Harbor Injection Technology (73 Speece Cones)

In order to provide 725,500 lbs/day of oxygen to the critical segment of the harbor, 73 Speece cones could provide up to 730,000 lbs/day of oxygen for the critical season. Though the Speece cone injection technology is the most cost effective technology for seasonal application, other scenarios and combinations of alternatives become potentially feasible as more off set of BOD is needed. Costs between 73 Speece cones and costs of other technologies begin to become comparable based on +/- 50 percent accuracy in the estimated preliminary costs. Technologies that offer an annual treatment option include the discharge collection network in conjunction with either storage and controlled discharge pond or a seaward discharge pipeline with timed tidal discharge.

Concept 1 Alternative 2B – Speece Cones with Discharge Network and Storage System

Utilizing a combination of technologies, a discharge network and storage system in conjunction with Speece cones to provide 725,500 lbs/day BOD reduction is another alternative. A discharge collection network could be installed connecting three of the top five dischargers resulting in a potential reduction of BOD loading of up to 327,000 lbs/day and would be capable of transferring a combined total of 60 million gallons per day (MGD) to a centralized storage lagoon during the critical season. The discharge collection network would be injected with approximately 80,000 lbs/day of pure oxygen to maintain aerobic conditions. The centralized storage lagoon (consisting of an earthen berm) could be constructed to hold up to 60 days of flow and would require approximately 1200 acres of land. The 60-day retention time would provide time for additional degradation of BOD in the treated effluent. The discharge

collection network and storage pond could potentially eliminate most of the 367,000 lbs/day BOD from Harbor point source dischargers. Oxygen injection using Speece cones may be appropriate to provide a DO offset for the remaining load from Harbor sources and the 268,500 lbs/day residual BOD from upstream point source dischargers as well as the 90,000 lbs/day BOD from non-point source loads. Utilizing scheduled maintenance shut downs among four of the top five dischargers could reduce the need for Speece cones to operate the entire 90 days. Utilizing a shutdown scenario may allow some number of Speece cones to be turned off thereby reducing the supplemental oxygen requirements and O&M costs. Approximately 40 Speece cones would be needed for this alternative.

4.2.3 Phase I, Step 3 (~68,250 lbs/day Reduction)

- critical season (assumed 90 days)

Options for Phase I, Step 3 require an elimination of 68,250 lbs/day of oxygen to the critical segment of the harbor.

Concept I Alternative 3A – Harbor Injection Technology – (7 Speece cones)

Seven Speece cones could provide up to 70,000 lbs/day of oxygen for the critical season. This alternative could be used to further increase DO levels in the Harbor at any period in the seasonal cycle. This would account for the elimination of 68,250 lbs/day BOD from point source dischargers.

Concept I Alternative 3B – Harbor Injection Technology – (7 Speece cones with scheduled maintenance shut downs)

A similar conceptual design would use the Speece cones in combination with use scheduled maintenance shut downs in four of the top five dischargers. This would reduce the need for Speece cones to operate for the entire 90 days. Utilizing a shutdown scenario should reduce the supplemental oxygen requirements, thereby lessening the number of days that all the Speece cones need to be operated and the total annual O&M costs.

Concept I Alternative 3C – Seaward Discharge pipeline with tide-coordinated discharge

Another design capable of providing this required level of DO improvement is a harbor discharge relocation. Relocating the discharge from the largest point source discharger to a seaward location outside the critical area could meet the DO improvements required for this step. A seaward discharge pipeline would have to be constructed that is a little over 10 miles long.

4.2.4 Phase I, Step 4 (~503,500 lbs/day Reduction)

- critical season (assumed 90 days)

Options for Phase I, Step 4 require an elimination of of 503,500 lbs/day BOD loading (point source dischargers set a full permitted flow) in the Savannah River Estuary during the critical period.

Concept 1 Alternative 4A – Harbor Injection Technology – (50 Speece cones)

In order to provide 503,500 lbs/day of oxygen to the critical segment of the harbor, fifty Speece cones could provide up to 500,000 lbs/day of oxygen

Concept 1 Alternative 4B – Harbor Injection Technology – (50 Speece cones with scheduled maintenance shut downs)

As with the previous levels of DO improvement, a variation of this design the use of Speece cones in combination with scheduled maintenance shut downs in four of the top five dischargers. This could reduce the need for all the Speece cones to operate for the entire 90 days.

Concept 1 Alternative 4C – (Speece cones with Discharge Network and Storage System)

A further modification of that design would be to use Speece cones, scheduled maintenance shut downs, and a Discharge Collection Network.” Seventeen Speece cones could provide up to 170,000 lbs/day of supplemental oxygen for the critical season. The upkeep and capital costs of the oxygen injection technologies, used for 90 days for 20 years, would become comparable to costs for the permanent pipeline and storage option as presented in Phase I, Step 2 (Section 4.2.2). The combined collection network and storage pond would reduce 327,023 lbs/day BOD from Harbor point source dischargers and the Speece Cones would offset up to 170,000 lbs/day. Oxygen supplied to the pipeline will be needed to keep the

discharge in an aerobic state. Utilizing scheduled maintenance shut downs between four of the top five dischargers would reduce the O&M costs for the Speece Cones.

4.3 DEVELOPMENTAL CONCEPTUAL DESIGN ALTERNATIVES PHASE II

The second phase of the screening level evaluation considers potential effects of future deepening of the deep-draft harbor on DO levels. The alternatives purposed in Phase II of this report will address an incremental increase of 0.2 mg/L DO concentration in the bottom waters of the Savannah Harbor. These design alternatives may be used in addition to the Phase I design requirements to meet and exceed the recommended DO concentrations in the critical segment of the Savannah River Estuary during the critical summer period.

The Phase II conceptual design requires incremental increases of 0.2 mg/L up to 0.8 mg/L DO in Savannah Harbor. Proposed high purity oxygen technology systems have been designed to increase the DO concentration in the Harbor. Speece Cone technology can be used to inject a superoxygenated side-stream discharge into the bottom levels of the Savannah Harbor.

4.3.1 Phase II, Step 1, Incremental Increase (0.2 mg/L)

A 0.2 mg/L increase would require ~72,818 lbs/day of oxygen during the critical season. Concept 2 Alternative 1A consists of the use of eight (8) Speece cones to supplement the oxygen at various locations in the harbor. If mounted on barges Concept 2 Alternative 1B, the barges could be moved to supply supplemental oxygen to various areas of the harbor depending on model predictions or real-time monitoring data. Other methods of providing this level of DO improvement would consist of the use of the approaches described in Section 4.1.1 to address loadings of up to 100,000 lbs/day.

4.3.2 Phase II, Step 2, Incremental Increase (0.4 mg/L)

A 0.4 mg/L increase would require ~145,636 lbs/day of oxygen during the critical season. Concept 2 Alternative 2A consists of the use of fifteen (15) Speece cones located along the shore of the harbor to supplement the oxygen. Concept 2 Alternative 2B is very similar and consists of the use of two mobile barges, each with eight (8) Speece cones each may be used to supplement the oxygen. These concepts differ in their land requirements, potential effects on navigation, and flexibility to address specific sites

that develop low DO levels. Other methods of providing this level of DO improvement would consist of the use of the approaches described in Section 4.1.2 to address loadings between 100,000 and 300,000 lbs/day.

4.3.3 Phase II, Step 3, Incremental Increase (0.6 mg/L)

A 0.6 mg/L increase would require ~218,455 lbs/day of oxygen during the critical season. Concept 2 Alternative 3A consists of the use of twenty-two (22) Speece cones located along the shore of the harbor to supplement the oxygen. Concept 2 Alternative 3B is very similar and consists of the same total number of Speece cones, but in this concept the cones would be grouped together as 7-8 cones mounted on mobile barges that could be moved where most needed in the harbor. These concepts differ in their land requirements, potential effects on navigation, and flexibility to address specific sites that develop low DO levels. Other methods of providing this level of DO improvement would consist of the use of the approaches described in Section 4.1.2 to address loadings between 100,000 and 300,000 lbs/day.

4.3.4 Phase II, Step 4, Incremental Increase (0.8 mg/L)

A 0.8 mg/L increase would require ~291,273 lbs/day of oxygen during the critical season. Concept 2 Alternative 4A consists of the use of twenty-nine (29) Speece cones located along the shore of the harbor to supplement the oxygen. Concept 2 Alternative 4B is very similar and consists of the same total number of Speece cones, but in this concept the cones would be grouped together as 7-8 cones mounted on mobile barges that could be moved where most needed in the harbor. These concepts differ in their land requirements, potential effects on navigation, and flexibility to address specific sites that develop low DO levels. Other methods of providing this level of DO improvement would consist of the use of the approaches described in Section 4.1.2 to address loadings between 100,000 and 300,000 lbs/day.

5.0 COST-EFFECTIVENESS EVALUATION

The "Opinion of Construction Cost" Tables 5.1 were prepared using MACTEC's best judgment as experienced and qualified professionals generally familiar with the construction industry. However, since MACTEC has no control over the cost of labor, materials, equipment, or services furnished by others, or over the construction contractor's methods of determining prices, or over competitive bidding or market conditions, MACTEC cannot and does not guarantee that proposals, bids, or actual construction cost will not vary from the Opinion of Probable Construction Costs prepared by MACTEC. We have attempted to consider major aspects of the work and site conditions based on information made available to us at this stage of the project. Costs will need to be modified during subsequent stages as the level of project definition increases.

The cost estimating classification for the "Opinion of Construction Costs" is an "Order of Magnitude" or "Study" level of estimate. Construction component items and estimated quantities were based on available information and assumptions as indicated on the backup detailed cost tables (Appendix E). Unit prices were obtained from published cost information, manufacturers, project experience, and other sources as noted on the backup tables. The source and methods of pricing were consistent with the preliminary level of project definition. The expected accuracy is in the range of plus or minus 50 percent using the assumptions presented. Various combinations of discharge networks, storage options (12-hour retention, 30-day retention, and 60-day retention), and seaward pipeline discharge points are included in Appendix E.

5.1 PHASE I

There are several assumption in the development of the "Opinion of Construction Costs" that are applicable to the various design scenarios presented and are provided below.

ASSUMPTIONS:

- 15 percent oversight
- 50 percent capital cost contingency
- 30 percent annual cost contingency
- no land acquisition required for proposed collection network pipelines
- dredge resource areas available without cost for storage pond(s) and pipelines
- 50 foot barge(s) available for use with no storage expenses

- alternatives are required for a maximum of 90 days (summer critical season)
- costs associated with land acquisition and acquisition of right-of-ways and required local, state and federal permitting are not included
- costs associated with construction of electrical service or costs for diesel generators are not included.

5.1.1 Phase I, Step 1 (~290,250 lbs/day Reduction)

The most cost effective methods for meeting the total oxygen requirement of 290,250 lbs/day during the critical summer months is through the use of oxygen injection technology in the harbor. Three designs are presented. The first (Design 1-1A) is the use of twenty-nine (29) Speece cones for the 90 days of the summer period, injecting a total of 290,000 lbs/day. At \$425,000 per cone, the capital cost would be \$12,325,000. Each Speece cone would require an oxygen plant at \$325,000 per cone for a capital cost of \$9,425,000. Assuming a 15 percent oversight cost and 50 percent contingency cost, total capital costs for 29 Speece cones is approximately \$35,887,500. During the operating period from mid-July through mid-September DO critical period, O&M and energy costs for each Speece cone are 200 kWh/ton (operation of Speece cone) and 600 kWh/ton (energy cost for pulsed swing adsorption (PSA)) respectively or \$24/ton per day O₂ and \$72/ton per day O₂.

The Speece cone alternative has higher annual costs with the assumed 90 days of operation. Over 20 years the O&M costs are considerable. However, actual durations for operating the Speece cones will generally be much less than 90 days and will occur during periods when critical low flows coincide with high temperatures in the Savannah River. For example, an oxygen injection system on the Tombigbee River in Alabama has had several years where it was not needed (high flows). For other years there was limited use (a few weeks). Periods where continuous use was needed coincided with extreme rare drought conditions (Appendix D).

Assuming 30 percent oversight for O&M, the total annual costs are approximately \$1,628,640 for Design 1-1A. The total opinion of probable cost construction and implementation is \$37,516,140. Projecting this total probable cost over a 20 year operating cycle, results in a total cost of approximately \$68,460,300. The cost breakdown for Design 1-1A is presented in Table 5.1, Figure 5.1. Speece cone locations in this configuration are spaced in groups of 2-3 cones along the Harbor.

A variation on that design (Design 1-1B) consists of twenty-nine (29) Speece cones to inject DO into the system, in combination with rolling maintenance shutdowns of four major industrial point source dischargers (IP Augusta, GA Pacific, Weyerhaeuser, and IP Savannah). It typically requires a plant two weeks to perform its annual maintenance shutdown, so the loads could be reduced for four two-week periods each summer. Implementing the rolling maintenance shutdown program from the upstream area and the harbor would limit the oxygen supplementation needed by the Speece cones and potentially reduce O&M costs as shown below.

Table 5.0 Potential Oxygenation Cost Savings during Scheduled Maintenance Shutdown	
Facility	Potential Oxygenation Cost Savings per Day (\$)
IP Augusta	3360
GA Pacific	960
Weyerhaeuser	480
IP Savannah	6240

Assuming 30 percent oversight for O&M, the total annual costs are approximately \$1,427,712 for Design 1-1B. The total opinion of probable cost construction and implementation is \$37,315,212. Projecting this total probable cost over a 20 year operating cycle, results in a total cost of approximately \$64,441,740. The cost breakdown for Design 1-1B is presented in Table 5.1, Figure 5.1.

Another design (Design 1-1C) is the use of a Discharge Collection Network. A discharge collection network could be installed connecting one of the top five dischargers, routing their effluent to a storage pond, and then pumping the effluent for discharge downstream of the critical area to around River Mile 5.5. The centralized storage lagoon (consisting of an earthen berm) could be constructed to hold up to 60 days of flow and would require approximately 650 acres of land. The 60-day retention time would provide time for additional degradation of BOD in the treated effluent. Roughly 10 miles of pipeline would be required. The total opinion of probable costs for construction and implementation are \$71,671,710. Assuming a 30 percent oversight for O&M, the total annual costs are approximately \$213,525. Projecting this total probable cost over a 20-year operating cycle, results in a total cost of approximately \$75,728,685. This alternative assumes a retention time of only 60 days rather than 90 days

treatment as compared to the Speece Cone estimates. Storing the effluent for only 30 days reduces the pond size and this alternative approaches similar costs as compared to the Speece cone alternative with the total opinion of probable costs for construction and implementation of \$62,709,483. Assuming a 30 percent oversight for O&M, the total annual costs are approximately \$213,525. Projecting this total probable cost over a 20-year operating cycle, results in a total cost of approximately \$66,766,458.

5.1.2 Phase I, Step 2 (~727,500 lbs/day Reduction)

The most cost effective methods for meeting the total oxygen requirement of 727,500 lbs/day during the critical summer months appear to be through the use of oxygen injection technology in the harbor. Two designs are presented. The first (Design 1-2A) is to provide the total oxygen requirement of 725,000 lbs/day during the critical summer months through the use of oxygen injection technology in the harbor. Seventy-three (73) Speece cones would be used to meet the required 727,500 lbs/day oxygen at a probable cost of \$94.4 million for the first year. Assuming 30 percent oversight for O&M, the total annual costs are approximately \$4,099,680 for Design 1-2A. The total opinion of probable costs for construction and implementation are \$94,437,180. Projecting this total probable cost over a 20-year operating cycle, results in a total cost of approximately \$172,331,100. The cost breakdown for Design 1-2A is presented in Table 5.2 Alternative 2A.

The second alternative (Design 1-2B) is to provide the total oxygen requirement of 725,000 lbs/day during the critical summer months through the use of oxygen injection technology in the harbor. Seventy-three (73) Speece cones would be used in combination with rolling maintenance shutdowns to meet the required 727,500 lbs/day oxygen at a probable cost of ~\$94.2 million for the first year. Assuming 30 percent oversight for O&M, the total annual costs are approximately \$3,898,752 for Design 1-2B. The total opinion of probable costs for construction and implementation are \$94,236,252. Projecting this total probable cost over a 20-year operating cycle, results in a total cost of approximately \$168,312,540. The cost breakdown for Design 1-2B is presented in Table 5.2 Alternative 2B.

A variation on that design is Design 1-2C. This is the combination of 40 Speece cones and a Discharge Network collecting Weyerhaeuser, IP Savannah, and President Street effluent (Appendix E, Option I-B) and routing it to a storage pond (approximately 614 acres) for 30-day retention for subsequent discharge. This design has a cost that is comparable to that of the use of the 73 Speece cones described above in the previous paragraph. Figure 5.2 shows possible Speece cone locations as well as the Discharge Collection Network, and Storage pond options depending on retention time required (12-hour, 30-day, or 60-day).

This technology may reduce loading for 30 days during the critical season. Approximately, 400,000 lbs/day is offset with 40 Speece cones and ~327,500 lbs/day is rerouted through the Discharge Network for three dischargers at a cost of ~\$118 million for the first year. For this combination, assuming 30 percent oversight for O&M, the total annual costs are approximately \$2,258,997 for Design 1-2C. The total opinion of probable cost construction and implementation is \$117,695,094. Projecting this total probable cost over a 20 year operating cycle, results in a total cost of approximately \$160,616,037. The cost breakdown for Design 1-2C is presented in Table 5.2 Alternative C.

If Speece cones were used for either alternative, rolling maintenance shutdowns may be used to limit the number of cones operating during the shutdowns with similar operating cost savings as presented in Table 5.0.

As previously mentioned, the Speece cone alternative has higher annual costs with the assumed 90 days of operation. Over 20 years the O&M costs are considerable. However, actual durations for operating the Speece cones will generally be much less than 90 days and will typically occur during periods when critical low flows coincide with high temperatures in the Savannah Harbor.

5.1.3 Phase I, Step 3 (~68,000 lbs/day Reduction)

The most cost effective methods for meeting the total oxygen requirement of 68,250 lbs/day during the critical summer months appear to be through the use of oxygen injection technology in the harbor. Two designs are presented. The first (Design 1-3A) is through the use of 7 Speece cones to provide the total supplemental oxygen requirement for the system during the critical summer months in the harbor. For 90 days of the summer, the 7 Speece cones would be required to inject approximately 70,000 lbs/day. The capital cost for those cones is \$425,000 each, for a total capital cost of \$2,975,000. Each Speece cone would require an oxygen plant at \$325,000 per cone for a capital cost of \$2,275,000. Assuming 15 percent oversight cost and 50 percent contingency cost, total capital costs for 7 Speece cones is approximately \$8,662,500. During the operating period from mid-July through mid-September and when flows are near critical, O&M and energy costs for each Speece cone are 200 kWh/ton and 600 kWh/ton, respectively or \$24/ton per day O₂ and \$72/ton per day O₂.

Assuming 30 percent oversight for O&M, the total annual costs are approximately \$393,120 for Design 1-3A. The total opinion of probable cost construction and implementation is \$9,055,620. Projecting this

total probable cost over a 20 year operating cycle, results in a total cost of approximately \$16,524,900. Design 1-3A is presented in Figure 5.3.

The second design (Design 1-3B) is the use of Speece cones in combination with rolling maintenance shutdowns of the four largest industrial point source dischargers. This would reduce O&M costs, as estimated in Table 5.3. For 34 days of the summer, the 7 Speece cones would be required to operate at their full capacity and inject approximately 70,000 lbs/day. If Speece cones were used, rolling maintenance shutdowns may be used to reduce O&M costs as estimated in Table 5.0.

Assuming 30 percent oversight for O&M, the total annual costs are approximately \$244,608 for Design 1-3B. The total opinion of probable cost construction and implementation is \$8,907,108. Projecting this total probable cost over a 20 year operating cycle, results in a total cost of approximately \$13,554,660. The cost breakdown for Design 1-3B is presented in Table 5.3 and Figure 5.3.

5.1.4 Phase I, Step 4 (~503,500 lbs/day Reduction)

The most cost effective methods for meeting the total oxygen requirement of 503,500 lbs/day during the critical summer months appear to be through the use of oxygen injection technology in the harbor. Two designs are presented. The first (Design 1-4A) is through the use of Speece cones. Fifty (50) Speece cones would meet the required 503,500 lbs/day oxygen need at a probable capital cost of \$61,875,000 (Table 5.4 Alternative A). To estimate annual operating costs, the system is assumed to operate at full capacity for 90 days. The annual costs for this design are estimated to be \$2,808,000 while the total probable cost to construct and operate this alternative over a 20-year period is \$118,035,000.

A variation is Design 1-4B, the use of Speece cones in combination with rolling maintenance shutdowns. Again, fifty (50) Speece cones would meet the required 503,500 lbs/day oxygen for the majority of the critical summer period. However, the rolling maintenance shutdowns would reduce the number of days the Speece cones would have to operate at full capacity. This would reduce annual operating costs. To estimate annual operating costs, the injection system is assumed to operate at full capacity for 34 days. For the remaining 56 days, injection requirements would be lower because of the reduced point source loading. The annual costs for this design are estimated to be \$2,607,072, while the total probable costs to construct and operate this alternative over a 20-year period is \$114,016,440.

Another variation is Design 1-4C, the use of twentyfour (24) Speece cones, rolling maintenance shutdowns, and a Discharge Network collecting the IP Savannah (Appendix E, Option II-A-1) effluent and routing to a timed tidal discharge outfall near RM 5.5 is approximately \$86.3 million for the first year. This would transport the effluent past the critical DO segment. The annual costs for this design are estimated to be \$1,360,437, while the total probable costs to construct and operate this alternative over a 20-year period is \$112,218,416. See Table 5.4 Alternative C and Figure 5.4.

Another variation is Design 1-4D, the use of twentyfour (24) Speece cones, rolling maintenance shutdowns; a Discharge Network collecting Weyerhaeuser, IP Savannah, and President Street effluent (Appendix E, Option I-B); and routing to a storage pond for 30-day retention with direct discharge in the Back River. The capital cost for this design is estimated to be ~\$97 million for the first year. The \$10 million additional capital cost over the previous design is the result of the costs to construct the detention pond for 30-day storage of effluent from the three industrial facilities. The multiple features in this design would reduce loading for 30 days during the critical season. The annual costs for this design are estimated to be \$1,360,437, while the total probable costs to construct and operate this alternative over a 20-year period is \$122,844,837. See Table 5.4 Alternative D and Figure 5.4.

As previously mentioned, the Speece cone alternative has higher annual costs with the assumed 90 days of operation. Over 20 years the O&M costs are considerable. However, actual durations for operating the Speece cones will generally be much less than 90 days and will occur during periods when critical low flows coincide with high temperatures in the Savannah Harbor.

5.2 PHASE II

ASSUMPTIONS:

- 15 percent oversight
- 50 percent capital cost contingency
- 30 percent annual cost contingency
- 50 foot barge(s) available for use with no storage expenses
- alternatives are required for 90 days (summer season)
- costs associated with land acquisition and acquisition of right-of-ways and required local, state and federal permitting are not estimated
- costs associated with construction of electrical service or costs for diesel generators are not estimated

5.2.1 Phase II, Step 1, Incremental Increase (0.2 mg/L)

A DO incremental increase of 0.2 mg/L equates to approximately 72,818 lbs/day. One of the more cost-effective methods for meeting the total oxygen requirement of 72,818 lbs/day during the critical summer months is to use an oxygen injection technology in the harbor, such as Speece cones. For 90 days of the summer months, 8 Speece cones would be required to inject 80,000 lbs/day at \$425,000 per cone for a capital cost of \$3,400,000. Each Speece cone would require an oxygen plant at \$325,000 per cone for a capital cost of \$2,600,000. Assuming a 15 percent oversight cost and 50 percent contingency cost, total capital costs for 8 Speece cones is approximately \$9,900,000. During the operating period from mid-July through mid-September and when flows and temperatures are near critical, O&M and energy costs for each Speece cone are 200 kWh/ton and 600 kWh/ton respectively or \$24/ton per day O₂ and \$72/ton per day O₂.

Assuming a 90 day operation and 30 percent oversight and reporting for O&M, the total annual costs are approximately \$449,280 for Phase II, Step 1. The total opinion of probable cost construction and implementation is \$10,349,280. Projecting this total probable cost over a 20-year operating cycle, results in a total cost of approximately \$18,885,600. The cost breakdown for Phase II, Step 1 is presented in Table 5.5 and Figure 5.5.

5.2.2 Phase II, Step 2, Incremental Increase (0.4 mg/L)

A DO incremental increase of 0.4 mg/L equates to approximately 145,636 lbs/day. As stated previously, one of the more cost-effective methods for meeting the total oxygen requirement of 145,636 lbs/day during the critical summer months is to use an oxygen injection technology in the harbor, such as Speece cones. For 90 days of the summer months, 15 Speece cones would be required to inject 150,000 lbs/day at \$425,000 per cone for a capital cost of \$6,375,000. Each Speece cone would require an oxygen plant at \$325,000 per cone for a capital cost of \$4,875,000. Assuming a 15 percent oversight cost and 50 percent contingency cost, total capital costs for 15 Speece cones is approximately \$18,562,500. During the operating period from mid-July through mid-September and when flows and temperatures are near critical, O&M and energy costs for each Speece cone are 200 kWh/ton and 600 kWh/ton respectively or \$24/ton per day O₂ and \$72/ton per day O₂.

Assuming 30 percent oversight and reporting for O&M, the total annual costs are approximately \$842,400 for Phase II, Step 2. The total opinion of probable cost construction and implementation is

\$19,404,900. Projecting this total probable cost over a 20-year operating cycle, results in a total cost of approximately \$35,410,500. The cost breakdown for Phase II, Step 2 is presented in Table 5.6 and Figure 5.6.

5.2.3 Phase II, Step 3, Incremental Increase (0.6 mg/L)

A DO incremental increase of 0.6 mg/L equates to approximately 218,455 lbs/day. One of the more cost-effective methods for meeting the total oxygen requirement of 218,455 lbs/day during the critical summer months is to use an oxygen injection technology in the harbor, such as Speece cones. For 90 days of the summer months, 22 Speece cones would be required to inject 220,000 lbs/day at \$425,000 per cone for a capital cost of \$9,350,000. Each Speece cone would require an oxygen plant at \$325,000 per cone for a capital cost of \$7,150,000. Assuming a 15 percent oversight cost and 50 percent contingency cost, total capital costs for 22 Speece cones is approximately \$27,225,000. During the operating period from mid-July through mid-September and when flows and temperatures are near critical, O&M and energy costs for each Speece cone are 200 kWh/ton and 600 kWh/ton respectively or \$24/ton per day O₂ and \$72/ton per day O₂. Assuming a summer month treatment time period of 90 days, 22 Speece cones would run for 56 days providing approximately 220,000 lbs/day.

Assuming 30 percent oversight and reporting for O&M, the total annual costs are approximately \$1,235,520 for Phase II Step 3. The total opinion of probable cost construction and implementation is \$28,460,520. Projecting this total probable cost over a 20-year operating cycle, results in a total cost of approximately \$51,935,400. The cost breakdown for Phase II, Step 3 is presented in Table 5.7 and Figure 5.7.

5.2.4 Phase II, Step 4, Incremental Increase (0.8 mg/L)

A DO incremental increase of 0.8 mg/L equates to approximately 291,273 lbs/day. One of the more cost-effective methods for meeting the total oxygen requirement of 291,273 lbs/day during the critical summer months is to use an oxygen injection technology in the harbor, such as Speece cones. For 90 days of the summer months, 29 Speece cones would be required to inject 290,000 lbs/day at \$425,000 per cone for a capital cost of \$12,325,000. Each Speece cone would require an oxygen plant at \$325,000 per cone for a capital cost of \$9,425,000. Assuming a 15 percent oversight cost and 50 percent contingency cost, total capital costs for 29 Speece cones is approximately \$35,887,000. During the operating period from mid-July through mid-September and when flows and temperatures are near critical, O&M and energy costs

for each Speece cone are 200 kWh/ton and 600 kWh/ton respectively or \$24/ton per day O₂ and \$72/ton per day O₂. Assuming a summer operating period of 90 days, 29 Speece cones would run for 90 days providing approximately 290,000 lbs/day.

Assuming 30 percent oversight and reporting for O&M, the total annual costs are approximately \$1,628,640 for Phase II Step 4. The total opinion of probable cost construction and implementation is \$37,516,140. Projecting this total probable cost over a 20-year operating cycle, results in a total cost of approximately \$68,460,300. The cost breakdown for Phase II, Step 4 is presented in Table 5.8 and Figure 5.8.

6.0 FINAL SELECTION OF CONCEPTUAL DESIGN ALTERNATIVES

The conceptual design alternatives are a collection of selected DO improvement technologies, which together will achieve the current and needed DO concentrations in the Savannah Harbor. Technologies were evaluated based on requirements to meet current and proposed TMDL DO requirements in the critical segment of the Savannah River Estuary. These technologies were evaluated on several characteristics, including cost, energy consumption, and oxygen transfer efficiency. Those technologies that scored best in the second level screening evaluation have been incorporated into the conceptual design phase.

6.1 PHASE I

The following Phase I final selections are conceptual designs based on the cost effectiveness of oxygen injection technologies for achieving required TMDL DO concentrations to counteract discharges from Upstream and Harbor BOD point sources and BOD from non-point sources.

6.1.1 Phase I, Step 1 (~200,000 lbs/day Reduction)

One of the more cost effective methods for meeting the total oxygen requirement of 290,250 lbs/day during the critical summer months is to use an oxygen injection technology to supplement reaeration in the harbor, such as Speece cones in combination with rolling maintenance shutdowns. During the critical season, 29 Speece cones would be required to inject 290,000 lbs/day at \$425,000 per cone for a capital cost of \$12,325,000. Each Speece cone would require an oxygen plant at \$325,000 per cone for a capital cost of \$9,425,000. The rolling maintenance shutdown program could be applied on a basin wide scale and potentially result in long-term cost savings as shown in Table 5.0.

The total opinion of probable cost construction and implementation is \$37,713,324. Projecting this total probable cost over a 20 year operating cycle, results in a total cost of approximately \$72,403,980. The cost breakdown for Phase 1, Step 1 was presented in Table 5.1 and Figure 6.1. Speece cones would be grouped in 3 to 4 cones per fixed location or with up to 8 cones per barge.

6.1.2 Phase I, Step 2 (~725,500 lbs/day Reduction)

One of the more cost effective methods for meeting the total oxygen requirement of 725,500 lbs/day during the critical summer months is to use an oxygen injection technology to supplement reaeration in the harbor, such as Speece cones in combination with rolling maintenance shutdowns. During the critical season, 73 Speece cones would be required to inject 725,500 lbs/day at \$425,000 per cone for a capital cost of \$31,025,000. Each Speece cone would require an oxygen plant at \$325,000 per cone for a capital cost of \$23,725,000. The O&M and energy costs are directly proportional to the days the oxygen injection is needed. Further study using the Harbor Model may help to refine where, when, and how much oxygen is needed.

The total opinion of probable cost construction and implementation is \$95,451,921. Projecting this total probable cost over a 20 year operating cycle, results in a total cost of approximately \$192,625,920. The cost breakdown for Phase 1, Step 2 was presented in Table 5.2 Alternative A and Figure 6.2.

6.1.3 Phase I, Step 3 (~68,000 lbs/day Reduction)

One of the more cost effective methods for meeting the total oxygen requirement of 68,250 lbs/day during the critical summer months is to use an oxygen injection technology to supplement reaeration in the harbor, such as Speece cones in combination with rolling maintenance shutdowns. For 56 days of the summer months 7 Speece cones may be used to inject 70,000 lbs/day at \$425,000 per cone a capital cost of \$2,975,000. Each Speece cone would require an oxygen plant at \$325,000 per cone for a capital cost of \$2,275,000. Rolling maintenance shutdowns may be used to reduce the total O&M costs.

The total opinion of probable cost construction and implementation is \$9,216,729. Projecting this total probable cost over a 20 year operating cycle, results in a total cost of approximately \$19,747,080. The cost breakdown for Phase 1, Step 3 was presented in Table 5.3 and Figure 6.3.

6.1.4 Phase I, Step 4 (~504,000 lbs/day Reduction)

One of the more cost effective methods for meeting the total oxygen requirement of 503,500 lbs/day during the critical summer months is to use an oxygen injection technology to supplement reaeration in the harbor, such as Speece cones in combination with rolling maintenance shutdowns. Fifty (50) Speece cones may be used to meet the required 503,500 lbs/day oxygen. During the critical season, 50 Speece cones would be required to inject 503,500 lbs/day at \$425,000 per cone for a capital cost of \$21,250,000.

Each Speece cone would require an oxygen plant at \$325,000 per cone for a capital cost of \$16,250,000. Assuming a 15 percent oversight cost and 50 percent contingency cost, total capital costs for 73 Speece cones is approximately \$61,875,000. The O&M and energy costs are directly proportional to the days the oxygen injection is needed. Further study using the Savannah Harbor model may help to refine where, when, and how much oxygen is needed.

Application of the Rolling Maintenance BMP may result in an O&M savings. Projecting this total probable cost over a 20 year operating cycle, results in a total cost of approximately \$132,014,940. The cost breakdown for Phase I, Step 4 is presented in Table 5.4 Alternative A and Figure 6.4.

6.2 PHASE II

6.2.1 Phase II, Step 1, Incremental Increase (0.2 mg/L)

A DO incremental increase of 0.2 mg/L equates to approximately 72,818 lbs/day. One of the more cost-effective methods for meeting the total oxygen requirement of 72,818 lbs/day during the critical summer months is to use an oxygen injection technology to supplement reaeration in the harbor, such as Speece cones. For 90 days of the summer months, 8 Speece cones would be required to inject 80,000 lbs/day at \$425,000 per cone for a capital cost of \$3,400,000. Each Speece cone would require an oxygen plant at \$325,000 per cone for a capital cost of \$2,600,000. Assuming a 15 percent oversight cost and 50 percent contingency cost, total capital costs for 8 Speece cones is approximately \$9,900,000. During the operating period from mid-July through mid-September and when flows are near critical, O&M and energy costs for each Speece cone are 200 kWh/ton and 600 kWh/ton respectively or \$24/ton per day O_2 and \$72/ton per day O_2 . Assuming a summer month treatment time period of 90 days, 8 Speece cones would run for 90 days providing approximately 80,000 lbs/day.

Assuming 30 percent oversight and reporting for O&M, the total annual costs are approximately \$449,280 for Phase II Step 1. The total opinion of probable cost construction and implementation is \$10,349,280. Projecting this total probable cost over a 20-year operating cycle, results in a total cost of approximately \$18,885,600. The cost breakdown for Phase II, Step 1 is presented in Table 5.5 and Figure 6.5.

6.2.2 Phase II, Step 2, Incremental Increase (0.4 mg/L)

A DO incremental increase of 0.4 mg/L equates to approximately 145,636 lbs/day. As stated previously, one of the more cost-effective methods for meeting the total oxygen requirement of 145,636 lbs/day during the critical summer months is to use an oxygen injection technology to supplement reaeration in the harbor, such as Speece cones. For 90 days of the summer months, 15 Speece cones would be required to inject 150,000 lbs/day at \$425,000 per cone for a capital cost of \$6,375,000. Each Speece cone would require an oxygen plant at \$325,000 per cone for a capital cost of \$4,875,000. Assuming a 15 percent oversight cost and 50 percent contingency cost, total capital costs for 15 Speece cones is approximately \$18,562,500. During the operating period from mid-July through mid-September and when flows are near critical, O&M and energy costs for each Speece cone are 200 kWh/ton and 600 kWh/ton respectively or \$24/ton per day O_2 and \$72/ton per day O_2 . Assuming a summer month treatment time period of 90 days, 15 Speece cones would run for 90 days providing approximately 150,000 lbs/day.

Assuming 30 percent oversight and reporting for O&M, the total annual costs are approximately \$842,400 for Phase II Step 2. The total opinion of probable cost construction and implementation is \$19,404,900. Projecting this total probable cost over a 20-year operating cycle, results in a total cost of approximately \$35,410,500. The cost breakdown for Phase II, Step 2 is presented in Table 5.6 and Figure 6.6

6.2.3 Phase II, Step 3, Incremental Increase (0.6 mg/L)

A DO incremental increase of 0.6 mg/L equates to approximately 218,455 lbs/day. One of the more cost-effective methods for meeting the total oxygen requirement of 218,455 lbs/day during the critical summer months is to use an oxygen injection technology to supplement reaeration in the harbor, such as Speece cones. For 90 days of the summer months, 22 Speece cones would be required to inject 220,000 lbs/day at \$425,000 per cone for a capital cost of \$9,350,000. Each Speece cone would require an oxygen plant at \$325,000 per cone for a capital cost of \$7,150,000. Assuming a 15 percent oversight cost and 50 percent contingency cost, total capital costs for 22 Speece cones is approximately \$27,225,000. During the operating period from mid-July through mid-September and when flows and temperatures are near critical, O&M and energy costs for each Speece cone are 200 kWh/ton and 600 kWh/ton respectively or \$24/ton per day O_2 and \$72/ton per day O_2 . Assuming a summer month treatment time period of 90 days, 22 Speece cones would run for 90 days providing approximately 220,000 lbs/day of oxygen added.

Assuming 30 percent oversight and reporting for O&M, the total annual costs are approximately \$1,235,520 for Phase II Step 3. The total opinion of probable cost construction and implementation is \$28,460,520. Projecting this total probable cost over a 20-year operating cycle, results in a total cost of approximately \$51,935,400. The cost breakdown for Phase II, Step 3 is presented in Table 5.7 and Figure 6.7.

6.2.4 Phase II, Step 4, Incremental Increase (0.8 mg/L)

A DO incremental increase of 0.8 mg/L equates to approximately 291,273 lbs/day. One of the more cost-effective methods for meeting the total oxygen requirement of 291,273 lbs/day during the critical summer months is to use an oxygen injection technology to supplement reaeration in the harbor, such as Speece cones. For 90 days of the summer months, 29 Speece cones would be required to inject 290,000 lbs/day at \$425,000 per cone for a capital cost of \$12,325,000. Each Speece cone would require an oxygen plant at \$325,000 per cone for a capital cost of \$9,425,000. Assuming a 15 percent oversight cost and 50 percent contingency cost, total capital costs for 29 Speece cones is approximately \$35,887,000. During the operating period from mid-July through mid-September and when flows are near critical, O&M and energy costs for each Speece cone are 200 kWh/ton and 600 kWh/ton respectively or \$24/ton per day O₂ and \$72/ton per day O₂. Assuming a summer month treatment time period of 90 days, 29 Speece cones would run for 90 days providing approximately 290,000 lbs/day.

Assuming 30 percent oversight and reporting for O&M, the total annual costs are approximately \$1,628,640 for Phase II Step 4. The total opinion of probable cost construction and implementation is \$37,516,140. Projecting this total probable cost over a 20-year operating cycle, results in a total cost of approximately \$68,460,300. The cost breakdown for Phase II, Step 4 is presented in Table 5.8 and Figure 6.8.

7.0 RECOMMENDED DESIGN ALTERNATIVES

Conclusions reached during this screening of technologies applicable to the Savannah Harbor for improving DO concentrations as well as providing for future expansion of the harbor are as follows.

Tertiary treatment costs for each discharger may need to be researched because treatment options such as membrane filtration requires specific effluent characterization for an effective design. Some BOD characterization has been performed thus far in the Savannah Harbor Wastewater Characterization Study which analyzed samples from August 1999 for select dischargers. In any event, the complete elimination of all point source discharges in Augusta and Savannah would only reduce the critical DO deficit by 0.55 ug/L.

Capital costs for technologies to reroute or store BOD loadings from the top five dischargers exceed the capital costs for direct oxygen injection to supplement reaeration in the harbor. Therefore, recommendations for each phase involve oxygen injection technology. Rolling maintenance shutdowns may have an impact on reducing the BOD loadings but are only effective for a period of an individual shutdown. This managerial implementation is the most cost effective technology besides direct oxygen injection. Combined together these two technologies may satisfy any phase and step considered in this study.

In summary, a 12 feet diameter Speece Cone 15 feet tall with the discharge placed 50 feet below the water surface may provide the following results:

- 60 mg/L DO Concentration in the discharge
- 34 cfs cone flow
- 10,000 to 12,000 lbs O₂/day injected
- 45 horsepower (hp) pump utilized
- >90% oxygen absorption
- <200 kW hr/ton DO consumed depending on depth
- Cost of units - \$85,000/ton DO/day (\$500,000 per 12 feet diameter unit with pump)

The results of this system's high efficiency and low unit energy consumption occur in part because turbulence is confined to the inside of the cone with no bottom scouring. These results are also achieved

without interfering with ship channel traffic. Other advantages of the Speece cone technology are the ability to become a self contained mobile or stationary oxygenation barge.

Oxygen injection technologies may also be used to superoxygenate municipal and industrial discharges. Using this technology, sufficient DO may be added to a discharge to provide sufficient oxygen to offset a portion of the BOD contribution thereby limiting the impact to the harbor DO sources. (Appendix D, Section 6).

The final selection conceptual design figures here in represent a conceptual distribution of locations for oxygen injection technologies. Further study utilizing the Harbor Model is recommended to optimize the locations and operating parameters for oxygen injection. One Speece cone may provide approximately 10,000-12,500 lbs/day oxygen. Combining more Speece cones in one area (up to four) may provide 40,000-50,000 lbs/day oxygen. Using a mobile injection station such as a barge with up to 8 Speece cones providing approximately 80,000-96,000 lbs/day oxygen allows flexibility by providing oxygen to an area based on real-time DO monitoring. Another scenario that may optimize the use of Speece cones is injecting oxygen into the Harbor only during incoming tides.

It is also recommended to study the feasibility of using direct power for energy needs versus diesel generators. Availability of electrical service may also help determine the locations for harbor injection technology. A key consideration in supplementing oxygen to the harbor is the availability of land at key location defined by DO deficient conditions within the harbor, upon which the oxygenation system may be placed. The availability of electricity is another consideration. Generally it is quite expensive to bring in electrical service. These two factors; the availability of real estate in the vicinity of the needed oxygen supplementation and the availability of electricity will be significant initial cost factors. A self contained unit, with its own PSA oxygen generation source, may be driven by an internal combustion engine which does not require an electrical power source. Furthermore, the pumps required to move water through the oxygen transfer vessel may be powered by combustion engine driver pumps. Thus, the barge units may only need to be supplied with diesel fuel. Propane may also be substituted for diesel fuel.

For future expansion of the harbor, the Speece cone technology also satisfies the supplemental oxygen need at varying depths. Speece cones have been implemented in lakes and river bodies at depths over 50 feet (Speece, Appendix D).

*Identification and Screening Level Evaluation of Measures to Improve
Dissolved Oxygen in the Savannah River Estuary
USACE Savannah District
Savannah, Georgia*

*FINAL
June 2005
MACTEC Project 6301-05-0001
Contract No. W91273-04-D-0009, Delivery Order C/F01*

For more detailed analysis of the different oxygenation technologies considered in this screening please refer to Appendix D.

8.0 REFERENCES

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*Identification and Screening Level Evaluation of Measures to Improve
Dissolved Oxygen in the Savannah River Estuary
USACE Savannah District
Savannah, Georgia*

*FINAL
June 7, 2005
MACTEC Project 6301-05-0001
Contract No. W91278-04-D-0009, Delivery Order C/P3*

TABLES

USACE, SHEPHERS
Chatham County, Georgia

MACTEC Project Number: 6301-05-0001
Contract Number: W912798-04-4-0009-CV01
March 31, 2005

Table 2.1

Top Five Point Source Dischargers¹
Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen in the Savannah River Estuary
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Project
Chatham County, Georgia

Facility Name	NPDES ID	Full Permit Limits					Oxygen Demanding Load Based on Current Permit Limits				
		Flow ^a (MGD)	TMDL Flow ^a (MGD)	BOD ₅ ^c (lbs/day)	NH ₃ (mg/L)	NH ₃ (lbs/day)	F-Ratio	CBOD ₅ (lbs/day)	NBOD ₅ (lbs/day)	TBOD ₅ (lbs/day)	Permit Limit TBOD ₅ (lbs/day)
International Paper (Savannah)	GA0001988	38.00	1.30	25,000	NA	NA	10.7	267,500	NA	267,500	267,500
International Paper (Augusta)	GA0002801	40.00	NA	30,000	NA	NA	6	180,000	NA	180,000	135,000 ^d
Fort James Paper (GA Pacific)	GA0046973	33.00	0.80	10,850	NA	NA	5	54,250	NA	54,250	54,250
Weyerhaeuser-Port Wentworth	GA0002798	22.00	0.10	6,700	NA	NA	4.5	30,150	NA	30,150	30,150
President Street	GA0025348	27.00	27.00	4,166	12.9	2,905	3.9	16,247	13,276	29,523	29,523

Facility Name	NPDES ID	Flow ^a (MGD)
International Paper (Augusta)	GA0002801	30.00
International Paper (Savannah)	GA0001988	28.00
Fort James Paper (GA Pacific)	GA0046973	19.00
Weyerhaeuser-Port Wentworth	GA0002798	11.75
President Street	GA0025348	25.83

Prepared By: _____
Checked By: _____

Notes:
NPDES - National Pollutant Discharge Elimination System
MGD - million gallons per day
TMDL - Total Maximum Daily Load
BOD₅ - Biochemical Oxygen Demand
lbs/day - pounds per day
mg/L - milligrams per liter
CBOD₅ - Carbonaceous Ultimate Biochemical Oxygen Demand
NBOD₅ - Nitrogenous Ultimate Biochemical Oxygen Demand
TBOD₅ - Total Ultimate Biochemical Oxygen Demand
NA - Not Applicable
RM - River Mile
m³/ton - cubic meters per ton

(1) Based on current permit limits as reported in USEPA Envirofacts Database. For upstream dischargers 75% of the permitted load was used to complete the ranking.
(a) As reported in the Draft TMDL (USEPA, 2004). Values for IP-Savannah, GAFAC, Weyerhaeuser are assumed to be erroneous. Permit limits and discharge monitoring report (DMR) data were used to provide flow information for design.
(b) Indicates the following flow assumptions:
 IP Augusta maximum capacity taken from USEPA Envirofacts Database, 2005 (80.05 m³/ton flow to surface water multiplied by 1900 tons/day consumer packaging)
 GA Pacific & IP Savannah taken from yearly maximum actual flow as reported in the facilities 1999 DMR.
 Weyerhaeuser taken from yearly maximum actual flow as reported in the facilities 2000 DMR.
 President Street NPDES permitted flow criteria (taken from EPA Envirofacts website)
(c) USEPA, 2004. Draft Total Maximum Daily Load (TMDL) for Dissolved Oxygen in Savannah Harbor River Basin: Chatham and Effingham Counties, Georgia. U.S. Environmental Protection Agency, August 2004.
(d) Assumes 75% TBOD₅ reaches the upper estuary area.
(e) Indicates the following flow assumptions:
 IP Augusta 1997-2001 average flow and CBOD₅ was taken from a graph from the Middle Savannah River Model from the Augusta Lock and Dam (RM 199.1) to Clio, Georgia (RM 59) (USEPA, 2003).
 USEPA, 2004. PowerPoint Presentation provided by Steve Whitlock, USEPA R4.
 GA Pacific & IP Savannah taken from yearly average actual flow and BOD as reported in the facilities 1999 DMR.
 Weyerhaeuser taken from yearly average actual flow as reported in the facilities 2000 DMR.
 President Street yearly maximum flow as reported in the facilities 1999 DMR.

Table 3.1
Level I Assessment of Dissolved Oxygen Technology
Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen in the Savannah River Estuary
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Project
Chatham County, Georgia

DISOXYGEN OXYGEN IMPROVEMENT TECHNOLOGY Harbor and Channel	Potentially Effective and Compatible with Site-Specific Conditions - Additional Evaluation Necessary		Comment
	Harbor System	Point Source Discharger	
ADVANCED TREATMENT			
Membrane Filtration	NO	YES	Membrane filtration is effective as a tertiary treatment process by removing sedimentary particles and particulate organics from the wastewater. However, it is not effective in reducing DO loadings from dissolved oxygen demand. Design criteria requires detailed subsurface characterization (including cost analysis). To achieve effective BOD removal, biological wastewater treatment occurs at a high mixed liquor suspended solids concentration and is a short-term and low-volume process. The high concentration of sludge causing bacteria consume readily available organic matter and are not suitable for the permit limits. Use of fine bubble diffusers is not effective in this harbor. Membrane filtration is not effective in this harbor. Membrane filtration is not suitable for the volume and configuration of Savannah Harbor.
AERATION ALTERNATIVES			
Cannula Aerator	NO	NO	Second surface aeration increases surface area of the water in contact with the atmosphere by rotating water over a series of rings. This turbulence increases the surface area and aerates it through diffusion at the air/water interface. This type of aeration could not be located in navigable waterways or be applicable for the volume and configuration of Savannah Harbor.
Channel - Natural Inversion	NO	NO	The Channel Natural Inversion process creates a vertical mixing zone by causing unusual inversion where high DO surface water mix with low DO deep water. This technology is very useful for static water bodies such as storage lagoons or ponds but is not applicable to rivers or other fast flowing water bodies.
Channel Bubble Diffuser	NO	NO	Channel bubble diffusers release air bubbles at the bottom of a water column. Oxygen transfer is achieved by diffusion at the air/water interface as the bubble rise through the water column. Oxygen transfer is limited by the bubble size (bubble surface area), atmospheric oxygen content, and water depth. Larger air bubbles have less total air flow area and, therefore oxygen transfer efficiencies are relatively low compared to other aeration technologies. Diffusers would need to be installed in the bottom of the navigation channel making them unsuitable for application in this harbor.
Fine Bubble Diffuser	NO	NO	Fine bubble diffusers have higher oxygen transfer efficiencies (than Channel Bubble) due to the smaller bubble size and higher surface area. These diffusers require a deep water column to maximize oxygen transfer. The diffusers would need to be installed in the bottom of the two specific channel making them unsuitable for application in this harbor.
McQuay - Sinker Barge	NO	NO	Sinker barge technology is similar to using fine bubble diffusers. Based on the size of the barge and the pressure on the air/oxygen delivery base, oxygen transfer rates are adjustable. The system is susceptible to pore clog and requires periodic, regular flow replacement. Deep water columns (greater than 100 feet) are needed to maximize oxygen transfer. The barge would need to be installed in the bottom of the navigation channel making them unsuitable for application in this harbor.
Mechanical Surface Aeration	NO	NO	Generally, mechanical surface aerators splash water to increase surface area to increase diffusion. Oxygen transfer is limited by the atmospheric oxygen content, not effective for deep water, and are capable of aerating only a small total area per unit. Surface aerators would need to be placed in unit along the navigation channel making them unsuitable for use in this harbor.

Table 3.2

Level II Assessment of Limitations - Harbor Improvements:
Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen in the Savannah River Estuary
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Project
Chatham County, Georgia

Alternatives	Performance/Effectiveness	Reliability	Evaluation Criteria				Capital Cost	Placement	Score
			O ₂ Absorption Efficiency (%)	Unit Energy per lbs. O ₂ (lbs. O ₂ /hp-hr)	Sidestream O ₂ Conc. (mg/L)				
OXYGEN INJECTION									
ECO-06 - SuperOxygenation (Species Code)	Effective in O ₂ transfer	Low Maintenance	>90	4	60 - 200	Medium	River bank, Barge	16	
Fine Bubble Diffuser using High Purity Oxygen	Requires deep water column. Bottom-maintained not suitable for harbor expansion. Suitable for average pool applications	Moderate Maintenance	60 (Assuming 40 ft water column)	N/A	N/A	Medium	River bottom		
Hydrelith - Aque Transfer System	Good Technical Specifications - limited by volume of DO required	Low Maintenance	60	5	7	High	River bank	4	
Precast - In-Situ Oxygenation	Floting airtanks - Not practical for river channel. Suitable for storage pool	Low Maintenance	>90	13	10	Medium	River Channel/Pool	10	
Sidestream Pressurized Oxygenation	Effective in O ₂ transfer	Low Maintenance	70 - 80	2	100	Medium	River bank	13	
U-Tube	Effective in O ₂ transfer	Low Maintenance	75 - 90	16	50 - 100	High	River bank	14	
Venturi Nozzle	Good Technical Specifications - limited by quantity of DO required	Low Maintenance	60	3	3	1	River bank	15	
						Medium	River bank	10	
PHYSICAL MODIFICATIONS									
Inflatable Weir	Bottom not practical for harbor expansion. Measure for controlling salt water intrusion & increasing mixing	Low Maintenance	N/A	N/A	N/A	Medium	River Channel		
Mechanical Pumps	High energy mixing, low dissolved oxygen improvements	Low Maintenance	N/A	N/A	N/A	Medium	River Channel	6	
								6	
Total Cost	Measure for controlling salt water intrusion not effective for increasing DO concentration	Low Maintenance	N/A	N/A	N/A	Medium	Solid Channel	6	

Notes:
NA - Data is Not Available or Not Applicable
Good - High - 3
Fair - Medium - 2
Poor - Low - 1
BDO - Dissolved Oxygen
ECO - Eco Oxygen Technologies, LLC

Physical Readiness Oxygen Injection Reading Summary: Prepared By: _____
Inflatable Weir - 6 - SuperOxygenation (Species Code) 14 Checked By: _____
Medium Channel - 6 - SuperOxygenation (Species Code) 14
Total Data - Sidestream Pressurized Oxygenation 14

Reader Scale:
Good - High - 3
Fair - Medium - 2
Poor - Low - 1
BDO - Dissolved Oxygen
ECO - Eco Oxygen Technologies, LLC

Table 2.3

Level II Assessment of Limitations - Point Sources
Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen in the Savannah River Estuary
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Project
Chatham County, Georgia

Alternatives		Performance/Effectiveness		Reliability	Evaluation Criteria		Seasonal Application	Score
ADVANCED TREATMENT		BOD Reduction (lbs/day)			Capital Cost			
Membrane Filtration	Tertiary treatment system	Medium Maintenance	Particulate organic solids not remove dissolved organics	High		Wastewater treatment system reconfiguration and site land availability	Annual	10
MANAGEMENT								
Raffing Maintenance Shutdown during Critical Periods	Maintenance shutdown at a facility producing 50% reduction in that dischargers effluent flow	Low Maintenance	0 - 134,000	Low		No area required. Requires coordination and agreement among dischargers along the river/harbor. Maintenance may not be required for a facility during the applicable season. Contingencies for emergency shutdowns and completing routine maintenance activities during a period of facility shutdown are required for other dischargers in the river/harbor. Actual BOD load during shutdowns is not known and would require further investigation	Summer	10
PHYSICAL MODIFICATIONS								
Urban Water Reuse Plan	Reuse of treated wastewater for irrigation during summer period	Medium Maintenance	0 - 30,000	High		Construction of a distribution network and an increase in consumer demand	Summer	10
Seward Pipeline with Treated Tidal Discharge	Reduce BOD loadings by collecting discharge and piping seaward to be discharged with tidal cycle	Medium Maintenance	0 - 500,000	High		Available land and right of ways for pipeline construction	Annual	14
Discharge Collection Network with Supplemental Oxygen Injection (Venturi Nozzle)	Reduces BOD loadings by collecting discharge	Medium Maintenance	~80,000	Medium		Available land area and need for right of ways for pipeline	Annual	18
Constructed Wetlands	Treatment system with increased residence time for polishing of BOD in treated wastewater	Medium Maintenance	0 - 500,000	High		Large land requirement also availability of suitable land and need for right of ways for pipeline construction	Annual	14
Storage and Controlled Discharge Pond	Storage of discharge reduces BOD loadings in the harbor segment during critical period	Low Maintenance	0 - 500,000	Medium		Large land requirement also availability of suitable land and need for right of ways for pipeline construction	Annual	17

Notes:
BOD - Biochemical Oxygen Demand

Ranking Summary:
Seward pipeline with treated tidal discharge (18)
Storage and controlled discharge pond (17)
Constructed wetlands (14)
Discharge collection network with venturi nozzles (14)
Urban water reuse during critical periods (10)

Prepared by: _____
Checked by: _____

Ranking Scale:
Point Source Performance Effectiveness:

1. Most favorable to DQ improvement goals (low maintenance, high BOD reduction (250,000 to 500,000 lbs/day), flow control, and most effective during summer season)
2. Moderate benefit to DQ improvement goals, moderate maintenance, and moderate BOD reduction (100,000 to 250,000 lbs/day), moderate capital costs, some new hardware, and least effective during summer season
3. Further research needed to meet DQ improvement goals, high maintenance, and low BOD reduction (< 100,000 lbs/day), high capital costs, no hardware, and limited seasonal applicability

USACE SHEP/STERS
Chatham County, Georgia

MACTEC Project Number: 6301-05-0001
Contract Number: W912798-04-D-0009; CV01
June 1, 2005

TABLE 5.1 Concept 1 Alternative 1A – Harbor Injection Technology (29 Speece Cones)

Cost Assessment for Design Phase I Step 1

Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen in the Savannah River Estuary
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Study
Chatham County, Georgia

MAJOR ASSUMPTIONS

Present TMDL requirements based on current Georgia DO standard and current (1999) BOD loadings

Required point source BOD reduction is 300,250 lbs/day

(69,000 lbs BOD/day removal from harbor & 161,250 lbs BOD/day removal from upstream)

Required nonpoint source BOD reduction is 90,000 lbs/day

Total Oxygen Requirements = 290,250 lbs/day

Supplemental DO needed during summer months

Harbor injection technology capable of 290,000 lbs O₂/day

Rolling maintenance shut downs for 8 weeks reduces Speece cone O&M

50 % BOD loading reduction from discharger during the scheduled facility maintenance period
(assumes 2-weeks to perform required facility maintenance for top five dischargers (will vary based on actual maintenance needs))

Additional load reduction may be possible if shutdowns are implemented basin wide for every discharger

O&M costs were based on a 90 day operation schedule. However, based on river flows, operation may be limited
and thereby substantially reducing O&M costs.

Costs NOT included in the estimate:

Land Acquisition/Right of Way and required local, state and federal permitting

Construction for electrical service or costs for diesel generators

Item	Quantity	Unit	Unit Cost	Opinion of Probable Cost
CAPITAL COSTS				
Harbor injection technology (Speece Cone)	29	cone	\$ 425,000	\$ 12,325,000
Harbor injection technology (PSA O ₂ plant)	29	cone	\$ 325,000	\$ 9,425,000
Rolling Maintenance Shut Down (JP Augusta)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (GA Pacific)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (Weyerhaeuser)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (JP Savannah)	2	weeks	\$ -	\$ -
			Subtotal	\$ 21,750,000
			Oversight (15%)	\$ 3,262,500
			Contingency (30%)	\$ 10,875,000
			TOTAL CAPITAL COSTS	\$ 35,887,500
ANNUAL COSTS				
Speece Cone O&M plus O ₂ generation energy	90	day	\$ 13,920	\$ 1,252,800
Speece Cone O&M plus O ₂ generation energy (JP Augusta shutdown)	0	day	\$ 10,560	\$ -
Speece Cone O&M plus O ₂ generation energy (GA Pacific shutdown)	0	day	\$ 12,960	\$ -
Speece Cone O&M plus O ₂ generation energy (Weyerhaeuser shutdown)	0	day	\$ 13,440	\$ -
Speece Cone O&M plus O ₂ generation energy (JP Savannah shutdown)	0	day	\$ 7,680	\$ -
			Subtotal	\$ 1,252,800
			Oversight & Reporting (30%)	\$ 375,840
			TOTAL ANNUAL COSTS	\$ 1,628,640

DO = dissolved oxygen

BOD = biochemical oxygen demand

O&M = Operations and Maintenance

CAPITAL COSTS	\$ 35,887,500
ANNUAL COSTS	\$ 1,628,640
TOTAL OPINION OF PROBABLE COSTS	\$ 37,516,140
TOTAL OPINION OF PROBABLE COSTS OVER 20 YEARS	\$ 68,460,300

Prepared By:

Checked By:

USACE SHEP/SHERS
Chatham County, Georgia

MACTEC Project Number: 6301-05-0001
Contract Number: W912798-04-D-0009; CV01
June 1, 2005

TABLE 5.1 Concept 1 Alternative 1B – Harbor Injection Technology (20 Speece Cones with scheduled maintenance shut downs)

Cost Assessment for Design Phase I Step 1

Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen in the Savannah River Estuary
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Study
Chatham County, Georgia

MAJOR ASSUMPTIONS

Present TMDL requirements based on current Georgia DO standard and current (1999) BOD loadings

Required point source BOD reduction is 200,250 lbs/day

(99,000 lbs BOD/day removal from harbor & 101,250 lbs BOD/day removal from upstream)

Required nonpoint source BOD reduction is 90,000 lbs/day

Total Oxygen Requirements = 290,250 lbs/day

Supplemental DO needed during summer months

Harbor injection technology capable of 290,000 lbs O₂/day

Rolling maintenance shut downs for 8 weeks reduces Speece cone O&M

50 % BOD loading reduction from discharger during the scheduled facility maintenance period
(assumes 2-weeks to perform required facility maintenance for top five dischargers (will vary based on actual maintenance needs))

Additional load reduction may be possible if shutdowns are implemented basin wide for every discharger

O&M costs were based on a 90 day operation schedule. However, based on river flows, operation may be limited
and thereby substantially reducing O&M costs.

Costs NOT included in the estimate:

Land Acquisition/Right of Way and required local, state and federal permitting

Construction for electrical service or costs for diesel generators

Item	Quantity	Unit	Unit Cost	Opinion of Probable Cost	
CAPITAL COSTS					
Harbor injection technology (Speece Cone)	29	cone	\$ -425,000	\$	12,325,000
Harbor injection technology (PSA O2 plant)	29	cone	\$ 325,000	\$	9,425,000
Rolling Maintenance Shut Down (IP Augusta)	2	weeks	\$ -	\$	-
Rolling Maintenance Shut Down (GA Pacific)	2	weeks	\$ -	\$	-
Rolling Maintenance Shut Down (Weyerhaeuser)	2	weeks	\$ -	\$	-
Rolling Maintenance Shut Down (IP Savannah)	2	weeks	\$ -	\$	-
Subtotal				\$	21,750,000
Oversight (15%)				\$	3,262,500
Contingency (50%)				\$	10,875,000
TOTAL CAPITAL COSTS				\$	35,887,500
ANNUAL COSTS					
Speece Cone O&M plus O2 generation energy	34	day	\$ 13,920	\$	473,280
Speece Cone O&M plus O2 generation energy (IP Augusta shutdown)	14	day	\$ 10,560	\$	147,840
Speece Cone O&M plus O2 generation energy (GA Pacific shutdown)	14	day	\$ 12,960	\$	181,440
Speece Cone O&M plus O2 generation energy (Weyerhaeuser shutdown)	14	day	\$ 13,440	\$	188,160
Speece Cone O&M plus O2 generation energy (IP Savannah shutdown)	14	day	\$ 7,680	\$	107,520
				\$	-
Subtotal				\$	1,098,240
Oversight & Reporting (30%)				\$	329,472
TOTAL ANNUAL COSTS				\$	1,427,712

DO - dissolved oxygen

BOD - biochemical oxygen demand

O&M - Operations and Maintenance

CAPITAL COSTS	\$	35,887,500
ANNUAL COSTS	\$	1,427,712
TOTAL OPINION OF PROBABLE COSTS	\$	37,315,212
TOTAL OPINION OF PROBABLE COSTS OVER 20 YEARS	\$	64,441,740

Prepared By:

Checked By:

USACE SHEP/SIERS
Chatham County, Georgia

MACTEC Project Number: 6301-05-0001
Contract Number: W912798-04-D-0009; CV01
June 1, 2005

TABLE 5.1 Concept I Alternative IC - Discharge Collection Network 60-day retention

Cost Assessment for Design Phase I Step 2

**Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen in the Savannah River Estuary
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Study
Chatham County, Georgia**

MAJOR ASSUMPTIONS

Present TMDL requirements based on current Georgia DO standard and current (1999) BOD loadings

Required point source BOD reduction is 300,250 lbs/day

(69,000 lbs BOD/day removal from harbor & 101,250 lbs BOD/day removal from upstream)

Required nonpoint source BOD reduction is 90,000 lbs/day

Total Oxygen Requirements = 290,250 lbs/day

Supplemental DO needed during summer months

Harbor injection technology capable of 290,000 lbs O₂/day

Rolling maintenance shut downs for 8 weeks reduces Speece cone O&M

*50 % BOD loading reduction from discharger during the scheduled facility maintenance period
(assumes 2-weeks to perform required facility maintenance for top five dischargers (will vary based on actual maintenance needs))*

*Additional load reduction may be possible if shutdowns are implemented basin wide for every discharger
O&M costs were based on a 90 day operation schedule. However, based on river flows, operation may be limited
and thereby substantially reducing O&M costs.*

Costs NOT included in the estimate:

Land Acquisition Right of Way and required local, state and federal permitting

Construction for electrical service or costs for diesel generators

Item	Quantity	Unit	Unit Cost	Opinion of Probable Cost
CAPITAL COSTS				
Harbor injection technology (Speece Cone)	0	cone	\$ 425,000	\$ -
Harbor injection technology (PSA O ₂ plant)	0	conc	\$ 325,000	\$ -
Discharge Collection Network 60-day HRT Pond (Option II-C-1)	1	network	\$ 42,902,991	\$ 42,902,991
Supplemental Oxygen Injection	10	mile	\$ 40,500	\$ 405,000
Rolling Maintenance Shut Down (IP Augusta)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (GA Pacific)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (Weyerhaeuser)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (IP Savannah)	2	weeks	\$ -	\$ -
			\$ -	\$ -
			Subtotal	\$ 43,307,991
			Oversight (15%)	\$ 6,496,199
			Contingency (50%)	\$ 21,653,996
			TOTAL CAPITAL COSTS	\$ 71,458,185
ANNUAL COSTS				
Speece Cone O&M plus O ₂ generation energy	0	day	\$ 19,200	\$ -
Speece Cone O&M plus O ₂ generation energy (IP Augusta shutdown)	0	day	\$ 15,840	\$ -
Speece Cone O&M plus O ₂ generation energy (GA Pacific shutdown)	0	day	\$ 18,240	\$ -
Speece Cone O&M plus O ₂ generation energy (Weyerhaeuser shutdown)	0	day	\$ 18,720	\$ -
Speece Cone O&M plus O ₂ generation energy (IP Savannah shutdown)	0	day	\$ 12,960	\$ -
Supplemental Oxygen Injection (energy required)	90	day	\$ 1,780	\$ 160,200
Supplemental Oxygen Injection (O&M)	0.1	\$	\$ 40,500	\$ 4,050
			\$ -	\$ -
			Subtotal	\$ 164,240
			Oversight & Reporting (30%)	\$ 49,275
			TOTAL ANNUAL COSTS	\$ 213,525
DO - dissolved oxygen				
BOD - biochemical oxygen demand				
O&M - Operations and Maintenance				
			CAPITAL COSTS	\$ 71,458,185
			ANNUAL COSTS	\$ 213,525
			TOTAL OPINION OF PROBABLE COSTS	\$ 71,671,710
			TOTAL OPINION OF PROBABLE COSTS FOR 20 YEARS	\$ 75,728,685

Prepared By:

Checked By:

USACE SHEP/SHERS
Chatham County, Georgia

MACTEC Project Number: 6301-05-0001
Contract Number: W912798-04-D-0009; CV/01
June 1, 2005

TABLE 5.1 Concept 1 Alternative 1C - Discharge Collection Network 30-day retention

Cost Assessment for Design Phase I Step 2

Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen in the Savannah River Estuary
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Study
Chatham County, Georgia

MAJOR ASSUMPTIONS

Present TMDL requirements based on current Georgia DO standard and current (1999) BOD loadings

Required point source BOD reduction is 290,250 lbs/day

(99,000 lbs BOD/day removal from harbor & 101,250 lbs BOD/day removal from upstream)

Required nonpoint source BOD reduction is 90,000 lbs/day

Total Oxygen Requirements = 290,250 lbs/day

Supplemental DO needed during summer months

Harbor injection technology capable of 250,000 lbs O₂/day

Rolling maintenance shut downs for 8 weeks reduces Speece cone O&M

50 % BOD loading reduction from discharger during the scheduled facility maintenance period
(assumes 2-weeks to perform required facility maintenance for top five dischargers (will vary based on actual maintenance needs))

Additional load reduction may be possible if shutdowns are implemented basin wide for every discharger

O&M costs were based on a 90 day operation schedule. However, based on river flows, operation may be limited
and thereby substantially reducing O&M costs.

Costs NOT included in the estimate:

Land Acquisition/Right of Way and required local, state and federal permitting

Construction for electrical service or costs for diesel generators

Item	Quantity	Unit	Unit Cost	Optimum of Probable Cost
CAPITAL COSTS				
Harbor injection technology (Speece Cone)	0	cone	\$ -425,000	\$ -
Harbor injection technology (PSA O ₂ plant)	0	cone	\$ -325,000	\$ -
Discharge Collection Network 30-day HRT Pond (Option II-B-1)	1	network	\$ 37,471,338	\$ 37,471,338
Supplemental Oxygen Injection	10	milc	\$ 40,500	\$ 405,000
Rolling Maintenance Shut Down (IP Augusta)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (GA Pacific)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (Weyerhaeuser)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (IP Savannah)	2	weeks	\$ -	\$ -
			\$ -	\$ -
			Subtotal	\$ 37,876,338
			Oversight (15%)	\$ 5,681,451
			Contingency (50%)	\$ 18,938,169
			TOTAL CAPITAL COSTS	\$ 62,495,958
ANNUAL COSTS				
Speece Cone O&M plus O ₂ generation energy	0	day	\$ 19,200	\$ -
Speece Cone O&M plus O ₂ generation energy (IP Augusta shutdown)	0	day	\$ 15,840	\$ -
Speece Cone O&M plus O ₂ generation energy (GA Pacific shutdown)	0	day	\$ 18,240	\$ -
Speece Cone O&M plus O ₂ generation energy (Weyerhaeuser shutdown)	0	day	\$ 18,720	\$ -
Speece Cone O&M plus O ₂ generation energy (IP Savannah shutdown)	0	day	\$ 12,960	\$ -
Supplemental Oxygen Injection (energy required)	90	day	\$ 1,780	\$ 160,200
Supplemental Oxygen Injection (O&M)	0.1	\$	\$ 40,500	\$ 4,050
			\$ -	\$ -
			Subtotal	\$ 164,250
			Oversight & Reporting (30%)	\$ 49,275
			TOTAL ANNUAL COSTS	\$ 213,525
DO - dissolved oxygen				
BOD - biochemical oxygen demand				
O&M - Operations and Maintenance				
			CAPITAL COSTS	\$ 62,495,958
			ANNUAL COSTS	\$ 213,525
			TOTAL OPINION OF PROBABLE COSTS	\$ 62,709,483
			TOTAL OPINION OF PROBABLE COSTS FOR 20 YEARS	\$ 66,766,458

Prepared By:

Checked By:

USACE SHEP/STIERS
Chatham County, Georgia

MACTEC Project Number: 6301-05-0001
Contract Number: W912798-04-D-0009; CV/01
June 1, 2005

TABLE 5.2 Concept 1 Alternative 2A – Harbor Injection Technology (73 Speece Cones)

Cost Assessment for Design Phase I Step 2

Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen in the Savannah River Estuary
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Study
Chatham County, Georgia

MAJOR ASSUMPTIONS

Present TMDL requirements based on current Georgia DO standard and current (1999) BOD loadings.

Required Point Source BOD reduction is 635,500 lbs/day

Required Nonpoint Source BOD reduction is 90,000 lbs/day

Total Oxygen Requirements = 725,500 lbs/day

Supplemental DO needed during summer months

Harbor injection technology capable of ~30,000 lbs O₂/day

Inject harbor near midpoint of Hutchinson Island and via mobile barge.

Barge available for use and no storage expense.

Rolling maintenance shut downs for 8 weeks reduces Speece cone O&M

30 % BOD loading reduction from an individual discharger during the scheduled facility maintenance period
(assumes 2-weeks to perform required facility maintenance for top five dischargers)

Additional load reduction may be possible if shutdowns are implemented down wide for every discharger

O&M costs were based on a 90 day operation schedule. However, based on river flows, operation may be limited
and thereby substantially reducing O&M costs.

Costs NOT included in the estimate:

Land Acquisition/Right of Way and required local, state and federal permitting

Construction for electrical service or costs for diesel generators

Item	Quantity	Unit	Unit Cost	Opinion of Probable Cost
CAPITAL COSTS				
Harbor injection technology (Speece Cone)	73	cone	\$ 425,000	\$ 31,025,000
Harbor injection technology (PSA O ₂ plant)	73	cone	\$ 325,000	\$ 23,725,000
Discharge Collection Network 30-day HRT Pond	0	network	\$ 39,556,271	\$ -
Rolling Maintenance Shut Down (IP Augusta)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (GA Pacific)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (Weyerhaeuser)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (IP Savannah)	2	weeks	\$ -	\$ -
				\$ -
			Subtotal	\$ 54,750,000
			Oversight (15%)	\$ 8,212,500
			Contingency (50%)	\$ 27,375,000
			TOTAL CAPITAL COSTS	\$ 90,337,500
ANNUAL COSTS				
Speece Cone O&M plus O ₂ generation energy	90	day	\$ 35,040	\$ 3,153,600
Speece Cone O&M plus O ₂ generation energy (IP Augusta shutdown)	0	day	\$ 31,680	\$ -
Speece Cone O&M plus O ₂ generation energy (GA Pacific shutdown)	0	day	\$ 34,080	\$ -
Speece Cone O&M plus O ₂ generation energy (Weyerhaeuser shutdown)	0	day	\$ 34,560	\$ -
Speece Cone O&M plus O ₂ generation energy (IP Savannah shutdown)	0	day	\$ 28,800	\$ -
Supplemental Oxygen Injection (energy required)	0	day	\$ 1,780	\$ -
Supplemental Oxygen Injection (O&M)	0		\$ 40,500	\$ -
				\$ -
			Subtotal	\$ 3,153,600
			Oversight & Reporting (30%)	\$ 946,080
			TOTAL ANNUAL COSTS	\$ 4,099,680
DO - dissolved oxygen				
BOD - biochemical oxygen demand				
O&M - Operations and Maintenance				
			CAPITAL COSTS	\$ 90,337,500
			ANNUAL COSTS	\$ 4,099,680
			TOTAL OPINION OF PROBABLE COSTS	\$ 94,437,180
			TOTAL OPINION OF PROBABLE COSTS FOR 20 YEARS	\$ 172,331,100

Prepared By:
Checked By:

USACE SHEP/SHERS
Chatham County, Georgia

MACTEC Project Number: 6301-05-0001
Contract Number: W912798-04-D-0009; CV01
June 1, 2005

TABLE 5.2 Concept 1 Alternative 2B – Harbor Injection Technology (73 Speece Cones with scheduled maintenance shutdowns)

Cost Assessment for Design Phase I Step 2

Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen in the Savannah River Estuary
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Study
Chatham County, Georgia

MAJOR ASSUMPTIONS

Present TMDL requirements based on current Georgia DO standard and current (1999) BOD loadings

Required Point Source BOD reduction is 653,500 lbs/day

Required Nonpoint Source BOD reduction is 90,000 lbs/day

Total Oxygen Requirements = 725,500 lbs/day

Supplemental DO needed during summer months

Harbor injection technology capable of 750,000 lbs O₂/day

Inject harbor near midpoint of Hutchinson Island and via mobile barge

Barge available for use and no storage expense

Rolling maintenance shut downs for 8 weeks reduces Speece cone O&M

30 % BOD loading reduction from an individual discharger during the scheduled facility maintenance period
(assumes 2-weeks to perform required facility maintenance for top five dischargers)

Additional load reduction may be possible if shutdowns are implemented basin wide for every discharger
O&M costs were based on a 90 day operation schedule. However, based on river flows, operation may be limited
and thereby substantially reducing O&M costs.

Costs NOT included in the estimate:

Land Acquisition/Right of Way and required local, state and federal permitting

Construction for electrical service or costs for diesel generators

Item	Quantity	Unit	Unit Cost	Opinion of Probable Cost
CAPITAL COSTS				
Harbor injection technology (Speece Cone)	73	cone	\$ -425,000	\$ 31,025,000
Harbor injection technology (PSA O ₂ plant)	73	cone	\$ -325,000	\$ 23,725,000
Discharge Collection Network 30-day HRT Pond	0	network	\$ 39,556,271	\$ -
Rolling Maintenance Shut Down (IP Augusta)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (GA Pacific)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (Weyerhaeuser)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (IP Savannah)	2	weeks	\$ -	\$ -
				\$ -
			Subtotal	\$ 54,750,000
			Oversight (15%)	\$ 8,212,500
			Contingency (50%)	\$ 27,375,000
			TOTAL CAPITAL COSTS	\$ 90,337,500
ANNUAL COSTS				
Speece Cone O&M plus O ₂ generation energy	34	day	\$ - 35,040	\$ 1,191,360
Speece Cone O&M plus O ₂ generation energy (IP Augusta shutdown)	14	day	\$ 31,680	\$ 443,520
Speece Cone O&M plus O ₂ generation energy (GA Pacific shutdown)	14	day	\$ 34,080	\$ 477,120
Speece Cone O&M plus O ₂ generation energy (Weyerhaeuser shutdown)	14	day	\$ 34,560	\$ 483,840
Speece Cone O&M plus O ₂ generation energy (IP Savannah shutdown)	14	day	\$ 28,800	\$ 405,200
Supplemental Oxygen Injection (energy required)	0	day	\$ 1,780	\$ -
Supplemental Oxygen Injection (O&M)	0		\$ 40,500	\$ -
				\$ -
			Subtotal	\$ 2,999,040
			Oversight & Reporting (30%)	\$ 899,712
			TOTAL ANNUAL COSTS	\$ 3,898,752

DO - dissolved oxygen

BOD - biochemical oxygen demand

O&M - Operations and Maintenance

CAPITAL COSTS	\$	90,337,500
ANNUAL COSTS	\$	3,898,752
TOTAL OPINION OF PROBABLE COSTS	\$	94,236,252
TOTAL OPINION OF PROBABLE COSTS FOR 20 YEARS	\$	168,312,540

Prepared By:

Checked By:

TABLE 5.2 Concept 1 Alternative 2C – Speece Cones with Discharge Network and Storage System

Cost Assessment for Design Phase 1 Step 2

Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen in the Savannah River Estuary
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Study
Chatham County, Georgia

MAJOR ASSUMPTIONS

Presents TMDL requirements based on current Georgia DO standard and current (1999) BOD loadings

Required Point Source BOD reduction is 635,500 lbs/day

Required Nonpoint Source BOD reduction is 90,000 lbs/day

Total Oxygen Requirements = 725,500 lbs/day

Supplemental DO needed during summer months

Harbor injection technology capable of 400,000 lbs O₂/day

Inject harbor near midpoint of Hutchinson Island and via mobile barge

Discharge Collection Network (Includes Weyerhaeuser, IP Savannah, and President St. discharge) (227,500 lbs/day retention)

Supplemental oxygen injection for 10 miles capable of 80,000 lbs O₂/day

(requires 22 injectors and 44 nozzles every 2400 feet)

Storage pond system (30-day retention)

Barge available for use and no storage expense

Rolling maintenance shut downs for 8 weeks reduces Speece cone O&M

50 % BOD loading reduction from discharger during the scheduled facility maintenance period

(assumes 2-weeks to perform required facility maintenance for top five dischargers)

Additional load reduction may be possible if shutdowns are implemented basin wide for every discharger

O&M costs were based on a 90 day operation schedule. However, based on river flows, operation may be limited and thereby substantially reducing O&M costs.

Costs NOT included in the estimate:

Land Acquisition/Right of Way and required local, state and federal permitting

Construction for electrical service or costs for diesel generators

Item	Quantity	Unit	Unit Cost	Option of Probable Cost
CAPITAL COSTS				
Harbor injection technology (Speece Cone)	40	cone	\$ 425,000	\$ 17,000,000
Harbor injection technology (PSA O ₂ plant)	40	cone	\$ 325,000	\$ 13,000,000
Discharge Collection Network 30-day HRT Pond (Option 1-B)	1	network	\$ 39,556,271	\$ 39,556,271
Supplemental Oxygen Injection	10	mile	\$ 40,500	\$ 405,000
Rolling Maintenance Shut Down (IP Augusta)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (GA Pacific)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (Weyerhaeuser)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (IP Savannah)	2	weeks	\$ -	\$ -
			\$ -	\$ -
			Subtotal	\$ 69,961,271
			Oversight (15%)	\$ 10,494,191
			Contingency (50%)	\$ 34,980,636
			TOTAL CAPITAL COSTS	\$ 115,436,097
ANNUAL COSTS				
Speece Cone O&M plus O ₂ generation energy	34	day	\$ 19,200	\$ 652,800
Speece Cone O&M plus O ₂ generation energy (IP Augusta shutdown)	14	day	\$ 15,840	\$ 221,760
Speece Cone O&M plus O ₂ generation energy (GA Pacific shutdown)	14	day	\$ 18,240	\$ 255,360
Speece Cone O&M plus O ₂ generation energy (Weyerhaeuser shutdown)	14	day	\$ 18,720	\$ 262,080
Speece Cone O&M plus O ₂ generation energy (IP Savannah shutdown)	14	day	\$ 12,960	\$ 181,440
Supplemental Oxygen Injection (energy required)	90	day	\$ 1,780	\$ 160,200
Supplemental Oxygen Injection (O&M)	0.1		\$ 40,500	\$ 4,050
			\$ -	\$ -
			Subtotal	\$ 1,737,690
			Oversight & Reporting (30%)	\$ 521,307
			TOTAL ANNUAL COSTS	\$ 2,258,997
DO = dissolved oxygen				
BOD = biochemical oxygen demand				
O&M = Operations and Maintenance				
			CAPITAL COSTS	\$ 115,436,097
			ANNUAL COSTS	\$ 2,258,997
			TOTAL OPINION OF PROBABLE COSTS	\$ 117,695,094
			TOTAL OPINION OF PROBABLE COSTS FOR 20 YEARS	\$ 160,616,637

Prepared By:

Checked By:

USACE SHEP/SHERS
Chatham County, Georgia

MACTEC Project Number: 6301-05-0001
Contract Number: W912798-04-D-0009; CV/01
June 1, 2005

TABLE 5.3 Concept 1 Alternative 3A – Harbor Injection Technology (7 Speece cones)

Cost Assessment for Design Phase I Step 3

Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen in the Savannah River Estuary
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Study
Chatham County, Georgia

MAJOR ASSUMPTIONS

TMDL proposed DO Standard requirements and current (1999) BOD loadings

Required Point Source BOD reduction 68,250 lbs/day

Required Nonpoint Source BOD reduction is Not Applicable

Total Oxygen Requirements = 68,250 lbs/day

Supplemental DO needed during summer months

Harbor injection technology capable of 70,000 lbs O₂/day

Inject near midpoint of Hutchinson Island

Rolling maintenance shut downs for 8 weeks reduces Speece cone O&M

50 % BOD loading reduction from discharger during the scheduled facility maintenance period

(assumes 2-weeks to perform required facility maintenance for top five dischargers)

Additional load reduction may be possible if shutdowns are implemented basin wide for every discharger

O&M costs were based on a 90 day operation schedule. However, based on river flows, operation may be limited

and thereby substantially reducing O&M costs.

Costs NOT included in the estimate:

Land Acquisition/Right of Way and required local, state and federal permitting

Construction for electrical service or costs for diesel generators

Item	Quantity	Unit	Unit Cost	Opinion of Probable Cost
CAPITAL COSTS				
Harbor injection technology (Speece Cone)	7	conc	\$ -425,000	\$ 2,975,000
Harbor injection technology (PSA O ₂ plant)	7	conc	\$ 325,000	\$ 2,275,000
Rolling Maintenance Shut Down (IP Augusta)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (GA Pacific)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (Weyerhaeuser)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (IP Savannah)	2	weeks	\$ -	\$ -
			Subtotal	\$ 5,250,000
			Oversight (15%)	\$ 787,500
			Contingency (30%)	\$ 2,625,000
			TOTAL CAPITAL COSTS	\$ 8,662,500
ANNUAL COSTS				
Speece Cone O&M plus O ₂ generation energy	90	day	\$ 3,360	\$ 302,400
Speece Cone O&M plus O ₂ generation energy (IP Augusta shutdown)	0	day	\$ -	\$ -
Speece Cone O&M plus O ₂ generation energy (GA Pacific shutdown)	0	day	\$ 2,400	\$ -
Speece Cone O&M plus O ₂ generation energy (Weyerhaeuser shutdown)	0	day	\$ 2,880	\$ -
Speece Cone O&M plus O ₂ generation energy (IP Savannah shutdown)	0	day	\$ -	\$ -
Supplemental Oxygen Injection (energy required)	0	day	\$ 1,780	\$ -
Supplemental Oxygen Injection (O&M)	0		\$ 40,500	\$ -
			Subtotal	\$ 302,400
			Oversight & Reporting (30%)	\$ 90,720
			TOTAL ANNUAL COSTS	\$ 393,120
DO - dissolved oxygen			CAPITAL COSTS	\$ 8,662,500
BOD - biochemical oxygen demand			ANNUAL COSTS	\$ 393,120
O&M - Operations and Maintenance			TOTAL OPINION OF PROBABLE COSTS	\$ 9,055,620
			TOTAL OPINION OF PROBABLE COSTS FOR 20 YEARS	\$ 16,524,900

Prepared By:

Checked By:

USACE SHEP/SIERS
Chatham County, Georgia

MACTEC Project Number: 6301-05-0001
Contract Number: W912798-04-D-0009; CV01
June 1, 2005

TABLE 5.3 Concept 1 Alternative 3B – Harbor Injection Technology (7 Speece cones with scheduled maintenance shut downs)

Cost Assessment for Design Phase I Step 3

Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen in the Savannah River Estuary
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Study
Chatham County, Georgia

MAJOR ASSUMPTIONS

TMDL proposed DO Standard requirements and current (1999) BOD loadings

Required Point Source BOD reduction 68,250 lbs/day

Required Nonpoint Source BOD reduction is Not Applicable

Total Oxygen Requirements = 68,250 lbs/day

Supplemental DO needed during summer months

Harbor injection technology capable of ~0,000 lbs O₂/day

Impact near midpoint of Hutchinson Island

Rolling maintenance shut downs for 8 weeks reduces Speece cone O&M

30 % BOD loading reduction from discharger during the scheduled facility maintenance period

(assumes 2-weeks to perform required facility maintenance for top five dischargers)

Additional load reduction may be possible if shutdowns are implemented basin wide for every discharger

O&M costs were based on a 90 day operation schedule. However, based on river flows, operation may be limited and thereby substantially reducing O&M costs.

Costs NOT included in the estimate:

Land Acquisition/Right of Way and required local, state and federal permitting

Construction for electrical service or costs for diesel generators

Item	Quantity	Unit	Unit Cost	Opinion of Probable Cost
CAPITAL COSTS				
Harbor injection technology (Speece Cone)	7	cone	\$ 425,000	\$ 2,975,000
Harbor injection technology (PSA O ₂ plant)	7	cone	\$ 325,000	\$ 2,275,000
Rolling Maintenance Shut Down (JP Augusta)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (GA Pacific)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (Weyerhaeuser)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (JP Savannah)	2	weeks	\$ -	\$ -
			Subtotal	\$ 5,250,000
			Oversight (15%)	\$ 787,500
			Contingency (50%)	\$ 2,625,000
			TOTAL CAPITAL COSTS	\$ 8,662,500
ANNUAL COSTS				
Speece Cone O&M plus O ₂ generation energy	34	day	\$ 3,360	\$ 114,240
Speece Cone O&M plus O ₂ generation energy (JP Augusta shutdown)	14	day	\$ -	\$ -
Speece Cone O&M plus O ₂ generation energy (GA Pacific shutdown)	14	day	\$ 2,400	\$ 33,600
Speece Cone O&M plus O ₂ generation energy (Weyerhaeuser shutdown)	14	day	\$ 2,880	\$ 40,320
Speece Cone O&M plus O ₂ generation energy (JP Savannah shutdown)	14	day	\$ -	\$ -
Supplemental Oxygen Injection (energy required)	0	day	\$ 1,780	\$ -
Supplemental Oxygen Injection (O&M)	0		\$ 40,500	\$ -
			Subtotal	\$ 188,160
			Oversight & Reporting (30%)	\$ 56,448
			TOTAL ANNUAL COSTS	\$ 244,608

DO - dissolved oxygen

BOD - biochemical oxygen demand

O&M - Operations and Maintenance

CAPITAL COSTS	\$ 8,662,500
ANNUAL COSTS	\$ 244,608
TOTAL OPINION OF PROBABLE COSTS	\$ 8,907,108
TOTAL OPINION OF PROBABLE COSTS FOR 20 YEARS	\$ 13,554,660

Prepared By:

Checked By:

USACE SHEP/SHERS
Chatham County, Georgia

MACTEC Project Number: 6301-05-0001
Contract Number: W912798-04-D-0009; CV01
June 1, 2005

TABLE 5.3 Concept 1 Alternative 3C - Seaward Discharge

Cost Assessment for Design Phase I Step 4

Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen in the Savannah River Estuary
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Study
Chatham County, Georgia

MAJOR ASSUMPTIONS

TMDL proposed DO Standard requirements and current (1999) BOD loadings

Required Point Source BOD reduction 68,250 lbs/day

Required Nonpoint Sources BOD reduction is Not Applicable

Total Oxygen Requirements = 68,250 lbs/day

Supplemental DO needed during summer months

Harbor injection technology capable of 70,000 lbs O₂/day

Inject near midpoint of Hutchinson Island

Rolling maintenance shut downs for 8 weeks reduces Speece cone O&M

50 % BOD loading reduction from discharger during the scheduled facility maintenance period

(assumes 2-weeks to perform required facility maintenance for top five dischargers)

Additional load reduction may be possible if shutdowns are implemented basin wide for every discharger

O&M costs were based on a 90 day operation schedule. However, based on river flows, operation may be limited

and thereby substantially reducing O&M costs.

Costs NOT included in the estimate:

Land Acquisition/Right of Way and required local, state and federal permitting

Construction for electrical service or costs for diesel generators

Item	Quantity	Unit	Unit Cost	Opinion of Probable Cost
CAPITAL COSTS				
Harbor injection technology (Speece Cone)	0	cone	\$ 425,000	\$ -
Harbor injection technology (PSA O ₂ plant)	0	cone	\$ 325,000	\$ -
Supplemental Oxygen Injection	0	mile	\$ 40,500	\$ -
Discharge Collection Network Seaward Pipeline with Tided Tidal	1	network	\$ 33,116,016	\$ 33,116,016
Rolling Maintenance Shut Down (IP Augusta)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (GA Pacific)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (Weyerhaeuser)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (IP Savannah)	2	weeks	\$ -	\$ -
			Subtotal	\$ 33,116,016
			Oversight (15%)	\$ 4,967,402
			Contingency (50%)	\$ 16,558,008
			TOTAL CAPITAL COSTS	\$ 54,641,426
ANNUAL COSTS				
Speece Cone O&M plus O ₂ generation energy	0	day	\$ 24,000	\$ -
Speece Cone O&M plus O ₂ generation energy (IP Augusta shutdown)	0	day	\$ 20,640	\$ -
Speece Cone O&M plus O ₂ generation energy (GA Pacific shutdown)	0	day	\$ 23,040	\$ -
Speece Cone O&M plus O ₂ generation energy (Weyerhaeuser shutdown)	0	day	\$ 23,520	\$ -
Speece Cone O&M plus O ₂ generation energy (IP Savannah shutdown)	0	day	\$ 17,760	\$ -
Supplemental Oxygen Injection (energy required)	90	day	\$ 1,780	\$ 160,200
Supplemental Oxygen Injection (O&M)	0.1		\$ 40,500	\$ 4,050
			Subtotal	\$ 164,250
			Oversight & Reporting (30%)	\$ 49,275
			TOTAL ANNUAL COSTS	\$ 213,525
DO - dissolved oxygen			CAPITAL COSTS	\$ 54,641,426
BOD - biochemical oxygen demand			ANNUAL COSTS	\$ 213,525
O&M - Operations and Maintenance			TOTAL OPINION OF PROBABLE COSTS	\$ 54,854,951
			TOTAL OPINION OF PROBABLE COSTS FOR 20 YEARS	\$ 88,911,926

Prepared By:

Checked By:

USACE SHEP/SIERS
Chatham County, Georgia

MACTEC Project Number: 6301-05-0001
Contract Number: W912798-04-D-0009; CV01
June 1, 2005

TABLE 5.4 Concept 1 Alternative 4A - Harbor Injection Technology (50 Speece Cones)

Cost Assessment for Design Phase I Step 4

Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen in the Savannah River Estuary
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Study
Chatham County, Georgia

MAJOR ASSUMPTIONS

TMDL proposed DO Standard requirements; and Current (1999) BOD loadings

Required Point Source BOD reduction 503,500 lbs/day

Required Nonpoint Source BOD reduction is Not Applicable

Total Oxygen Requirements = 503,500 lbs/day

Supplemental DO needed during summer months

Harbor injection technology capable of 500,000-503,500 lbs O₂/day

Inject near midpoint of Hutchinson Island

Rolling maintenance shut downs for 8 weeks reduces Speece cone O&M

50 % BOD loading reduction from discharger during the scheduled facility maintenance period

(assumes 2-weeks to perform required facility maintenance for top five dischargers)

Additional load reduction may be possible if shutdowns are implemented basin wide for every discharger

O&M costs were based on a 90 day operation schedule. However, based on river flows, operation may be limited and thereby substantially reducing O&M costs.

Costs NOT included in the estimate:

Land Acquisition/Right of Way and required local, state and federal permitting

Construction for electrical service or costs for diesel generators

Item	Quantity	Unit	Unit Cost	Opinion of Probable Cost
CAPITAL COSTS				
Harbor injection technology (Speece Cone)	50	cone	\$ 425,000	\$ 21,250,000
Harbor injection technology (PSA O ₂ plant)	50	cone	\$ 325,000	\$ 16,250,000
Supplemental Oxygen Injection	0	mile	\$ 40,500	\$ -
Discharge Collection Network Seaward Pipeline with Timed Tidal	0	network	\$ 33,116,016	\$ -
Rolling Maintenance Shut Down (IP Augusta)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (GA Pacific)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (Weyerhaeuser)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (IP Savannah)	2	weeks	\$ -	\$ -
			Subtotal	\$ 37,500,000
			Oversight (15%)	\$ 5,625,000
			Contingency (50%)	\$ 18,750,000
			TOTAL CAPITAL COSTS	\$ 61,875,000
ANNUAL COSTS				
Speece Cone O&M plus O ₂ generation energy	90	day	\$ 24,000	\$ 2,160,000
Speece Cone O&M plus O ₂ generation energy (IP Augusta shutdown)	0	day	\$ 20,640	\$ -
Speece Cone O&M plus O ₂ generation energy (GA Pacific shutdown)	0	day	\$ 23,040	\$ -
Speece Cone O&M plus O ₂ generation energy (Weyerhaeuser shutdown)	0	day	\$ 23,520	\$ -
Speece Cone O&M plus O ₂ generation energy (IP Savannah shutdown)	0	day	\$ 17,760	\$ -
Supplemental Oxygen Injection (energy required)	0	day	\$ 1,780	\$ -
Supplemental Oxygen Injection (O&M)	0		\$ 40,500	\$ -
			Subtotal	\$ 2,160,000
			Oversight & Reporting (30%)	\$ 648,000
			TOTAL ANNUAL COSTS	\$ 2,808,000

DO - dissolved oxygen

BOD - biochemical oxygen demand

O&M - Operations and Maintenance

CAPITAL COSTS	\$ 61,875,000
ANNUAL COSTS	\$ 2,808,000
TOTAL OPINION OF PROBABLE COSTS	\$ 64,683,000
TOTAL OPINION OF PROBABLE COSTS FOR 20 YEARS	\$ 1,180,000

Prepared By:

Checked By:

USACE SHEP/SHERS
Chatham County, Georgia

MACTEC Project Number: 6301-05-0001
Contract Number: W912798-04-D-0009; CV01
April 7, 2005

TABLE 5.4 Concept 1 Alternative 4B - Harbor Injection Technology (50 Speece cones with scheduled maintenance shutdowns)

Cost Assessment for Design Phase I Step 4

Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen in the Savannah River Estuary
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Study
Chatham County, Georgia

MAJOR ASSUMPTIONS

TMDL proposed DO Standard requirements and Current (1999) BOD loadings.

Required Point Source BOD reduction 503,500 lbs/day

Required Nonpoint Source BOD reduction is Not Applicable

Total Oxygen Requirements = 503,500 lbs/day

Supplemental DO needed during summer months

Harbor injection technology capable of 500,000-503,500 lbs O₂/day

Inject near midpoint of Hutchinson Island

Rolling maintenance shut downs for 8 weeks reduces Speece cone O&M

50 % BOD loading reduction from discharger during the scheduled facility maintenance period
(assumes 2-weeks to perform required facility maintenance for top five dischargers)

Additional load reduction may be possible if shutdowns are implemented basin wide for every discharger
O&M costs were based on a 90 day operation schedule. However, based on river flows, operation may be limited
and thereby substantially reducing O&M costs.

Costs NOT included in the estimate:

Land Acquisition/Right of Way and required local, state and federal permitting

Construction for electrical service or costs for diesel generators

Item	Quantity	Unit	Unit Cost	Opinion of Probable Cost
CAPITAL COSTS				
Harbor injection technology (Speece Cone)	50	cone	\$ 425,000	\$ 21,250,000
Harbor injection technology (PSA O ₂ plant)	50	cone	\$ 325,000	\$ 16,250,000
Supplemental Oxygen Injection	0	mile	\$ 40,500	\$ -
Discharge Collection Network Seaward Pipeline with Tided Tidal	0	network	\$ 33,116,016	\$ -
Rolling Maintenance Shut Down (IP Augusta)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (GA Pacific)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (Weyerhaeuser)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (IP Savannah)	2	weeks	\$ -	\$ -
			Subtotal	\$ 37,500,000
			Oversight (15%)	\$ 5,625,000
			Contingency (50%)	\$ 18,750,000
			TOTAL CAPITAL COSTS	\$ 61,875,000
ANNUAL COSTS				
Speece Cone O&M plus O ₂ generation energy	34	day	\$ 24,000	\$ 816,000
Speece Cone O&M plus O ₂ generation energy (IP Augusta shutdown)	14	day	\$ 20,640	\$ 288,960
Speece Cone O&M plus O ₂ generation energy (GA Pacific shutdown)	14	day	\$ 23,040	\$ 322,560
Speece Cone O&M plus O ₂ generation energy (Weyerhaeuser shutdown)	14	day	\$ 23,520	\$ 329,280
Speece Cone O&M plus O ₂ generation energy (IP Savannah shutdown)	14	day	\$ 17,760	\$ 248,640
Supplemental Oxygen Injection (energy required)	0	day	\$ 1,780	\$ -
Supplemental Oxygen Injection (O&M)	0		\$ 40,500	\$ -
			Subtotal	\$ 2,005,440
			Oversight & Reporting (50%)	\$ 601,632
			TOTAL ANNUAL COSTS	\$ 2,607,072
DO - dissolved oxygen			CAPITAL COSTS	\$ 61,875,000
BOD - biochemical oxygen demand			ANNUAL COSTS	\$ 2,607,072
O&M - Operations and Maintenance			TOTAL OPINION OF PROBABLE COSTS	\$ 64,482,072
			TOTAL OPINION OF PROBABLE COSTS FOR 20 YEARS	\$ 114,016,440

Prepared By:

Checked By:

USACE SHEP/SIERS
Chatham County, Georgia

MACTEC Project Number: 6301-95-0001
Contract Number: W912798-04-D-0009; CV01
April 7, 2005

TABLE 5.4 Concept I Alternative 4C - Speece Cone & Seaward Pipeline with Timed Tidal Discharge

Cost Assessment for Design Phase I Step 4

Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen in the Savannah River Estuary
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Study
Chatham County, Georgia

MAJOR ASSUMPTIONS

TMDL proposed DO Standard requirements and Current (1999) BOD loadings

Required Point Source BOD reduction 503,500 lbs/day

Required Nonpoint Source BOD reduction is Not Applicable

Total Oxygen Requirements = 503,500 lbs/day

Supplemental DO needed during summer months

Harbor injection technology capable of 240,000 lbs O₂/day

Inject near midpoint of Hutchinson Island

Discharge Collection Network (Includes IP Savannah discharge)

Supplemental Oxygen Injection for 10 miles capable of 80,000 lbs O₂/day

(requires 22 injectors and 44 nozzles every 2400 feet)

Storage pond system (12-hours retention)

Seaward pipeline with timed tidal discharge at RM 3.5 (reroutes 267,500 lbs/day)

Rolling maintenance shut downs for 8 weeks reduces Speece cone O&M

30 % BOD loading reduction from discharger during the scheduled facility maintenance period

(assumes 2-weeks to perform required facility maintenance for top five dischargers)

Additional load reduction may be possible if shutdowns are implemented basin wide for every discharger.

O&M costs were based on a 90 day operation schedule. However, based on river flows, operation may be limited

and thereby substantially reducing O&M costs.

Costs NOT included in the estimate:

Land Acquisition/Right of Way and required local, state and federal permitting

Construction for electrical service or costs for diesel generators

Item	Quantity	Unit	Unit Cost	Opinion of Probable Cost
CAPITAL COSTS				
Harbor injection technology (Speece Cone)	24	cone	\$ 425,000	\$ 10,200,000
Harbor injection technology (PSA O ₂ plant)	24	cone	\$ 325,000	\$ 7,800,000
Supplemental Oxygen Injection	10	mile	\$ 40,500	\$ 405,000
Discharge Collection Network Seaward Pipeline with Timed Tidal (Option II - A-1)	1	network	\$ 33,116,016	\$ 33,116,016
Rolling Maintenance Shut Down (IP Augusta)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (GA Pacific)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (Weyerhaeuser)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (IP Savannah)	2	weeks	\$ -	\$ -
		Subtotal		\$ 51,521,016
		Oversight (15%)		\$ 7,728,152
		Contingency (50%)		\$ 25,760,508
		TOTAL CAPITAL COSTS		\$ 85,009,676
ANNUAL COSTS				
Speece Cone O&M plus O ₂ generation energy	34	day	\$ 11,520	\$ 391,680
Speece Cone O&M plus O ₂ generation energy (IP Augusta shutdown)	14	day	\$ 8,160	\$ 114,240
Speece Cone O&M plus O ₂ generation energy (GA Pacific shutdown)	14	day	\$ 10,560	\$ 147,840
Speece Cone O&M plus O ₂ generation energy (Weyerhaeuser shutdown)	14	day	\$ 11,040	\$ 154,560
Speece Cone O&M plus O ₂ generation energy (IP Savannah shutdown)	14	day	\$ 5,280	\$ 73,920
Supplemental Oxygen Injection (energy required)	90	day	\$ 1,780	\$ 160,200
Supplemental Oxygen Injection (O&M)	0.1		\$ 40,500	\$ 4,050
		Subtotal		\$ 1,046,490
		Oversight & Reporting (30%)		\$ 313,947
		TOTAL ANNUAL COSTS		\$ 1,360,437

DO - dissolved oxygen

BOD - biochemical oxygen demand

O&M - Operations and Maintenance

RM - River Mile

Prepared By:

Checked By:

TOTAL OPINION OF PROBABLE COSTS FOR 20 YEARS \$ 112,218,416

CAPITAL COSTS	\$ 85,009,676
ANNUAL COSTS	\$ 1,360,437
	\$ 86,370,113

USACE SHEP/SHERS
Chatham County, Georgia

MACTEC Project Number: 6301-05-0001
Contract Number: W912798-04-D-0009; CV01
April 7, 2005

TABLE 5.4 Concept 1 Alternative 4D : Speece Cone & Discharge Collection Network Alternative

Cost Assessment for Design Phase I Step 4

Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen in the Savannah River Estuary
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Study
Chatham County, Georgia

MAJOR ASSUMPTIONS

TMDL proposed DO Standard requirements and Current (1999) BOD loadings

Required Point Source BOD reduction 503,500 lbs/day

Required Nonpoint Source BOD reduction is Not Applicable

Total Oxygen Requirements = 503,500 lbs/day

Supplemental DO needed during summer months

Harbor injection technology capable of 240,000 lbs O₂/day

Inject near midpoint of Hutchinson Island

Discharge Collection Network (Includes Weyerhaeuser, IP Savannah, and President Street discharge)

Supplemental Oxygen Injection for 10 miles capable of 80,000 lbs O₂/day

(requires 22 injectors and 44 nozzles every 2400 feet)

Storage pond system (30 day retention) to Direct Outfall Discharge to Back River

Rolling maintenance shut downs for 8 weeks reduces Speece cone O&M

50 % BOD loading reduction from discharger during the scheduled facility maintenance period

(assumes 2-weeks to perform required facility maintenance for top five dischargers)

Additional local reduction may be possible if shutdowns are implemented basin wide for every discharger

O&M costs were based on a 90 day operation schedule. However, based on river flows, operation may be limited and thereby substantially reducing O&M costs.

Costs NOT included in the estimate:

Land Acquisition/Right of Way and required local, state and federal permitting

Construction for electrical service or costs for diesel generators

Item	Quantity	Unit	Unit Cost	Opinion of Probable Cost
CAPITAL COSTS				
Harbor injection technology (Speece Cone)	24	cone	\$ 425,000	\$ 10,200,000
Harbor injection technology (PSA O ₂ plant)	24	cone	\$ 325,000	\$ 7,800,000
Supplemental Oxygen Injection	10	miles	\$ 40,500	\$ 405,000
Discharge Collection Network 30-day HRT Pond (Option 1-B)	1	network	\$ 39,556,271	\$ 39,556,271
Rolling Maintenance Shut Down (IP Augusta)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (GA Pacific)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (Weyerhaeuser)	2	weeks	\$ -	\$ -
Rolling Maintenance Shut Down (IP Savannah)	2	weeks	\$ -	\$ -
Subtotal				\$ 57,961,271
Oversight (15%)				\$ 8,694,191
Contingency (30%)				\$ 28,980,636
TOTAL CAPITAL COSTS				\$ 95,636,097
ANNUAL COSTS				
Speece Cone O&M plus O ₂ generation energy	34	day	\$ 11,520	\$ 391,680
Speece Cone O&M plus O ₂ generation energy (IP Augusta shutdown)	14	day	\$ 8,160	\$ 114,240
Speece Cone O&M plus O ₂ generation energy (GA Pacific shutdown)	14	day	\$ 10,560	\$ 147,840
Speece Cone O&M plus O ₂ generation energy (Weyerhaeuser shutdown)	14	day	\$ 11,040	\$ 154,560
Speece Cone O&M plus O ₂ generation energy (IP Savannah shutdown)	14	day	\$ 5,280	\$ 73,920
Supplemental Oxygen Injection (energy required)	90	day	\$ 1,780	\$ 160,200
Supplemental Oxygen Injection (O&M)	0.1		\$ 40,500	\$ 4,050
Subtotal				\$ 1,046,490
Oversight & Reporting (30%)				\$ 313,947
TOTAL ANNUAL COSTS				\$ 1,360,437

DO - dissolved oxygen

BOD - biochemical oxygen demand

O&M - Operations and Maintenance

CAPITAL COSTS	\$	95,636,097
ANNUAL COSTS	\$	1,360,437
TOTAL OPINION OF PROBABLE COSTS	\$	96,996,534
TOTAL OPINION OF PROBABLE COSTS FOR 20 YEARS	\$	122,844,837

Prepared By:

Checked By:

Summary Information

	Design Alternative	Description	Capital Costs ¹	Annual Operating Costs	Total Life Cycle Costs
			(\$)	(\$)	(\$)
Phase 1, Step 1	Concept 1 Alternative 1A	29 Speece cones	37,516,140	1,628,640	68,460,300
Phase 1, Step 1	Concept 1 Alternative 1B	29 Speece cones + rolling maintenance shutdowns	37,315,212	1,427,712	64,441,740
Phase 1, Step 1	Concept 1 Alternative 1C	Discharge Collection Network 60 day retention	71,671,710	213,525	75,728,685
Phase 1, Step 1	Concept 1 Alternative 1C	Discharge Collection Network 30 day retention	62,495,958	213,525	66,766,458
Phase 1, Step 2	Concept 1 Alternative 2A	73 Speece Cones	94,437,180	4,099,680	172,331,100
Phase 1, Step 2	Concept 1 Alternative 2B	73 Speece Cones + rolling maintenance shutdowns	94,236,252	3,898,752	168,312,540
Phase 1, Step 2	Concept 1 Alternative 2C	Speece Cones with Discharge Network and Storage System	117,695,094	2,258,997	160,616,037
Phase 1, Step 3	Concept 1 Alternative 3A	7 Speece cones	9,055,620	393,120	16,524,900
Phase 1, Step 3	Concept 1 Alternative 3B	7 Speece cones + rolling maintenance shutdowns	8,907,108	244,608	13,554,660
Phase 1, Step 3	Concept 1 Alternative 3C	Seaward Discharge	54,854,951	213,525	58,911,926
Phase 1, Step 4	Concept 1 Alternative 4A	50 Speece Cones	64,683,000	2,808,000	118,035,000
Phase 1, Step 4	Concept 1 Alternative 4B	50 Speece cones + rolling maintenance shutdowns	64,482,072	2,607,072	114,016,440
Phase 1, Step 4	Concept 1 Alternative 4C	Speece Cone & Seaward Pipeline with Timed Tidal Discharge	86,370,113	1,360,437	112,218,416
Phase 1, Step 4	Concept 1 Alternative 4D	Speece Cone & Discharge Collection Network	96,996,534	1,360,437	122,844,837

Notes

1) Cost do not include land acquisition/right of way, required local, state, and federal permitting, construction for electrical service or costs for diesel generators.

USACE SHEP/SHERS
Chatham County, Georgia

MACTEC Project Number: 6301-05-0001
Contract Number: W912798-04-D-0009: CV01
June 01, 2005

TABLE 5.5 Concept 2 Alternative 1A - Harbor Injection Technology

Cost Assessment for Design Phase II Step 1

**Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen in the Savannah River Estuary
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Project
Chatham County, Georgia**

MAJOR ASSUMPTIONS

Phase I requirements have been met, using one of the first four design packets

Total Oxygen Requirements = 72,818 lbs/day

50 foot barge available for use and no storage expense

O&M costs were based on a 90 day operation schedule. However, based on river flows, operation may be limited to several days per year thereby substantially reducing O&M costs.

Costs NOT included in the estimate:

Land Acquisition/Right of Way and required local, state and federal permitting

Construction for electrical service or costs for diesel generators

Item	Quantity	Unit	Unit Cost	Opinion of Probable Cost
CAPITAL COSTS				
Harbor injection technology (Speece Cone	8	cone	\$ 425,000	\$ 3,400,000
Harbor injection technology (PSA O ₂ plant)	8	cone	\$ 325,000	\$ 2,600,000
				\$ -
			Subtotal	\$ 6,000,000
			Oversight (15%)	\$ 900,000
			Contingency (50%)	\$ 3,000,000
			TOTAL CAPITAL COSTS	\$ 9,900,000
ANNUAL COSTS				
Speece Cone O&M plus O ₂ generation energy	90	day	\$ 3,840	\$ 345,600
				\$ -
			Subtotal	\$ 345,600
			Oversight & Reporting (30%)	\$ 103,680
			TOTAL ANNUAL COSTS	\$ 449,280

O&M = Operations and Maintenance

CAPITAL COSTS	\$ 9,900,000
ANNUAL COSTS	\$ 449,280
TOTAL OPINION OF PROBABLE COSTS	\$ 10,349,280
TOTAL OPINION OF PROBABLE COSTS FOR 20 YEARS	\$ 18,885,600

Prepared By:
Checked By:

USACE SHEPHERDS
Chatham County, Georgia

MACTEC Project Number: 6301-05-0001
Contract Number: W912798-04-D-0009; CV01
June 01, 2005

TABLE 5.6 Concept 2 Alternative 2A - Harbor Injection Technology

Cost Assessment for Design Phase II Step 2
Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen in the Savannah River Estuary
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Project
Chatham County, Georgia

MAJOR ASSUMPTIONS

Phase I requirements have been met, using one of the first four design packets
Total Oxygen Requirements = 145,636 lbs/day
50 foot barge available for use and no storage expense
O&M costs were based on a 90 day operation schedule. However, based on river flows, operation may be limited to several days per year thereby substantially reducing O&M costs.
Costs NOT included in the estimate:
Land Acquisition Right of Way and required local, state and federal permitting
Construction for electrical service or costs for diesel generators

Item	Quantity	Unit	Unit Cost	Opinion of Probable Cost
CAPITAL COSTS				
Harbor injection technology (Speece Cone	15	cone	\$ 425,000	\$ 6,375,000
Harbor injection technology (PSA O ₂ plant)	15	cone	\$ 325,000	\$ 4,875,000
				\$ -
			Subtotal	\$ 11,250,000
			Oversight (15%)	\$ 1,687,500
			Contingency (50%)	\$ 5,625,000
			TOTAL CAPITAL COSTS	\$ 18,562,500
ANNUAL COSTS				
Speece Cone O&M plus O ₂ generation energy	90	day	\$ 7,200	\$ 648,000
				\$ -
			Subtotal	\$ 648,000
			Oversight & Reporting (30%)	\$ 194,400
			TOTAL ANNUAL COSTS	\$ 842,400

O&M - Operations and Maintenance

CAPITAL COSTS	\$ 18,562,500
ANNUAL COSTS	\$ 842,400
TOTAL OPINION OF PROBABLE COSTS	\$ 19,404,900
TOTAL OPINION OF PROBABLE COSTS FOR 20 YEARS	\$ 35,410,500

Prepared By:
Checked By:

USACE SHEP/SHRS
Chatham County, Georgia

MACTEC Project Number: 6301-05-0001
Contract Number: W912798-04-D-0009: CV01
June 01, 2005

TABLE 5.7 Concept 2 Alternative 3A - Harbor Injection Technology

Cost Assessment for Design Phase II Step 3

**Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen in the Savannah River Estuary
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Project
Chatham County, Georgia**

MAJOR ASSUMPTIONS

Phase I requirements have been met, using one of the first four design packets

Total Oxygen Requirements = 218,455 lbs/day

50 foot barge available for use and no storage expense

O&M costs were based on a 90 day operation schedule. However, based on river flows, operation may be limited to several days per year thereby substantially reducing O&M costs.

Costs NOT included in the estimate:

Land Acquisition/Right of Way and required local, state and federal permitting

Construction for electrical service or costs for diesel generators

Item	Quantity	Unit	Unit Cost	Opinion of Probable Cost
CAPITAL COSTS				
Harbor injection technology (Speece Cone	22	cone	\$ 425,000	\$ 9,350,000
Harbor injection technology (PSA O ₂ plant)	22	cone	\$ 325,000	\$ 7,150,000
				\$ -
			Subtotal	\$ 16,500,000
			Oversight (15%)	\$ 2,475,000
			Contingency (50%)	\$ 8,250,000
			TOTAL CAPITAL COSTS	\$ 27,225,000
ANNUAL COSTS				
Speece Cone O&M plus O ₂ generation energy	90	day	\$ 10,560	\$ 950,400
				\$ -
			Subtotal	\$ 950,400
			Oversight & Reporting (30%)	\$ 285,120
			TOTAL ANNUAL COSTS	\$ 1,235,520

O&M = Operations and Maintenance

CAPITAL COSTS	\$ 27,225,000
ANNUAL COSTS	\$ 1,235,520
TOTAL OPINION OF PROBABLE COSTS	\$ 28,460,520
TOTAL OPINION OF PROBABLE COSTS FOR 20 YEARS	\$ 51,935,400

Prepared By:
Checked By:

USACE SHEP/SUERS
Chatham County, Georgia

MACTEC Project Number: 6301-05-0001
Contract Number: W912798-04-D-0009; CV01
June 01, 2005

TABLE 5.8 Concept 2 Alternative 4A - Harbor Injection Technology

Cost Assessment for Design Phase II Step 4
Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen in the Savannah River Estuary
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Project
Chatham County, Georgia

MAJOR ASSUMPTIONS

Phase I requirements have been met, using one of the first four design packets
Total Oxygen Requirements = 291,273 lbs/day
50 foot barge available for use and no storage expense
O&M costs were based on a 90 day operation schedule. However, based on river flows, operation may be limited to several days per year thereby substantially reducing O&M costs.
Costs NOT included in the estimate:
Land Acquisition/Right of Way and required local, state and federal permitting
Construction for electrical service or costs for diesel generators.

Item	Quantity	Unit	Unit Cost	Opinion of Probable Cost	
CAPITAL COSTS					
Harbor injection technology (Speece Cone	29	cone	\$ 425,000	\$	12,325,000
Harbor injection technology (PSA O ₂ plant)	29	cone	\$ 325,000	\$	9,425,000
				\$	-
			Subtotal	\$	21,750,000
			Oversight (15%)	\$	3,262,500
			Contingency (30%)	\$	10,875,000
			TOTAL CAPITAL COSTS	\$	35,887,500
ANNUAL COSTS					
Speece Cone O&M plus O ₂ generation energy	90	day	\$ 13,920	\$	1,252,800
				\$	-
			Subtotal	\$	1,252,800
			Oversight & Reporting (30%)	\$	375,840
			TOTAL ANNUAL COSTS	\$	1,628,640

O&M - Operations and Maintenance

CAPITAL COSTS	\$	35,887,500
ANNUAL COSTS	\$	1,628,640
TOTAL OPINION OF PROBABLE COSTS	\$	37,516,140
TOTAL OPINION OF PROBABLE COSTS FOR 20 YEARS	\$	68,460,300

Prepared By:
Checked By:

USACE SHEP/SHERS
Chatham County, Georgia

MACTEC Project Number: 6301-05-0001
Contract Number: W912798-04-D-0009: CV01
June 01, 2005

Summary Information

	Design Alternative	Description	Capital Costs ¹	Annual Operating Costs	Total Life Cycle Costs
			(\$)	(\$)	(\$)
Phase 2, Step 1	Concept 2 Alternative 1A	8 Speece cones	10,349,280	449,280	18,885,600
Phase 2, Step 2	Concept 2 Alternative 2A	15 Speece cones	19,404,900	842,400	35,410,500
Phase 2, Step 3	Concept 2 Alternative 3A	22 Speece cones	28,460,520	1,235,520	51,935,400
Phase 2, Step 4	Concept 2 Alternative 4A	29 Speece cones	37,516,140	1,628,640	68,460,300

Notes

1) Cost do not include land acquisition/right of way, required local, state, and federal permitting, construction for electrical service or costs for diesel generators.

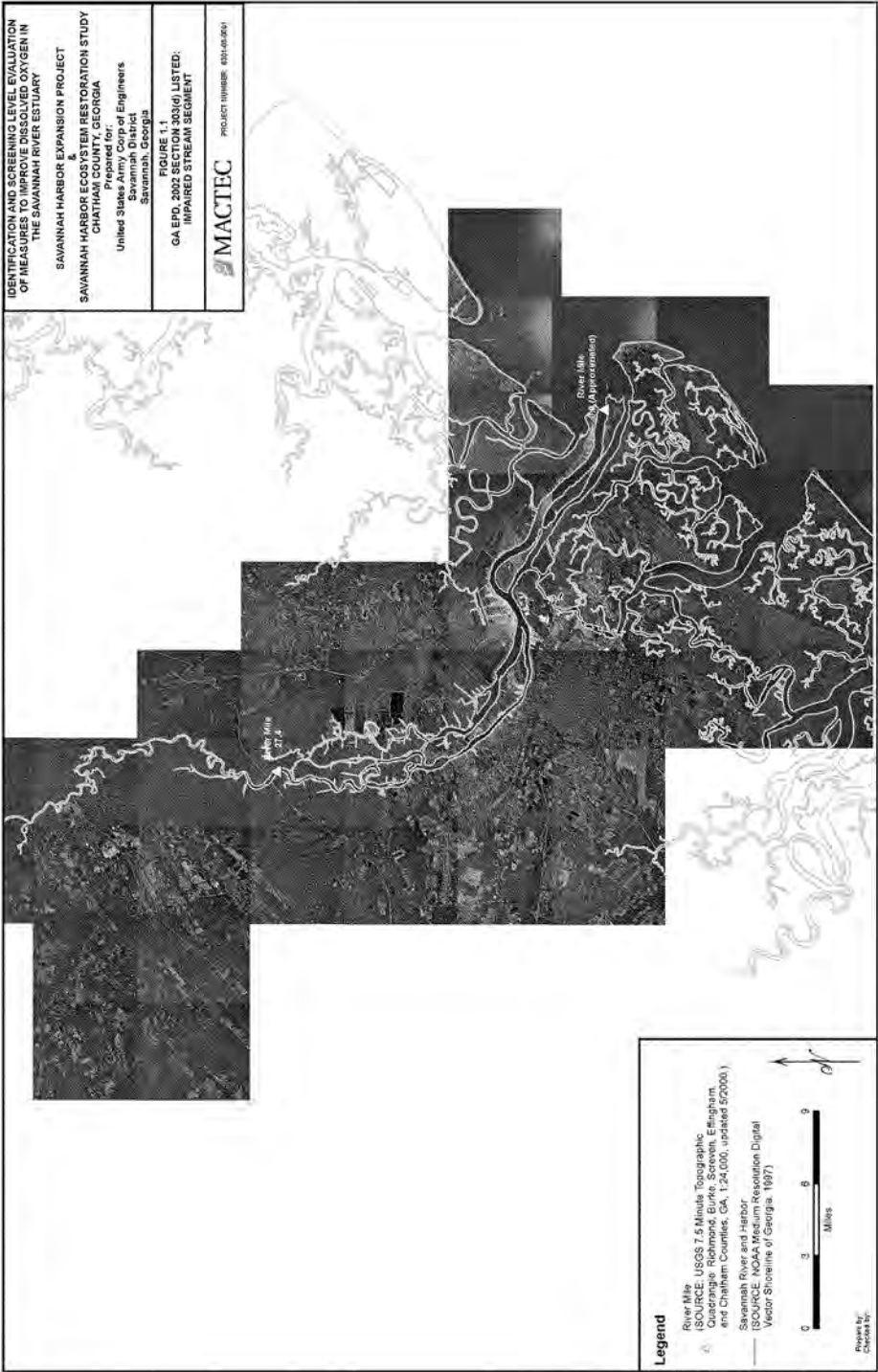
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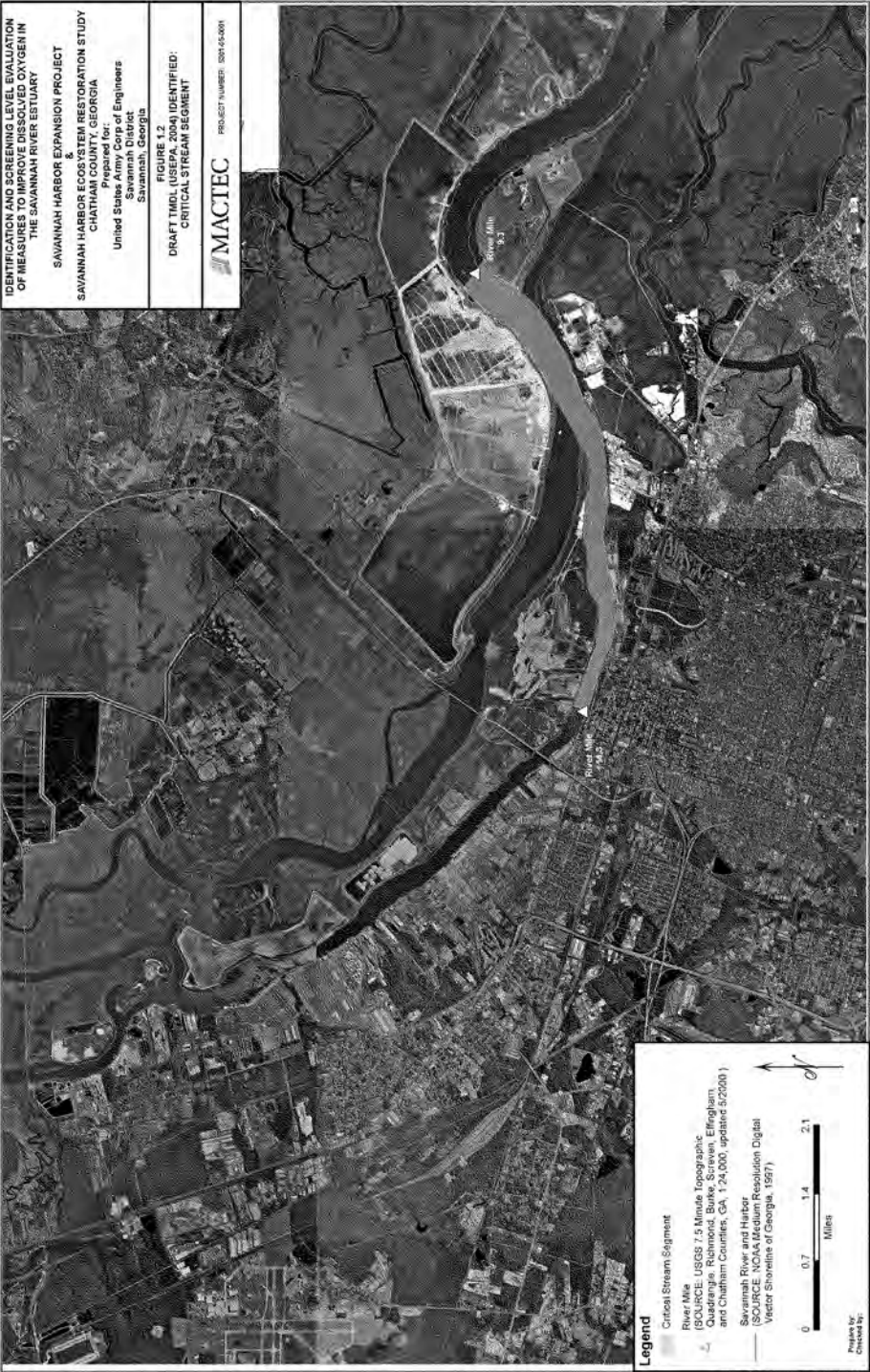
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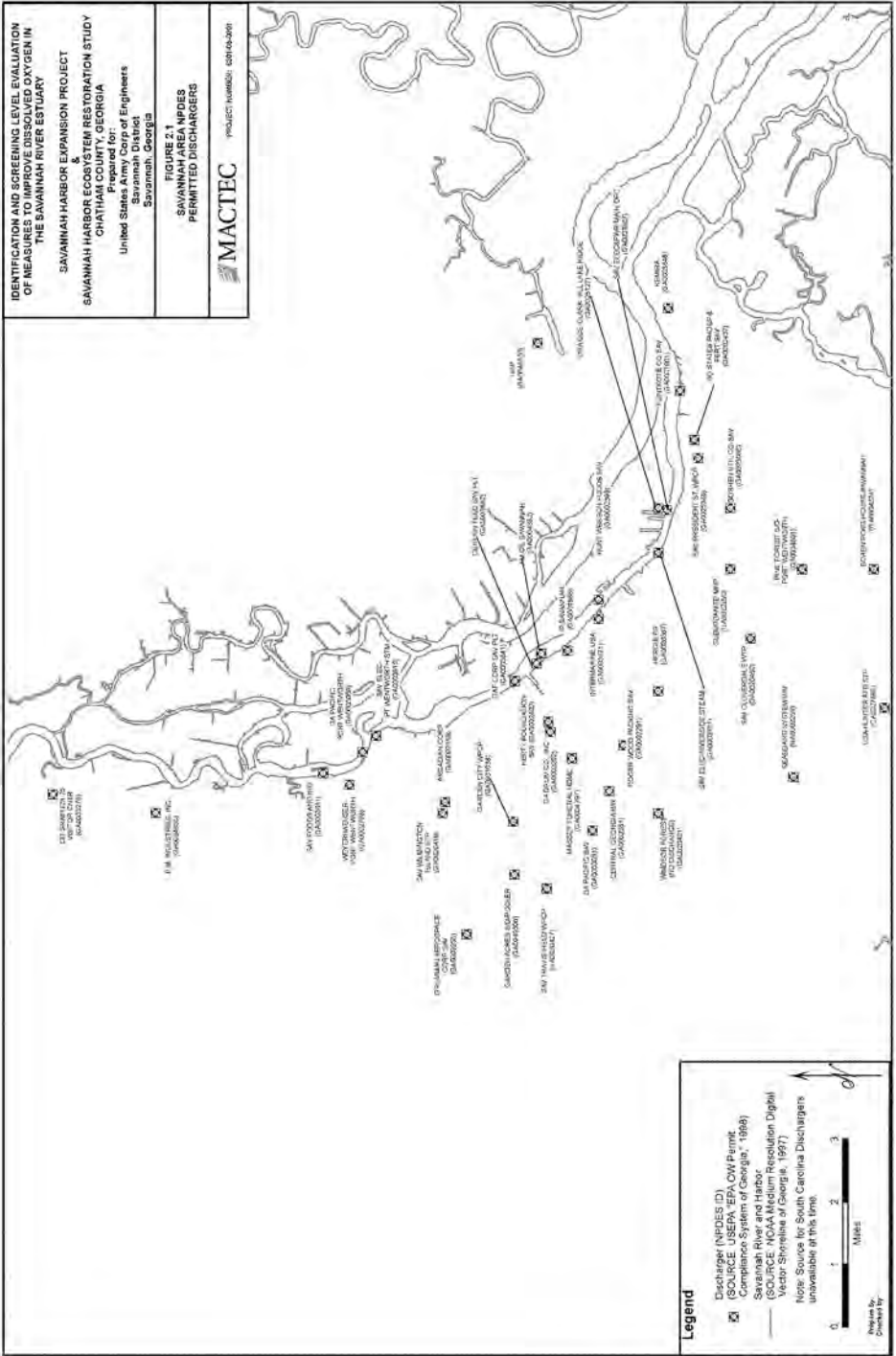
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Dissolved Oxygen in the Savannah River Estuary
USACE Savannah District
Savannah, Georgia*

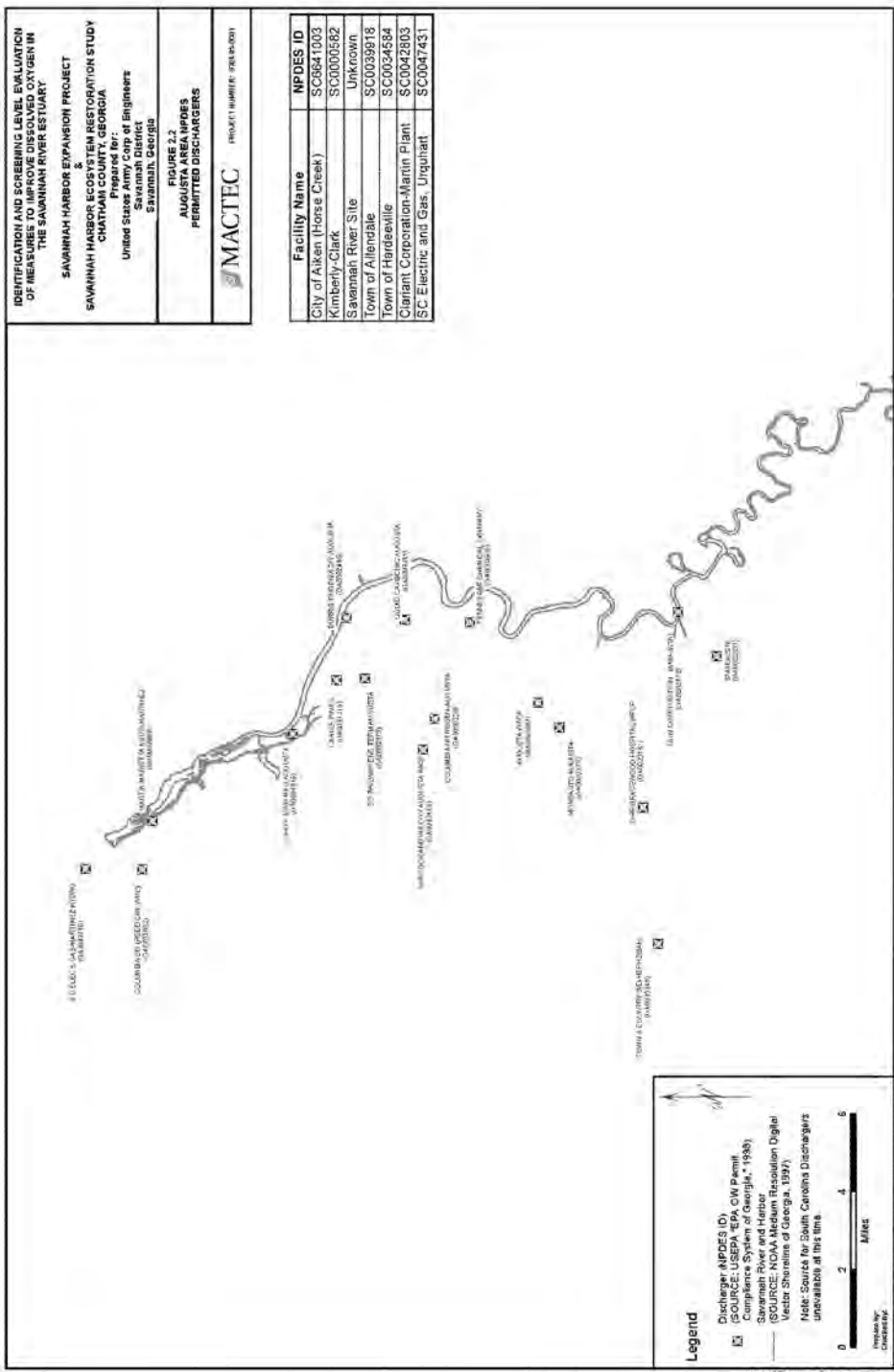
*FINAL
June 7, 2005
MACTEC Project 6301-05-0001
Contract No. W91278-04-D-0009, Delivery Order CF01*

FIGURES









Legend

Discharger NPDES ID, City Permit, Compliance System of Georgia, 1989

Savannah River and Harbor

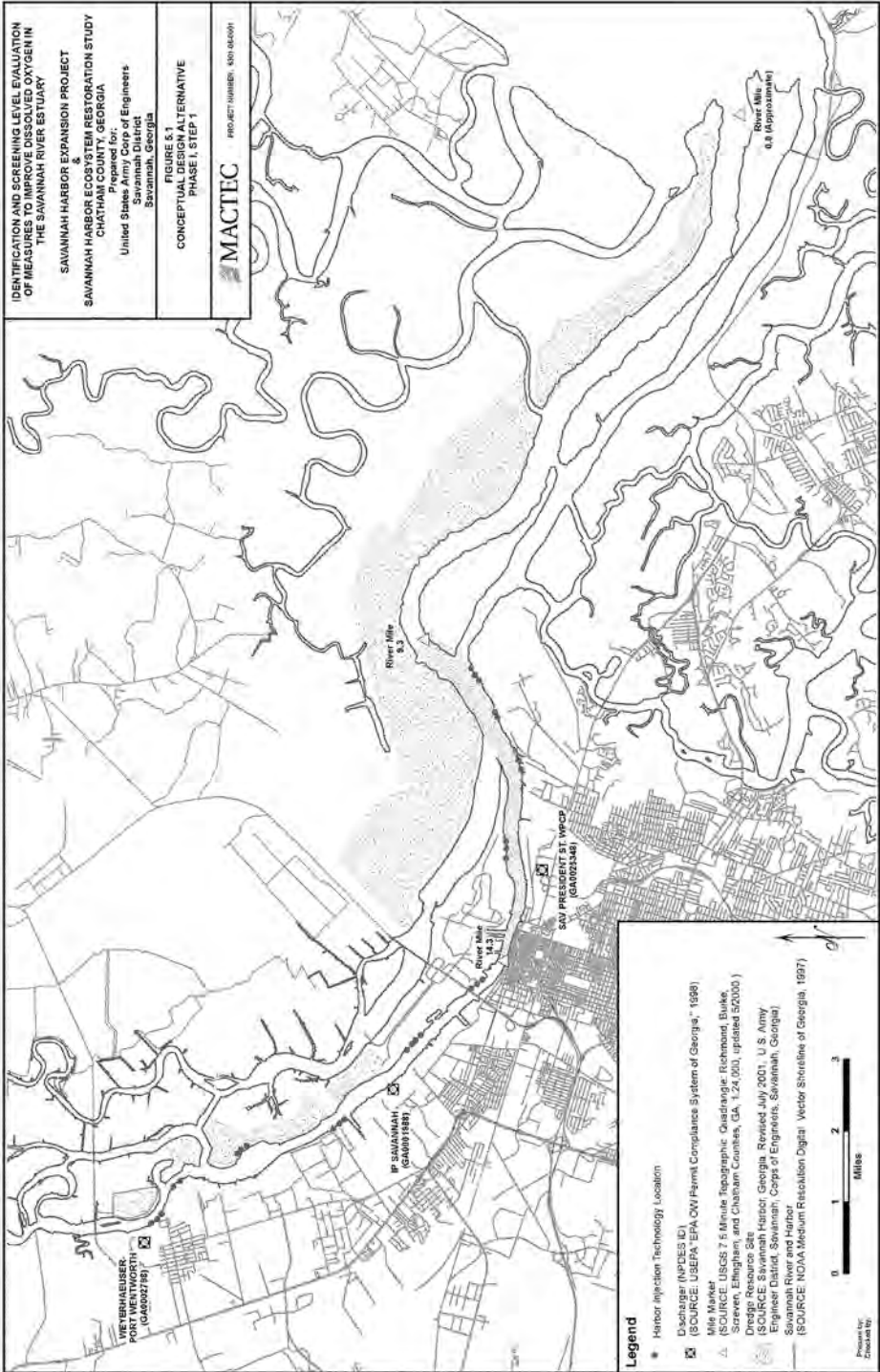
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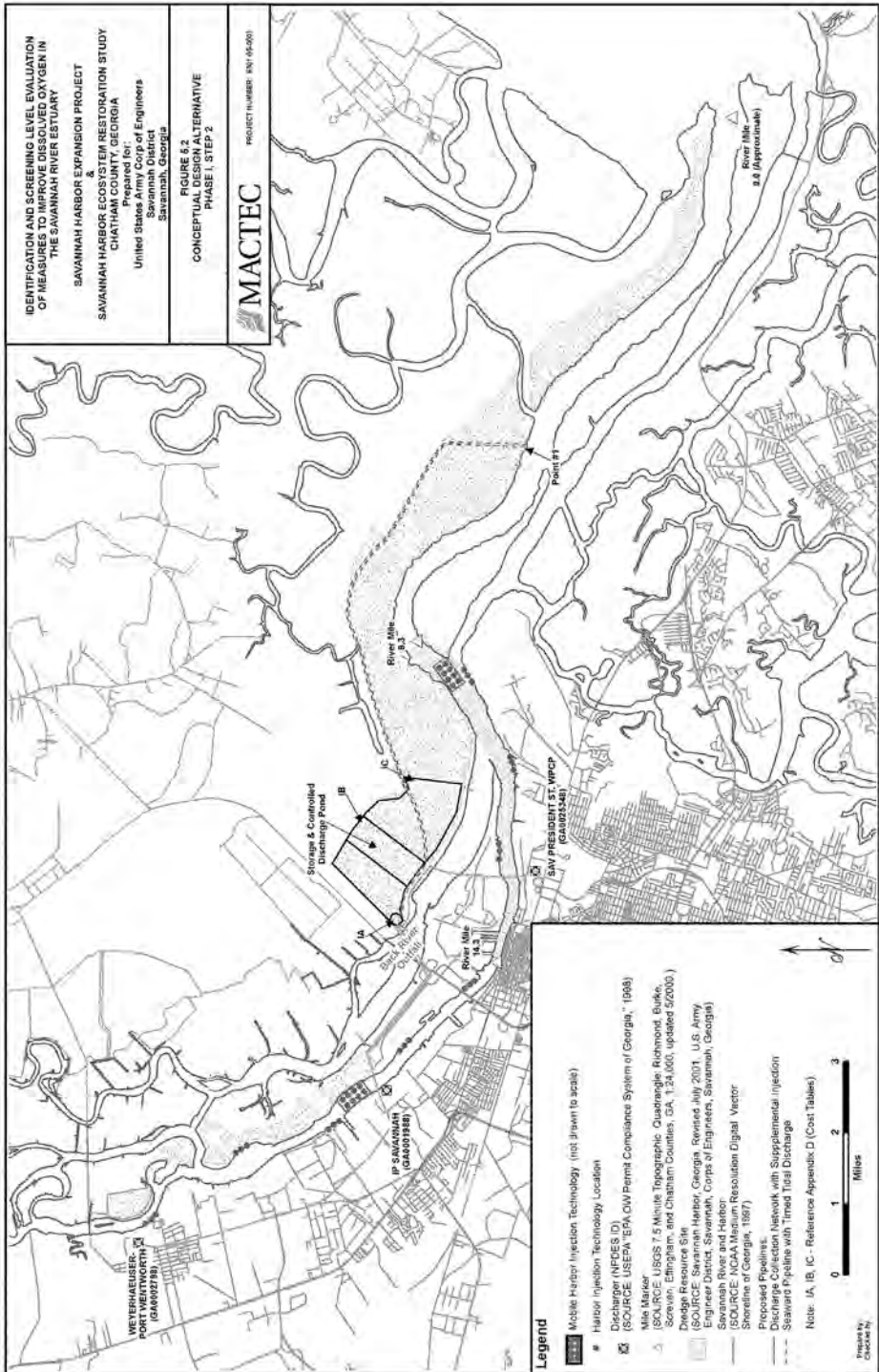
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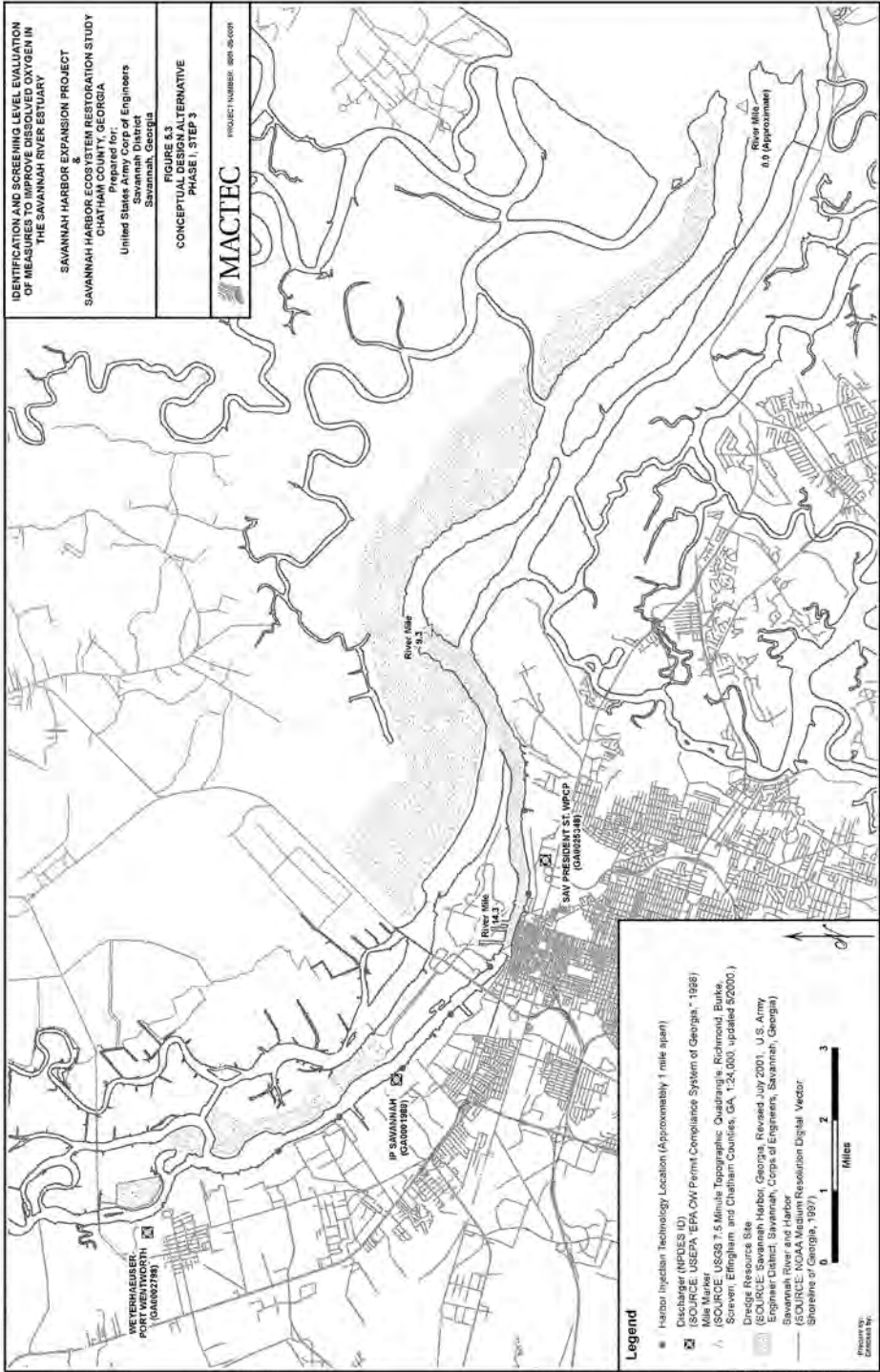
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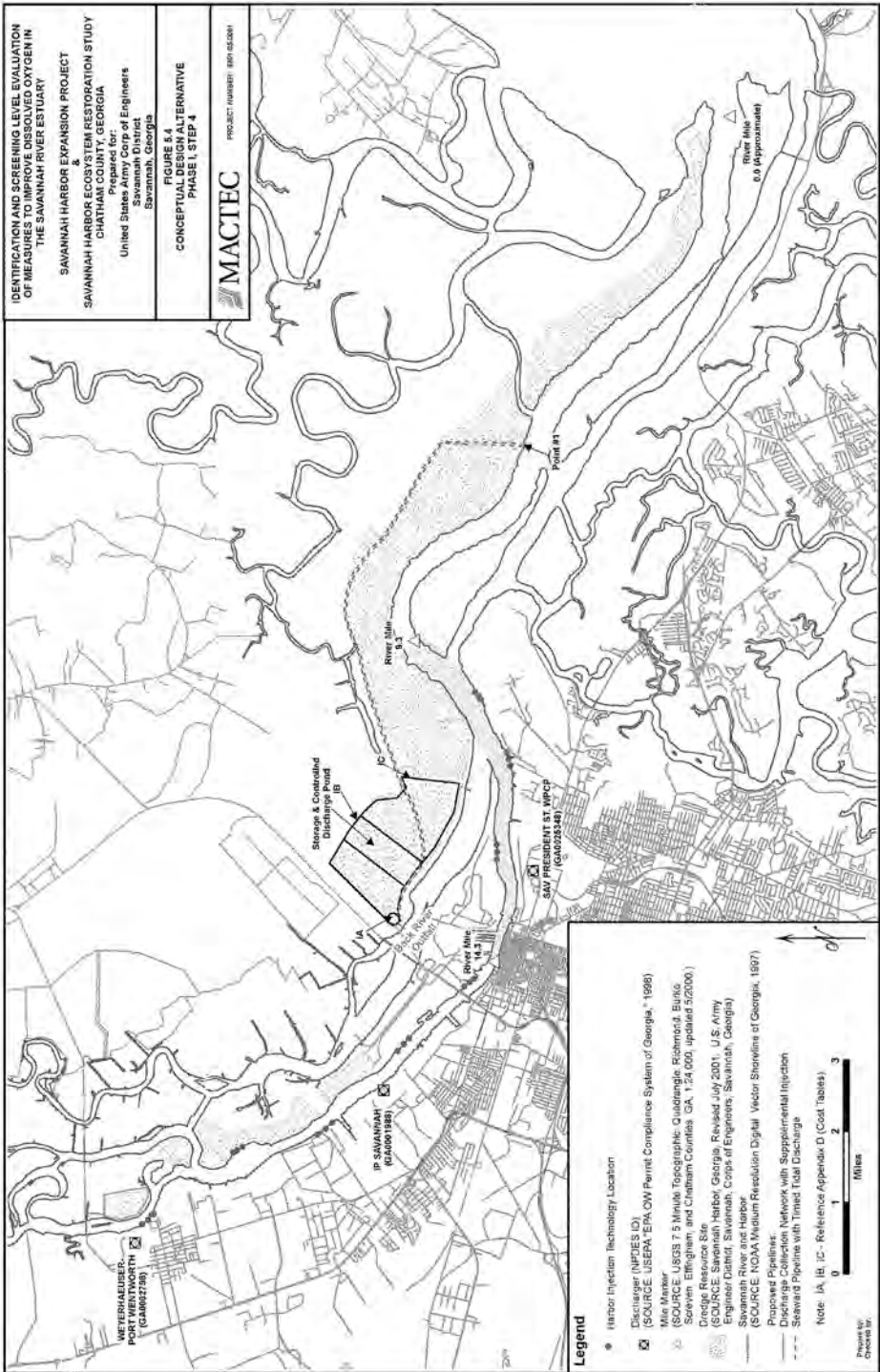
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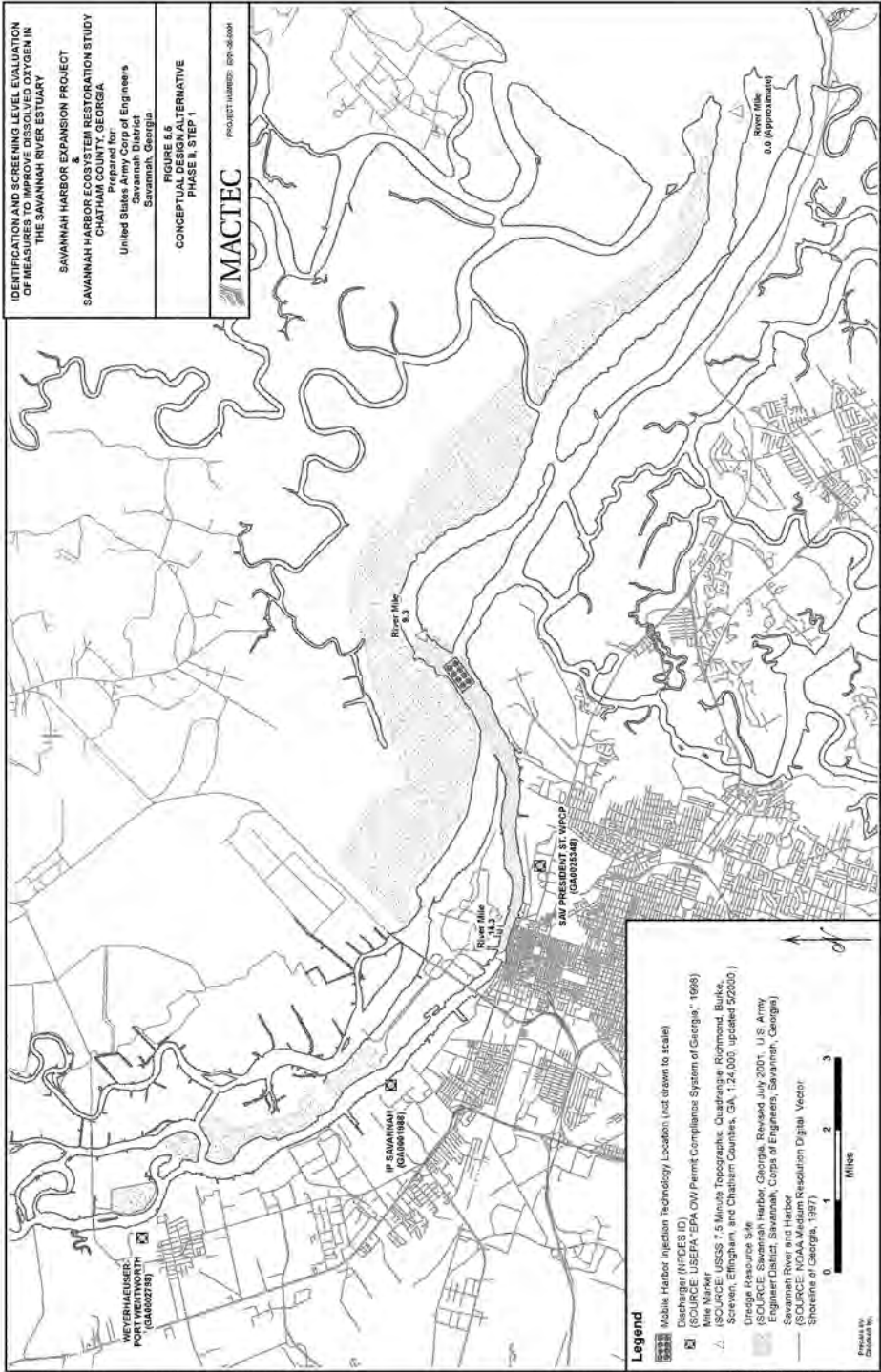


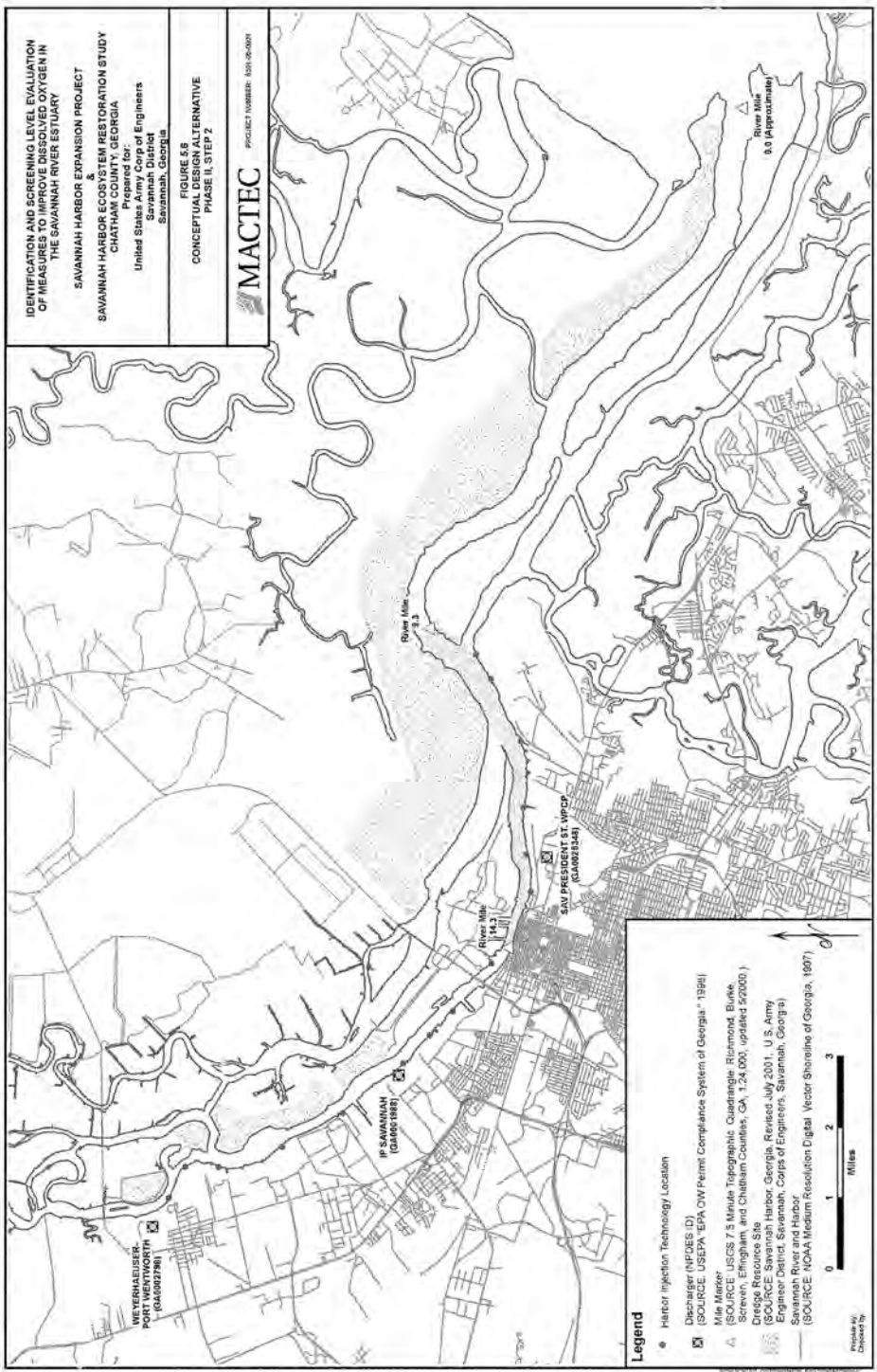


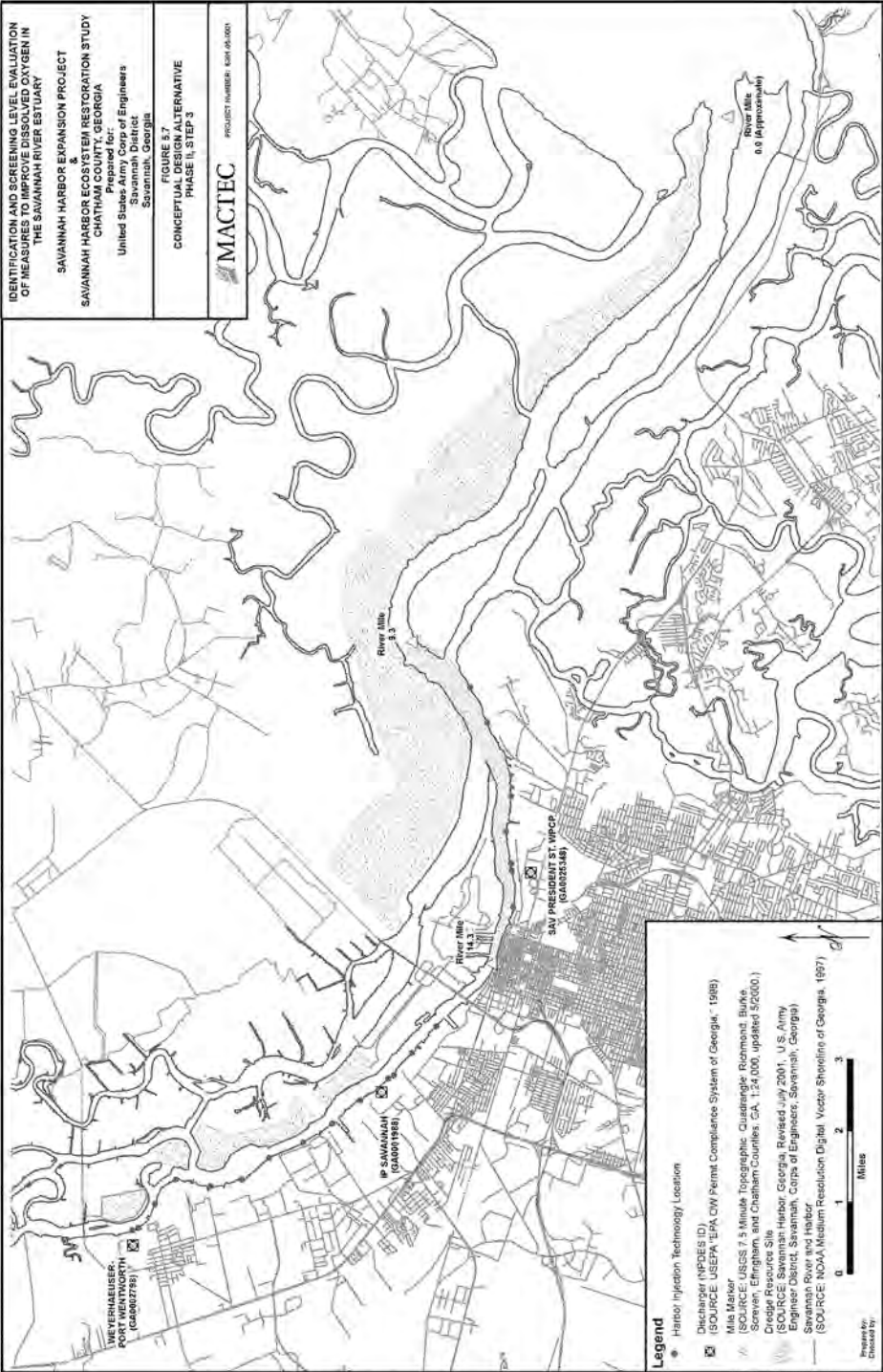


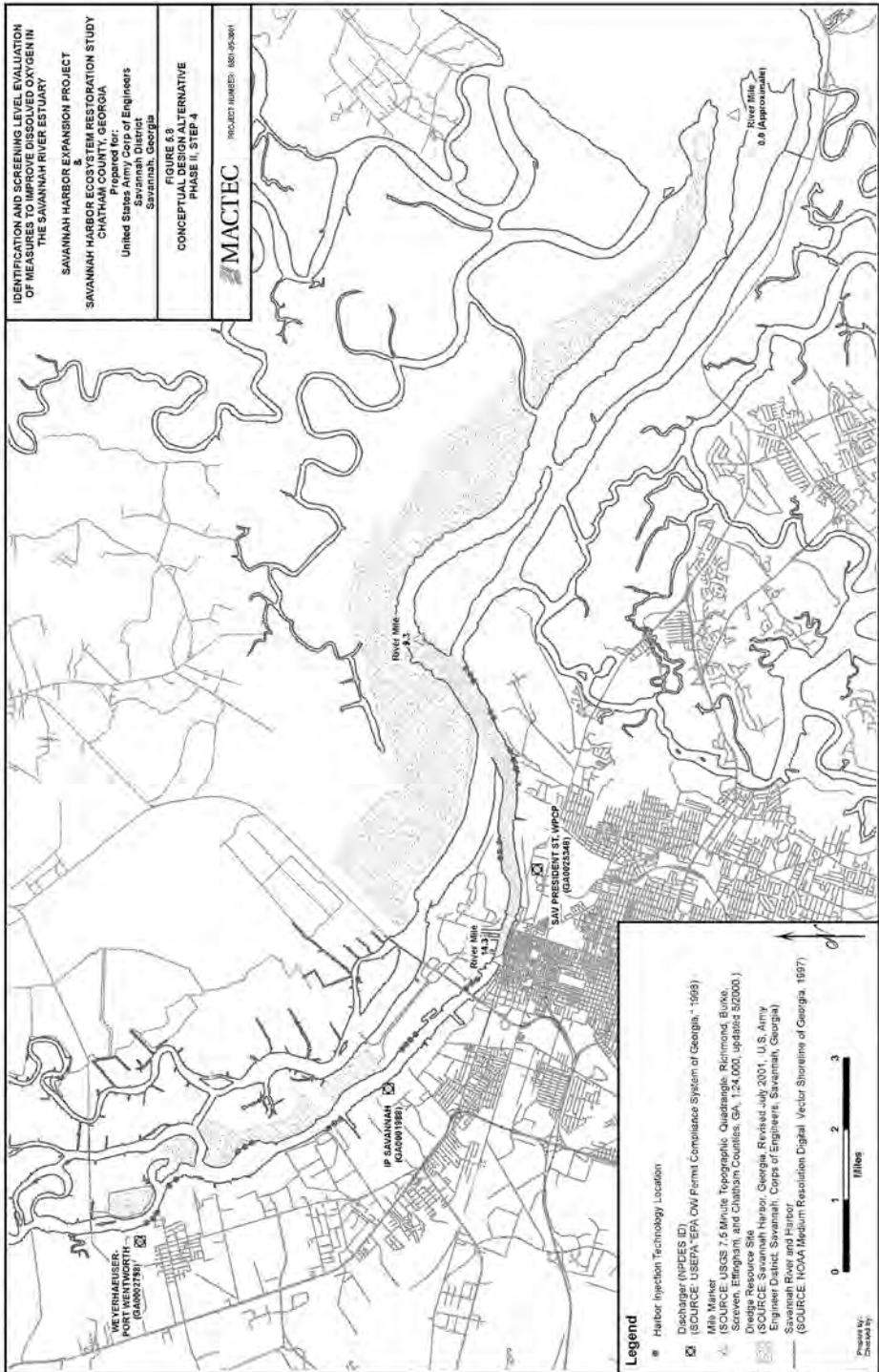
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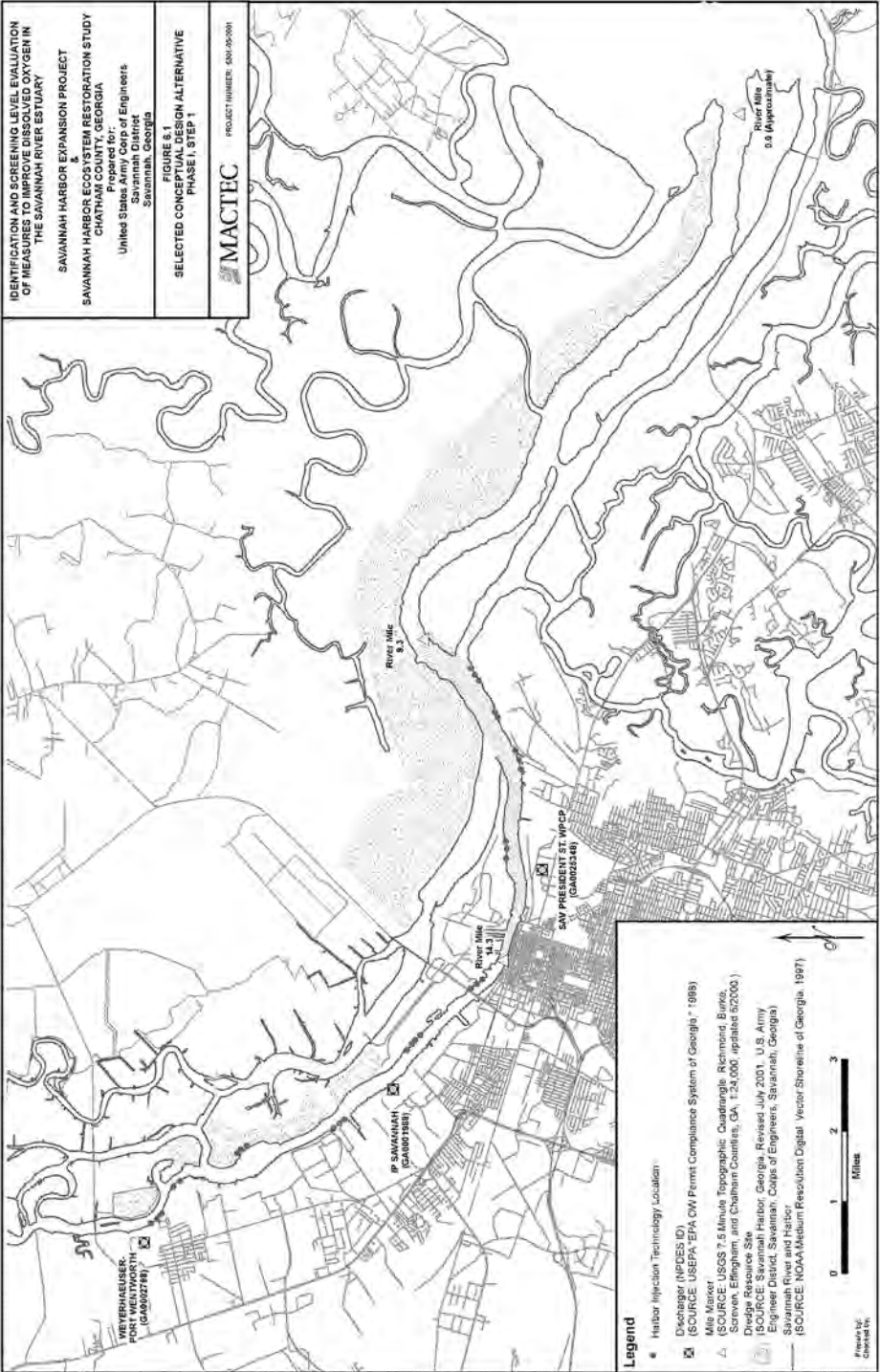


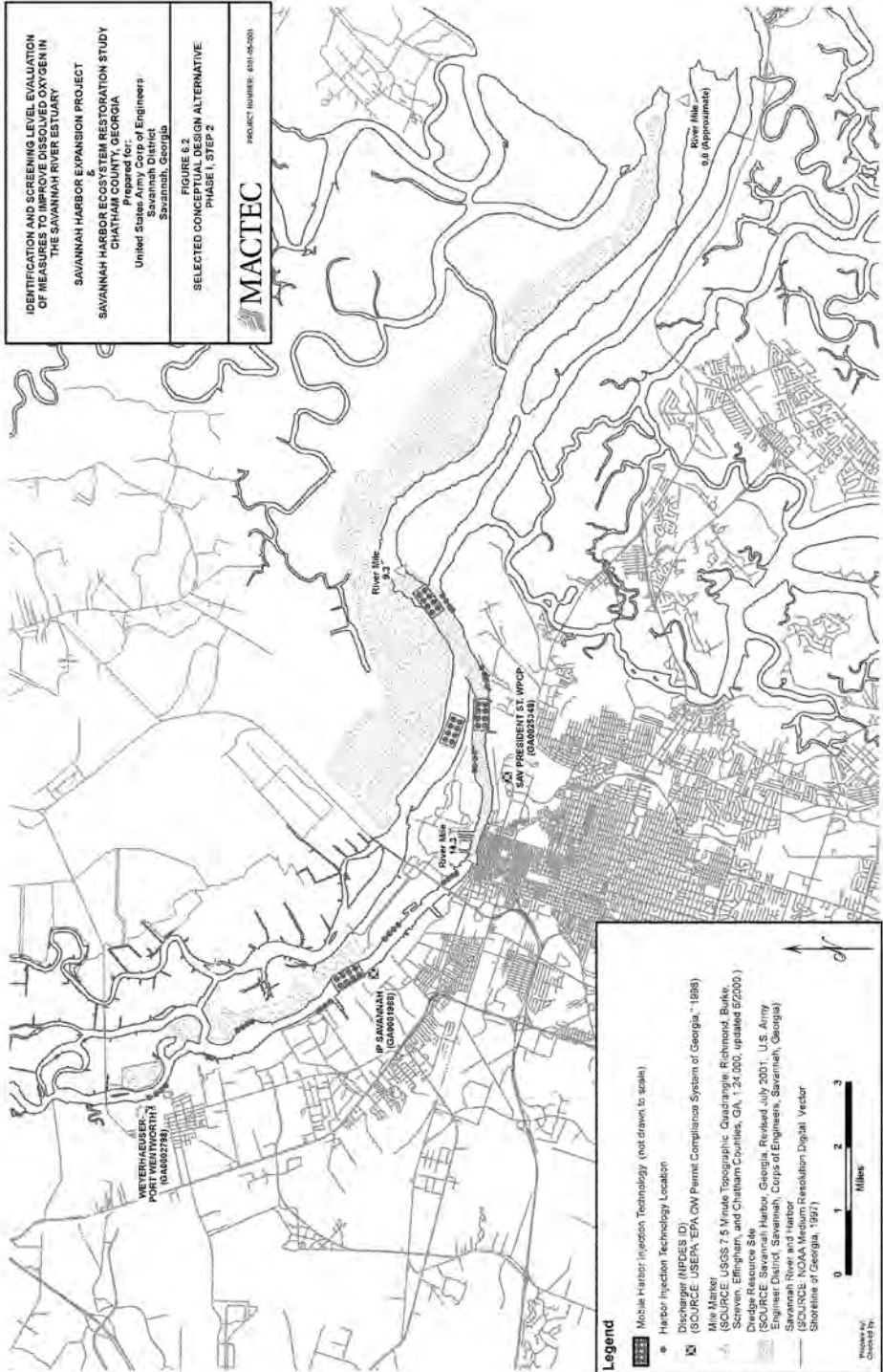


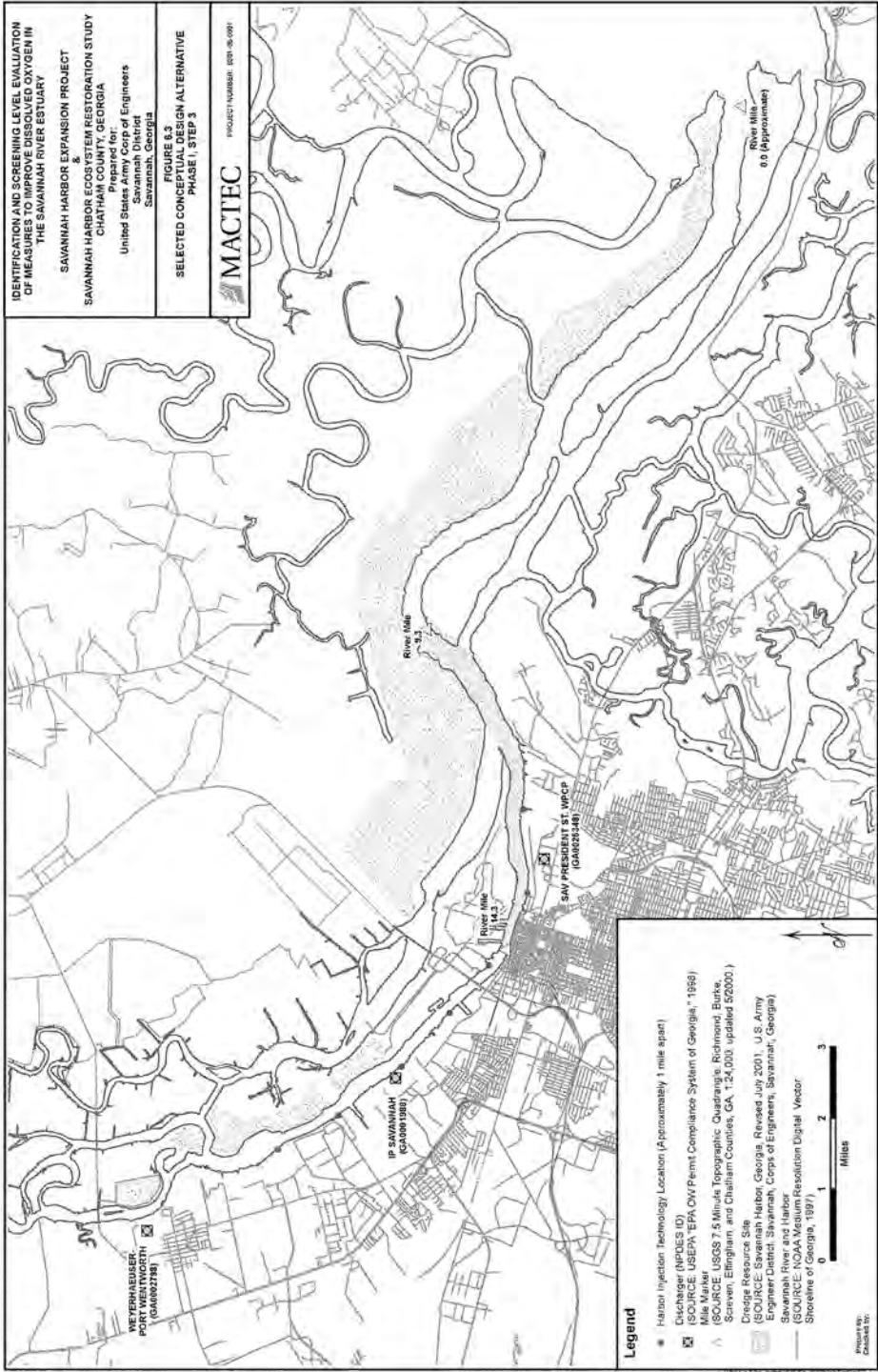


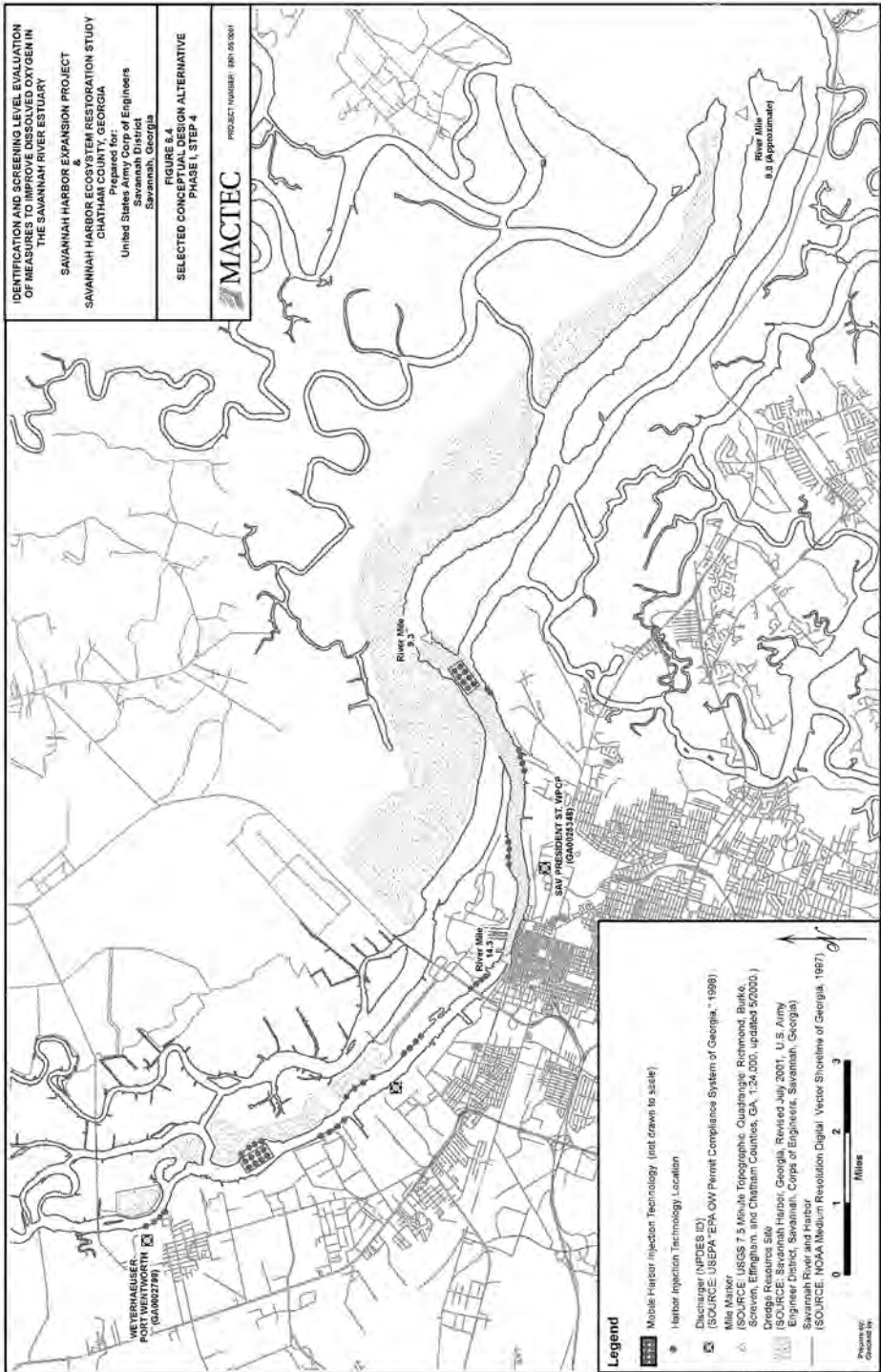


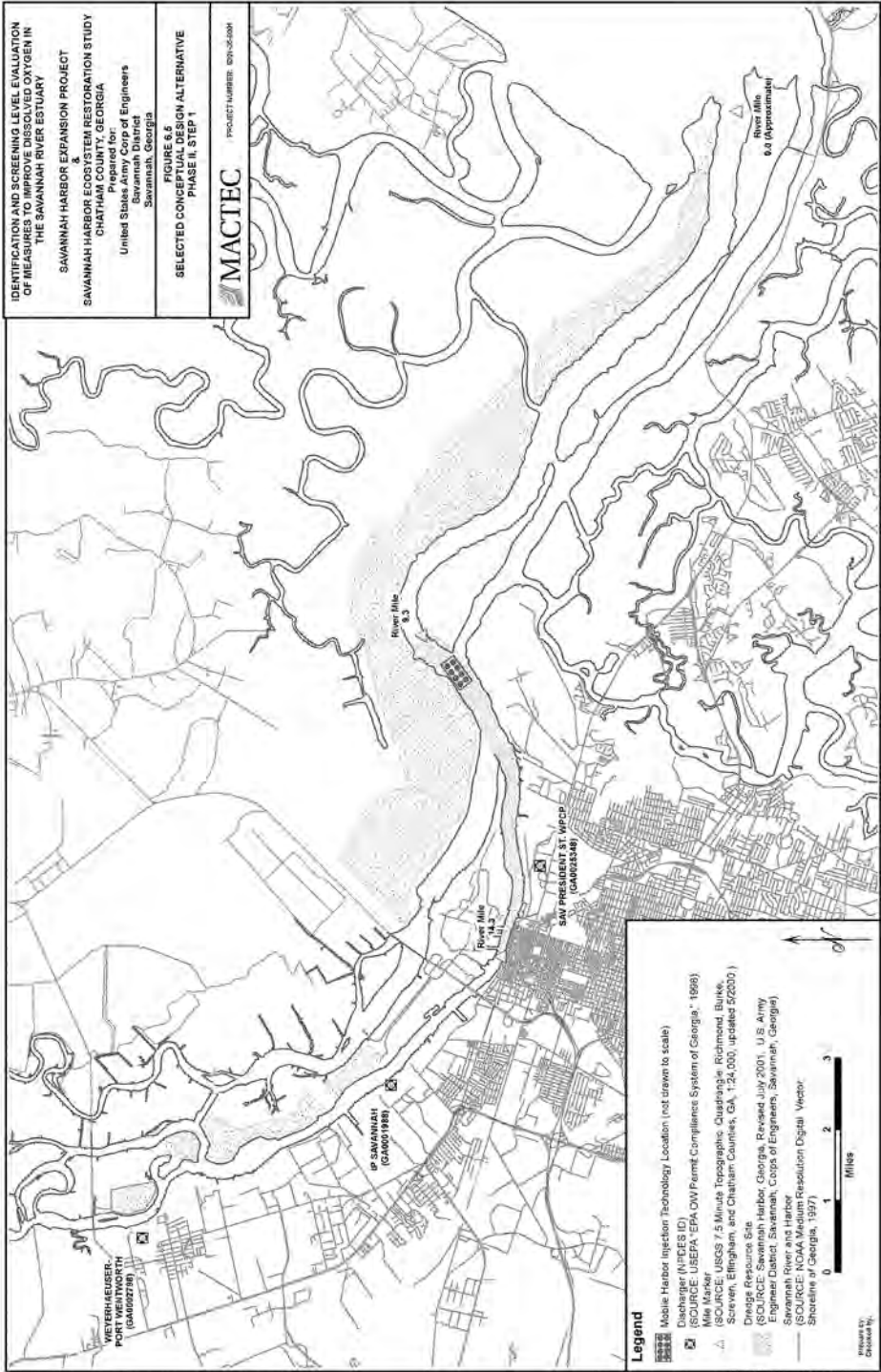


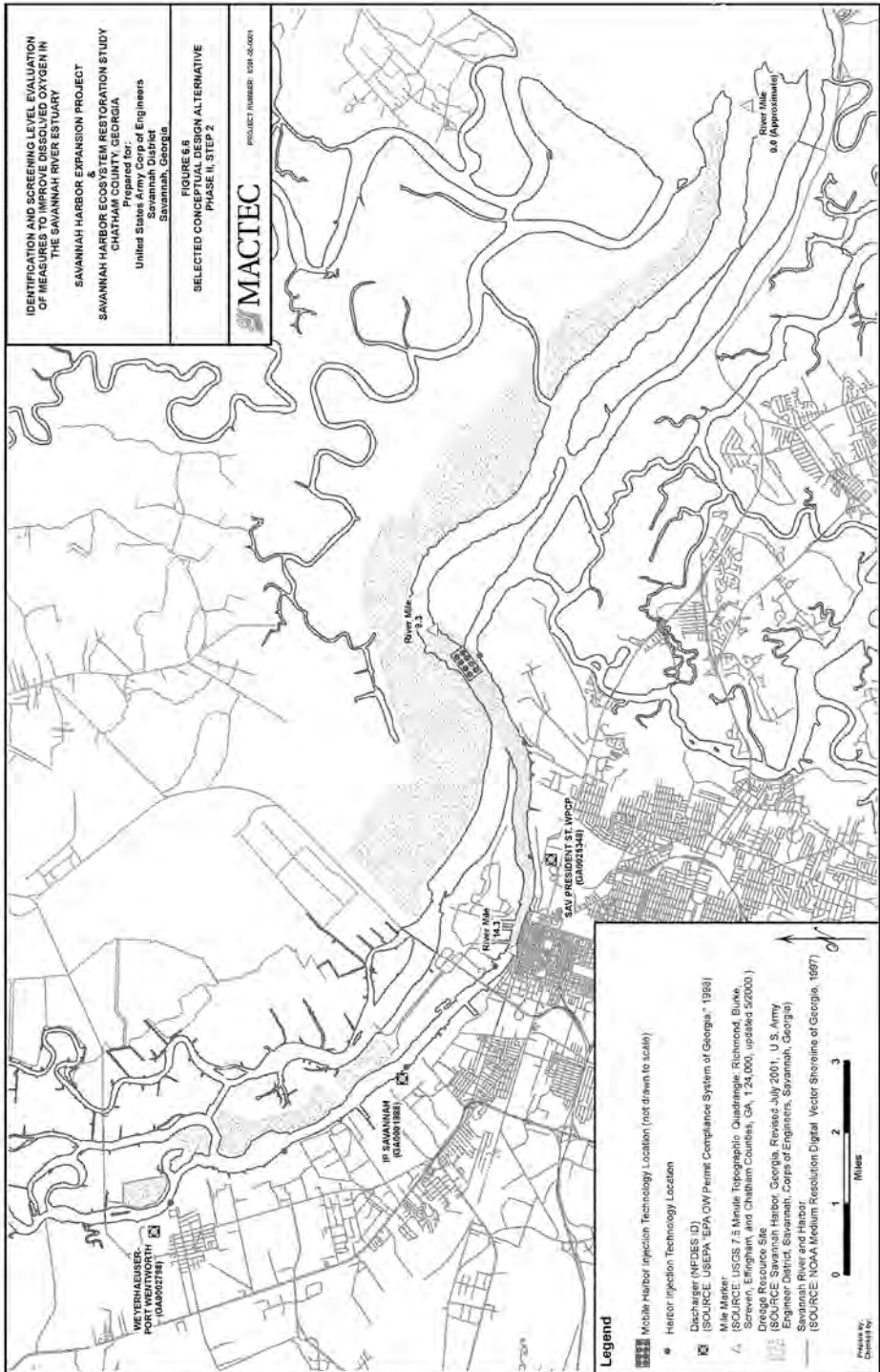


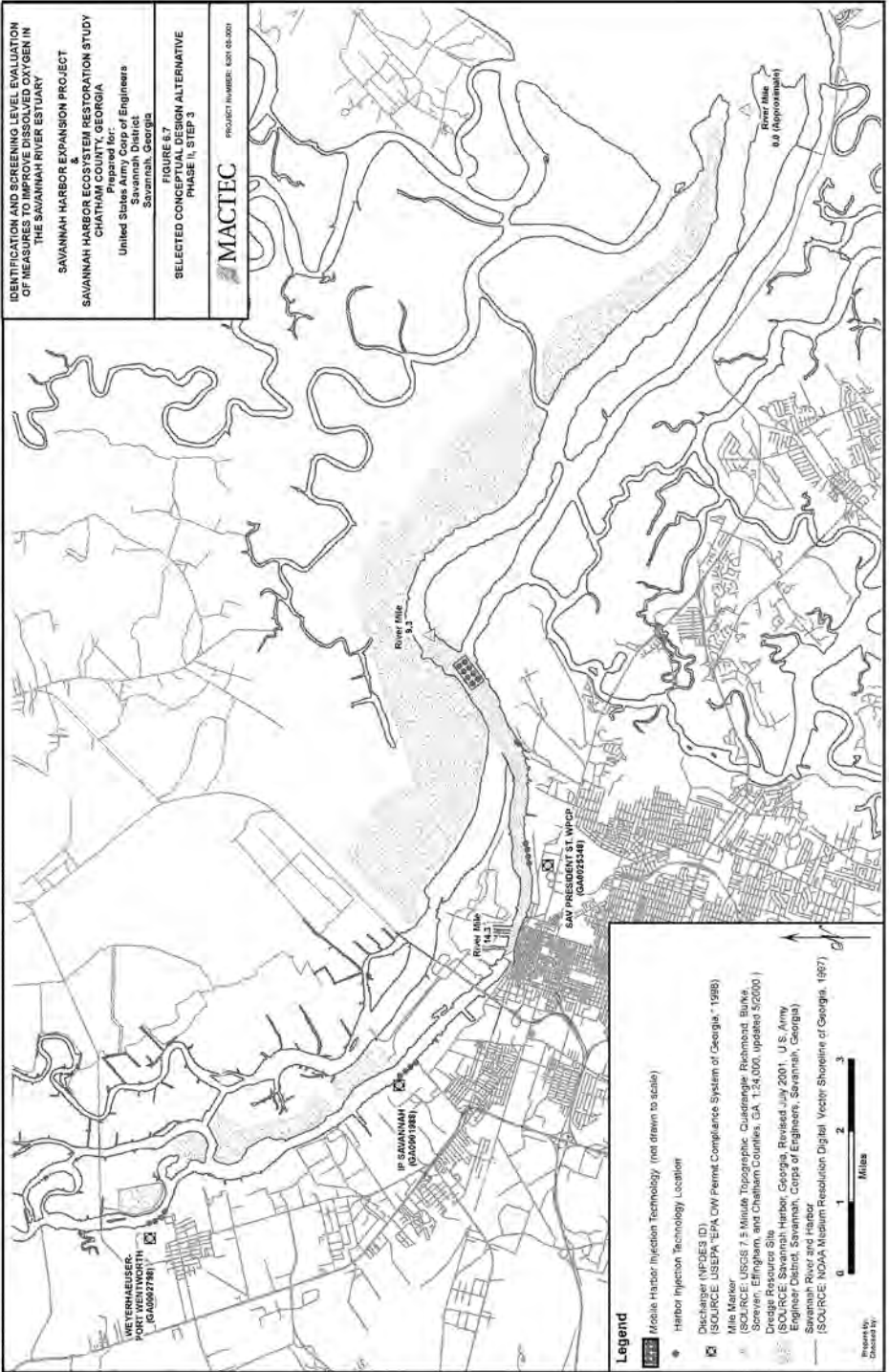


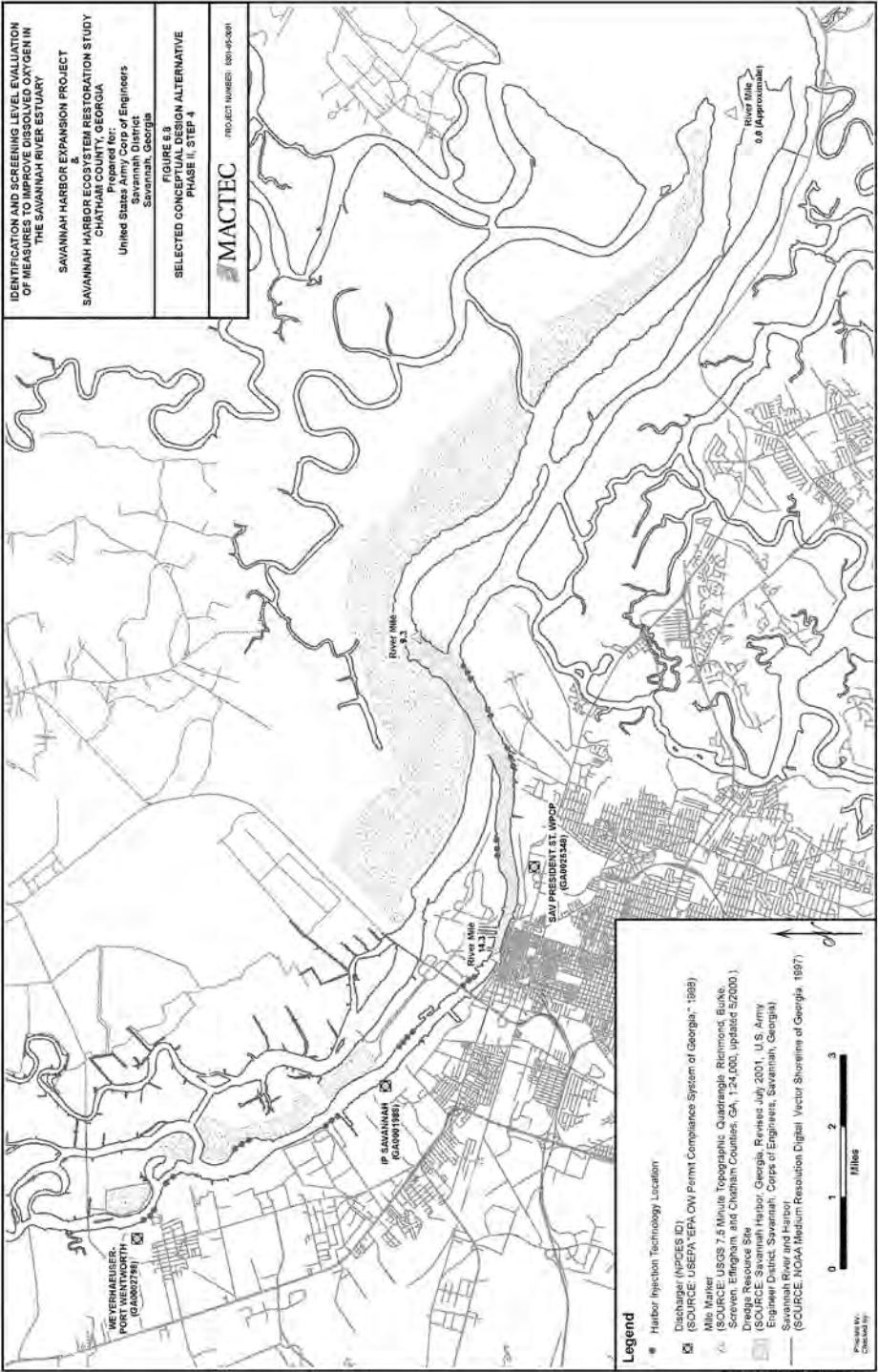












*Identification and Screening Level Evaluation of Measures to Improve
Dissolved Oxygen in the Savannah River Estuary
USACE Savannah District
Savannah, Georgia*

*FINAL
June 7, 2005
MACTEC Project 6301-03-0001
Contract No. W91278-04-D-0009, Delivery Order CPO1*

APPENDIX A

USACE SCOPE OF WORK

SCOPE OF WORK

IDENTIFICATION AND SCREENING LEVEL EVALUATION OF MEASURES TO IMPROVE DISSOLVED OXYGEN IN THE SAVANNAH RIVER ESTUARY

SAVANNAH HARBOR EXPANSION PROJECT & SAVANNAH HARBOR ECOSYSTEM RESTORATION STUDY CHATHAM COUNTY, GEORGIA

1.0 INTRODUCTION.

As components of both the Savannah Harbor Expansion Project and the Savannah Harbor Ecosystem Restoration Study, Savannah District needs to identify and conduct a screening level evaluation of potential measures that could improve dissolved oxygen in the Savannah River Estuary.

The Savannah Harbor Expansion Project is evaluating deepening the navigation channel in Savannah Harbor. Such deepening could reduce dissolved oxygen levels in some locations within the river during some periods of the year. The project desires to consider methods to reduce or eliminate that potential adverse effect. The project is also identifying cumulative impacts to the harbor's ecosystem that have resulted from previous developments.

The Savannah Harbor Ecosystem Restoration Study is examining ways to improve dissolved oxygen levels in the harbor. That study is focused on methods of improving existing levels of dissolved oxygen in the harbor during the critical summer months.

2.0 BACKGROUND.

Portion of Savannah Harbor has not met Georgia's water quality standards for dissolved oxygen in some locations during the summer months. The harbor is on Georgia's Section 303(d) list for waters that do not comply with water quality standards for dissolved oxygen. EPA Region 4 released a Draft TMDL for Dissolved Oxygen for the harbor in August 2004. That document identified a portion of the harbor which experiences low levels of dissolved oxygen during the summer months. The Draft TMDL calls for elimination of all point source waste loads exerted on the harbor, plus the addition of 90,000 lbs/day of oxygen to the harbor system during critical conditions. EPA's document indicates that the waste load from discharges within the harbor places a 99,000 lbs/day oxygen demand on the system, while the load from upriver discharges exerts an additional 100,000 lbs/day oxygen demand in the harbor. These combined loads equate to roughly a 0.4 mg/l of the oxygen deficit in the critical harbor segment. Roughly half of that load originates from discharges within the harbor, while the other half result from upriver discharges. EPA proposed an alternate TMDL consisting of a revised water quality standard and a 30 percent reduction in the total point source waste load to the harbor (a reduction of about 57,000 pounds/day TBODu to produce a remaining load of 132,000 pounds/day TBODu).

It is unlikely that the present Georgia water quality standard for dissolved oxygen will remain in place in its present form. EPA has stated that it is not effective and has proposed an alternate standard in the August 2004 Draft TMDL. The public comment period has not yet closed on EPA's proposal, so we cannot know if their proposal will be adopted as proposed. The effect of the deep-draft navigation channel on the system's ability to recover from the waste loadings is unknown at this time, but this factor is being investigated.

The Savannah Harbor Expansion Project has not determined the precise extent of its potential impact on dissolved oxygen levels. However, we believe it could reduce already low D.O. levels at the bottom by as much as 0.5 mg/L. The Expansion Project has identified several measures that could be used to improve dissolved oxygen within the harbor. Those measures are as follows:

- *Add air or oxygen to low dissolved oxygen waters*
 - Add air or oxygen upstream of the deep-draft harbor (Augusta to Savannah)
 - Floating aerators, air injection system, D.O. injection system
 - Add air or oxygen within the deep-draft harbor
 - Floating aerators, air injection system
 - D.O. injection system on bottom of river
 - D.O. injection system on Hutchinson Island
- Mix low dissolved oxygen waters on the bottom with higher D.O. surface waters
 - Inflatable weir
 - Pumps
- Increase releases from upstream reservoirs
- Reduce the BOD loads from industrial and municipal discharges in the harbor
- Reduce the BOD loads from industrial and municipal discharges further upriver

Other measures may also exist that are feasible and implementable. This initial study focuses on the potential improvements that are associated with BOD load reduction and addition of air or oxygen. The potential feasibility of other measures will be examined qualitatively. As part of its assessment of cumulative impacts, the Expansion Project is also identifying effects that past development of the harbor have produced on water quality.

3.0 OBJECTIVE. The objective of this study is to identify and conduct a screening level evaluation of potential measures that could improve dissolved oxygen in the Savannah River Estuary. This analysis will include an assessment of the engineering feasibility and cost effectiveness of potential improvement measures, as well as identification of implementation problems. This effort will be directed toward both the portion of the harbor and time of year that were identified in EPA's Draft TMDL for Dissolved Oxygen as having recurring low levels of D.O. The analysis will allow both Corps projects to consider alternate methods of improving dissolved oxygen from its present levels, as well as developing several increments of D.O. improvement.

4.0 METHODOLOGY. This study will be conducted in two phases, with multiple steps in each phase. Models currently exist for both the riverine portion of the Savannah River from Thurmond Dam to downstream of Clyo, Georgia (River Model) and for the Savannah Harbor

from Clio to the Atlantic Ocean (Harbor Models). These models need not be used in this screening level evaluation.

Phase I will be an assessment of potential D.O. improvement measures that could be used either singly or as a package to meet the Georgia water quality standard for dissolved oxygen. Since EPA has disapproved the present Georgia standard for D.O., this phase will include four steps. The first step will consider measures that would allow the harbor to comply with the present Georgia D.O. standard under existing waste loads. This would address the approximate 200,000 lbs/day excess oxygen demand presently in the harbor. The second step will consider measures that would allow the harbor to comply with the present Georgia D.O. standard under full permitted waste loads. This would address the discharged loads of approximate 367,000 lbs/day TBODu that are permitted in the harbor plus 75 percent of the 358,000 lbs/day TBODu that are permitted in the upriver areas. The third step will consider measures that would improve D.O. levels in the harbor to the extent that it meets the D.O. standard that EPA proposed for Georgia in its August 2004 Draft TMDL. This step would consider the effects of the existing waste loads. This step would develop plans that have the same effect as the 30 percent reduction in BOD loading proposed by EPA in its Alternate TMDL. The fourth step will also consider measures that would allow the harbor to comply with the D.O. standard that EPA proposed for Georgia in its August 2004 Draft TMDL. This step would consider the effects of full permitted waste loads -- 367,000 lbs/day TBODu permitted in the harbor area plus 75 percent of the 358,000 lbs/day TBODu that is permitted upriver. These steps can be summarized as follows:

Step	D.O. Standard	Point Source Loading
1	Present GA D.O. Standard	Present loading
2	Present GA D.O. Standard	Full permitted loads
3	EPA proposed standard	Present loading
4	EPA proposed standard	Full permitted loads

Phase II would consist of assessing potential measures that could be used either singly or as a package to further improve dissolved oxygen levels in the harbor. The improvements evaluated in this second phase could be larger scale designs of those identified in the first phase effort or could be a separate set of design solutions. This phase would also consist of four incremental steps, each improving bottom D.O. levels by 0.2 mg/L. Thus, this phase will develop four incremental designs for improving dissolved oxygen, the first capable of improving bottom D.O. levels by 0.2 mg/L, the second would improve D.O. levels by 0.4 mg/L, and the third would improve D.O. levels by 0.6 mg/L, and the fourth would improve D.O. levels by 0.8 mg/L. The work on this phase would assume the harbor already meets the D.O. standard the EPA proposed in August 2004.

5.0 WORK TO BE PERFORMED BY THE CONTRACTOR.

The scope of this study is to assess the feasibility and cost effectiveness of potential measures to improve dissolved oxygen (focusing on BOD load reduction and addition of air or oxygen) in the harbor during the summer months. Major steps within this study are:

- 1) Review the Draft TMDL for Dissolved Oxygen for the harbor that was proposed by EPA Region 4 in August 2004.
- 2) From EPA's Draft TMDL and the inputs to the computer models upon which it is based, conduct a screening level assessment of the potential contribution to the D.O. deficit from individual point source discharges along the river. This will include each of the discharges included in the TMDL models, whether they are located in Savannah, Augusta, or in between. Table 1 in EPA's Draft TMDL shows the permit loads calculated for dischargers in Savannah, while similar information for the upstream dischargers can be found in Appendix D of that report.
- 3) Develop a comprehensive list of potentially feasible measures to improve D.O. levels in Savannah Harbor during the summer months. This should include measures to address point source loads (upriver and in the harbor), non-point source loads, and storm water loads.
- 4) Identify and assess the largest contributors of BOD loads to the Savannah River. Develop a table ranking the BOD loads contributed by each source to identify the sources contributing the largest BOD loads. For the five largest point source contributors of BOD to the system, summarize their existing treatment systems. For each of those five sources, list the next two steps that would most traditionally be employed for additional BOD reductions and the estimated extent of reduction to be expected from each of those steps.
- 5) Assess the feasibility of each of the potentially feasible D.O. improvement measures identified above in step 3 in light of the conditions occurring in the Savannah River system. Briefly describe the conditions under which each measure would typically be most effective and the conditions that reduce its effectiveness.
- 6) For each step in Phase I, develop one suitable method for making the desired D.O. improvement. This will include a conceptual-level design for each alternative method. Coordination with either the point source dischargers or GA DNR-EPD may be necessary to obtain additional information on the physical and biological characteristics of each discharge. That information could be needed to assess the technical feasibility of potential improvement methods. This conceptual design will include description of the process to be employed and the size/scale of the major features. As part of the conceptual designs, identify problems or considerations that may limit the effectiveness of the measure or render it un-implementable. For Phase II, develop conceptual-level designs for making four incremental steps of improvement in D.O. in the harbor. Develop a conceptual design – as described above – for each of those four levels of D.O. improvement. The conceptual designs are expected to be screening level design layouts and include major features and/or BOD load reductions. Modeling to assess the impact of the conceptual designs to D.O. in the harbor will not be performed in this study. As part of each conceptual design, include the reasoning for why the design identified would be the most cost effective approach.
- 7) Evaluate the cost-effectiveness of the four conceptual designs for improving D.O. levels that were developed in Phase I and the four designs developed in Phase II. This will include implementation (access, land, equipment, construction, etc.) and operation costs. Cost estimates provided will be feasibility level cost evaluations and will be used to assess the cost-effectiveness of each conceptual design.
- 8) Identify the most cost effective D.O. improvement measure for each of the four steps in Phase I.
- 9) For the most cost-effective D.O. improvement designs developed through Phase I and the designs developed through Phase II, provide the following information to aid in the description of those designs: (A) a general location map, and (B) site map showing its

relation to nearby properties. Site maps will utilize readily available GIS/CADD tax parcel files. If files are unavailable, a figure showing predominant land use in the area may be substituted.

- 10) Prepare a report describing the procedures used, the measures that were considered, the conceptual designs that were developed, and the conclusions reached in the study.

6.0 MATERIALS TO BE FURNISHED BY SAVANNAH DISTRICT. Savannah District will provide no materials for this Delivery Order. However, the Savannah District may be able to research tax records in Savannah and surrounding areas.

7.0 DELIVERABLES. All deliverables should be provided to the U.S. Army Corps of Engineers, Attn: CESAS-PD-E (Mr. William Bailey), P O Box 889, Savannah, GA 31402.

7.1 MONTHLY PROGRESS REPORTS (Deliverable 1). Submit one (1) copy by the 10th of each month documenting the previous month's efforts.

7.2 DRAFT SUMMARY REPORT (Deliverable 2). Submit ten (10) bound copies of a report describing the procedures used in this work, as well as the findings and conclusions. Submit ten (10) CDs containing the report developed through this work.

7.3 FINAL SUMMARY REPORT (Deliverable 3). Submit twenty (20) bound copies of a report describing the procedures used in this work, as well as the findings and conclusions. Submit twenty (20) CDs containing the report developed through this work. Submit one (1) CD containing the report in both Microsoft WORD and ADOBE Acrobat formats.

8.0 SCHEDULE. The Contractor shall adhere to the following project schedule.

<u>Milestone</u>	<u>Due Date</u>
Initiate work	1 week after issuance of the Delivery Order
Monthly Progress Reports	10 th of each month until completion of the D. Order
Draft Summary Report	12 weeks from issuance of the Delivery Order
Final Summary Report	3 weeks from receipt of comments on Draft Report

The Government expects to provide comments on the Draft Summary Report after a 30-day review period.

9.0 POINT OF CONTACT. Mr. William Bailey (CESAS-PD-E) will be the US Army Corps of Engineers' point of contact for this work. He can be reached at 912-652-5781 (FAX 912-652-5787) or at the following address:

Mr. William Bailey
ATTN: PD-E
US Army Corps of Engineers
Savannah District
P.O. Box 889
Savannah, GA 31406-0889

All billing invoices should be sent to Mr. William Bailey.

*Identification and Screening Level Evaluation of Standards to Improve
Dissolved Oxygen in the Savannah River Estuary
USACE Savannah District
Savannah, Georgia*

FINAL
June 7, 2005
MACTEC Project 6301-03-0001
Contract No. W91273-04-D-0009; Delivery Order CY01

10.0 REFERENCES.

EPA, Region 4, August 2004. Draft Total Maximum Daily Load (TMDL) for Dissolved Oxygen in Savannah Harbor, Savannah River Basin, Chatham and Effingham Counties, Georgia. Report prepared by EPA Region 4, Atlanta, Georgia.

*Identification and Screening Level Evaluation of Measures to Improve
Dissolved Oxygen in the Savannah River Estuary
USACE Savannah District
Savannah, Georgia*

*FINAL
June 7, 2005
NACTEC Project 6301-05-0001
Contract No. W91278-04-D-0009, Delivery Order C/P01*

APPENDIX B

POINT SOURCE DISCHARGES

USACE SHEPHERDS
Chatham County, Georgia

MACTEC Project Number: 6361-05-0001
Contract Number: W612798-04-D-0068 CV01
March 3, 2005

Appendix B

Point Source Dischargers⁽¹⁾

Identification and Screening Level Evaluation of Measures to Improve Dissolved Oxygen in the Savannah River Estuary
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Project
Chatham County, Georgia

Facility Name	NPDES ID	Current Permit Limits				Oxygen Demanding Load Based on Current Permit Limits				
		Flow ^a (MGD)	BOD ₅ ^b (lb/day)	NH ₃ (mg/L)	NH ₃ (lb/day)	F-Ratio	CBOD ₅ (lb/day)	NBOD ₅ (lb/day)	TBOD ₅ (lb/day)	Permit Limit TBOD ₅ (lb/day)
Arcadian (PCS Nitrogen)	GA0002071	3.00	751		2,833			12,947	12,947	9,710 ^c
City of Augusta (Butler Creek)	GA0037621	45.10	3,845	1.5	577	4	15,379	2,636	18,015	13,511 ^d
City of Hartley	GA0003689	0.25	63			2	125		125	94
City of Santee	GA0020983	0.20	33	5.0	5	3	109	38	138	104
City of Springfield	GA0020770	0.60	104	5.0	21	2	309	95	304	225
City of Sylvan	GA0021366	1.61	378	17.4	219	2	766	1,001	1,757	1,316 ^e
City of Thomson	GA0020974	2.50	313	5.0	104	3.5	1,095	478	1,571	1,175 ^f
City of Waynesboro	GA0035466	2.00	500	15.0	250	3.5	1,751	1,143	3,895	2,171 ^g
Columbia County (Crawford Creek)	GA0031984	1.50	150	1.2	15	2	300	70	370	277 ^h
Columbia County (Little River)	GA0047775	3.00	375	8.7	218	3.5	1,314	995	2,308	1,731 ⁱ
Columbia County (Reed Creek)	GA0031992	4.80	384	2.0	77	4	1,535	351	1,885	1,414
DSM Chemicals	GA0027192		250		6,000	3	150	27,450	28,170	21,128 ^j
Fort Gordon	GA0023484	4.00	1,001	17.5	584	2	2,002	2,895	4,870	3,627 ^k
Fort James Paper (GA Pacific)	GA0048973		10,850			5	54,250		84,250	40,688 ^l
Gracewood School and Hospital	GA0022161	0.50	125	17.4	73	2	250	332	582	436 ^m
International Paper (Augusta)	GA0002801		30,000			6	150,000		180,000	135,000 ⁿ
NIPRO		3.00			6,000	3	9,900	27,420	37,320	27,990 ^o
Richmond County (Spart Creek)	GA0047147	2.24	560	17.4	325	2	1,121	1,436	2,606	1995 ^p
Engelhard	GA0048330				352			4,030	4,030	4,030
Gaston City	GA0031018	2.00	500	17.4	290	2.4	1,201	1,325	2,526	2,526
International Paper (Savannah)	GA0001958	3.00	25,000			10.7	267,500		267,500	267,500 ^q
Kerr-McGee Pigments	GA0002646	0.60								
President Street	GA0025348	27.00	4,166	12.9	2,905	3.9	18,247	13,276	29,523	29,523
Trans Field	GA0020447	1.60	250	11.6	145	2.3	575	863	1,233	1,233
Weyerhaeuser Port Wentzworth	GA0027390	0.10	6,700			4.5	30,150		30,150	30,150 ^r
Wright	GA0020443	4.80	1,128	17.4	653	2.5	2,815	2,384	5,799	5,799
Georgia Power Co. Plant Vogtle (Southern Nuclear)	GA0026786								0	0
Savannah Electric Plant Kraft	GA0003516								0	0
Savannah Electric Plant Riverstone	GA0003751								0	0
Savannah Electric Plant McIntosh	GA0003553								0	0
City of Aiken (Potts Creek)	SC0541002	26.0	7,155	11.0	2,395	3	21,468	10,901	32,369	24,770 ^s
Cashnet Corporation-Hardin Plant	SC0042803	1.8	564			3	1,852		1,852	1,850
Kimberty-Clark	SC0002802	11.2	4,031			3	12,093		12,093	9,070 ^t
Savannah River Site										
SC Electric and Gas - Unquahart	SC0047431	147.9								0
Town of Allendale	SC0035913	4.0	834	20.0	667	3	2,602	3,048	5,550	4183 ^u
Town of Hartsville	SC0004884	1.0	253			2	506		506	390 ^v

Notes:

- (1) NPDES - National Pollutant Discharge Elimination System
MGD - million gallons per day
TMDL - Total Maximum Daily Load
BOD₅ - Biochemical Oxygen Demand
lb/day - pounds per day
mg/L - milligrams per liter
CBOD₅ - Carbonaceous Ultimate Biochemical Oxygen Demand
NBOD₅ - Nitrogenous Ultimate Biochemical Oxygen Demand
TBOD₅ - Total Ultimate Biochemical Oxygen Demand
NA - Not Applicable
NH₃ - Ammonia
RM - River Mile
m³/ton - cubic meters per ton

Prepared By: _____
Checked By: _____

(1) Based on current permit limits as reported in USEPA EnviroFacts Database⁽¹⁾ For upstream dischargers 75% of the permitted load was used to complete the tanking.

(2) Information not available

(3) As reported in the Draft TMDL (USEPA, 2004). Values for IF-Savannah, GAPAC, Weyerhaeuser are assumed to be erroneous.

(4) Permit limits and discharge monitoring system (DMR) data were used to provide flow information for design.

(5) USEPA, 2004. Draft Total Maximum Daily Load (TMDL) for Dissolved Oxygen in Savannah Harbor Basin.

(6) Chatham and Effingham Counties, Georgia. U.S. Environmental Protection Agency. August 2004.

(7) Assumes 75% TBOD₅ reduction in Harbor.

*Identification and Screening Level Evaluation of Measures to Improve
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USACE Savannah District
Savannah, Georgia*

*FINAL
June 7, 2005
MACTEC Project 6301-05-0001
Contract No. W91278-04-D-0009, Delivery Order C101*

APPENDIX C

CORRESPONDANCES

Subacz, Jonathan

From: Kinnard, Tanya
Sent: Wednesday, April 06, 2005 11:18 AM
To: Subacz, Jonathan
Subject: FW: Reuse system questions

From: Tanner, Margaret
Sent: Monday, March 21, 2005 3:40 PM
To: bob_scanlon@savannahga.gov
Cc: Neal, Larry; Kinnard, Tanya; Subacz, Jonathan; Latalladi, Monique
Subject: Reuse system questions

Here are our questions and information needs for the City of Savannah Reuse plan

Current Water Reuse Plan

What were the costs to provide reuse water to the golf course on Hutchinson Island?
 What is the average design flowrate to the golf course during the summer months?
 What is the pipe diameter?
 What is the BOD loading or BOD5 concentration in the reuse water?
 What is the total golf course area currently being irrigated with the reuse water?

You mentioned that there was another golf course receiving reuse water. What is the name? Also, do you have information similar to the questions for the Hutchinson Island golf course? When did reuse start for this course (was it included in the flow estimates for the 1999 data)? Also, EPA is using DMR data to conduct the modeling from 1997-2003. When did the Hutchinson Island course go on line?

What is the total quantity of water currently designated for reuse?

Potential Future Water Reuse

On the City's website, we found information that suggested that there was some potential to provide reuse water to:

- Forsyth Park
- Daffin Park
- Paulsen Softball Complex
- Guy Minick Sports Complex
- County Soccer Complex

Can you provide addresses or (lat/lon data) for these sites?

Do you have the areas to be irrigated and the volume of reuse water to be provided for each of these sites?

Will each be supplied from the President's street facility? If not, what facility will supply the reuse water?

Has any type of cost analysis been done to assess the feasibility of this plan? If so, can this be provided?

Will the wastewater treatment plant need to be expanded to provide for increase reuse water usage? If so by what design flow? Have costs been developed for changes to the facility?

MARGARET E. TANNER – Senior Engineer
 MACTEC Engineering and Consulting, Inc.
 Kennesaw Technical Center
 Office 770.421.7032 – Mobile 770.605.3957 – Fax 770.421.3486
 Email metanner@mactec.com – Web www.mactec.com

RE: Question on Savannah RIV1 Model

Page 1 of 1

Subacz, Jonathan

From: Whitlock.Steve@epamail.epa.gov
Sent: Thursday, February 10, 2005 6:02 PM
To: Bailey, William G SAS
Cc: greenfield.jim@epamail.epa.gov
Subject: RE: Question on Savannah RIV1 Model

Bill,

Preliminary results are in:

I ran scenarios with upper boundary DO at normal observed levels and then at 20% higher. At Clio I saw no noticeable difference in DO. Also, since I did not change the BOD decay rate there was no difference in BOD. This means additions of DO at the Dam would only affect local DO and not the downstream reaches of the river or harbor.

.....

Steve Whitlock
US EPA Region 4, Water Management Division
TMDL Modeling and Support Section
61 Forsyth Street, SW, Atlanta, GA 30303-3104
phone 404-562-9242, fax 404-562-9224
whitlock.steve@epa.gov

.....

4/6/2005



Jeffrey S. Lynn
Manager of External Regulatory Affairs
Corporate Environment

International Place
6400 Poplar Ave.
Memphis, TN 38197
Phone 901-419-3956

Ms. Sibyl Cole
U.S. EPA Region IV
61 Forsyth St., S.W.
Atlanta, GA 30303

January 29, 2005

Re: Comments on the Savannah Harbor Draft TMDL for Dissolved Oxygen (DO) –
August 2004

Dear Ms. Cole:

As the world's largest paper and forest products company with two major manufacturing operations in the Savannah River Basin, located in Augusta and Savannah, International Paper has a significant interest in the development and implementation of a scientifically defensible and equitable TMDL to mitigate the dissolved oxygen (DO) impairment for the Savannah River Harbor.

While International Paper recognizes that EPA was under a consent decree obligation to issue this proposed TMDL, the company strongly objects to finalizing the proposed TMDL or any alternative TMDL without further public notice and comment. As discussed in greater detail below, any final TMDL based upon the existing Georgia water quality standard or the modeling system underlying EPA's August 2004 proposal is scientifically unsound and without basis in fact or law. International Paper reserves its right to provide further comment on any revised or alternative TMDL.

Under the aforementioned objection and reservation of rights, International Paper submits the following comments on behalf of both International Paper mills.

INTRODUCTION

International Paper is vigilant in its efforts to protect water quality and is committed to assuring that water quality in the Savannah River Harbor is appropriately protected. We further recognize that water quality protection is critical to the viability of our multi-billion dollar assets in the Savannah River Watershed; hence it is critical that the TMDL accurately reflect the current hydrodynamic regime and physical setting of the Harbor and that the TMDL be based upon a water quality standard that defines the appropriate level of protection necessary for the Harbor.

It is furthermore essential that the final TMDL for the Savannah River Harbor be based on a water quality standard that is attainable and recognizes the level of water quality protection necessary for an industrial port, such as the Savannah Harbor. As highlighted in the draft TMDL, the Harbor, even under natural conditions with no inputs from point source dischargers, could not meet the existing water quality standard that was used to develop the draft. Use of this inappropriate water quality standard resulted in a totally unrealistic outcome for point source dischargers, that being “zero discharge.” The concept of “zero discharge” is clearly unattainable, unachievable and wholly inappropriate. Neither municipal nor industrial point source dischargers can achieve such an impractical goal without significant social and economic disruption and the threat of abandoning continued operation. Another outcome MUST be achieved.

Prior to finalizing the TMDL, an appropriate water quality standard must be identified and incorporated into the TMDL. EPA’s recognition that this critical point has not been met should, by itself, provide the foundation to withdraw the draft TMDL until such time that an appropriate standard is adopted and a revised TMDL can be recalibrated using an amended and more appropriate water quality standard. It is entirely inappropriate to advance the draft TMDL, as it cannot be practically implemented. Furthermore, the alternative TMDL is not appropriate and contains many of the same deficiencies as the draft TMDL – i.e., use of an insufficient model, etc.

NON-TECHNICAL COMMENTS

The TMDL Does Not Appropriately Account for Past and Potential Future Harbor Deepening Projects

In 1989, the Georgia’s Environmental Protection Division (EPD) established the current Coastal Fishing DO standard for the Harbor. In 1989, the Harbor met that standard, with an authorized depth of 38 feet. The Harbor is currently authorized and dredged to a depth of 42 feet. In practice, this means that the Harbor can be anywhere from 44 to 46 feet deep in places where the COE overdredges to maintain the minimum 42 foot depth for ships to enter the port. The current depth of 42 feet was achieved in 1994. Since the deepening project in 1994, the Harbor has not met the DO standard. These past physical modifications (deepening events) have significantly impacted the water quality of the Savannah Harbor over the past several decades and are widely and logically believed to have had a specific impact on DO.

In addition, the Georgia Ports Authority and the US Army Corps of Engineers (COE) are reviewing yet another application to deepen the harbor an additional 6 feet which will further impact the Harbor’s DO. There is an effort currently spearheaded by the COE to establish a re-aeration project to mitigate impacts of historic Harbor deepening events. This is a federal cost-shared project with participation by federal and state government agencies and local shareholders. The City of Savannah serves as the local sponsor for this project. NPDES permit holders in the Harbor, including International Paper, are also contributing

time and resources to the project. The TMDL Project and the COE Restoration Project share a common goal - to quantify the oxygen deficit in the Harbor and determine options available for mitigation. A final plan of action has yet to be defined. However, at a minimum the Restoration Project must be coordinated and incorporated into the TMDL prior to its finalization and implementation. International Paper does not believe that public, nor for that matter private, funds should be used to alleviate a perceived water quality impairment based on a standard that is unattainable under present-day natural conditions.

The past and potential future deepening events are considered the "root cause" for the DO impairment of the Harbor. Point source dischargers are described as collectively contributing less than 0.5 ppm to the DO deficit in the Harbor. As such, it is completely inappropriate for point source dischargers to bear a 30% load reduction as suggested under the alternative TMDL scenario based on EPA's recommended DO standard. It is objectionable for point sources to bear such extreme costs associated with remedial actions to improve water quality when they are not the "primary" influence impacting DO levels in the Harbor.

Costs to Upgrade Wastewater Treatment Plants Exceed Point Source Contribution to the Impairment Problem

To further demonstrate the inequity of the 30% BOD load reduction proposed in the alternative TMDL we have conducted some preliminary engineering analyses to determine how the Augusta and Savannah Mills could achieve the proposed reductions. We also estimated the associated costs for these actions.

Both mills would have to significantly reconfigure their wastewater treatment systems to achieve the improved removal efficiencies mandated by the alternative TMDL. This action could only be achieved at a significant capital cost to each mill. Using standard engineering assumptions, the estimates to increase BOD removal efficiency at the Augusta and Savannah Mills, respectively, are \$28,275,000 and \$37,492,000. These figures represent the total costs anticipated to increase BOD removal efficiencies and assure compliance with anticipated limitations based on the suggested alternative TMDL.

It is wholly inappropriate to expect point source dischargers that, in aggregate, only contribute 0.5 ppm to the DO sag in the Harbor, to this extraordinarily heavy expense. Any cost associated with achieving the final DO standard for the Harbor should be assumed proportionally by the entities contributing to the problem. The projected high costs associated with wastewater treatment system upgrades to meet a 30% BOD reduction brings into question the viability of both of these mills. It is inappropriate to propose such high cost remedies when point sources are not the predominant contributory factor to the problem.

EPA's Model Must Account for the Harbor Deepening Events

Prior to finalizing the TMDL for the Harbor, EPA must specifically evaluate the impact of the historic and proposed deepening events. As stated above, the Harbor was considered in compliance with its DO water quality standard prior to the deepening events that have modified the physical configuration of the Harbor, thus allowing greater tidal influence, reduced water velocity, and increased residence time for precursors to DO reductions. Each of these factors and others ultimately led to the Harbor's unique DO situation. It is necessary for the COE to continuously dredge the Harbor in order to maintain the currently approved depth. This is an ongoing activity that must also be addressed. Without these deepening and depth maintenance activities the Harbor would naturally return to a much shallower depth and it is logical that DO concerns would return to a more normal and water quality standard compliant situation, inclusive of the point source contributions.

The impact of Harbor deepening must be modeled to assure that any actions recommended in the final TMDL are focused on the primary contributing factors the TMDL seeks to remedy. International Paper strongly urges EPA to more fully model the Harbor based on historic depths versus the current and proposed depths in order to more fully understand the relationship these deepening events have on DO levels in the Harbor. In addition, the model must focus on the Harbor as a whole and not just the areas that have been deepened or undergone depth maintenance activities.

Recommended DO Standard

The draft TMDL proposed a "zero discharge" limitation for all point sources based upon an effort to protect the existing DO water quality standard. We support EPA's recognition of the Savannah Harbor's inability to meet the existing water quality standard under natural conditions. The inability to comply naturally with an overly restrictive water quality standard led the authors of the draft TMDL to recommend the need for development of a more realistic DO water quality standard. The authors suggested a revised site-specific marine DO criterion based on data from estuaries in the Virginian Province, which is defined as Cape Cod to Cape Hatteras.

It is unknown whether the recommended DO criterion is fully appropriate for the Savannah Harbor situation and as such, we would further encourage EPA to validate this alternative criterion as appropriate and applicable to the Savannah Harbor. International Paper supports EPA's effort to identify a suitable criterion and encourages EPA to continue this effort expeditiously. We do, however, caution EPA that whatever criterion is finally adopted for the Harbor it MUST recognize that this waterbody is an industrial port and the standard of protection MUST reflect that realization and the complexities associated with a heavily modified waterbody. Identification and selection of an appropriate water quality standard for the Harbor is critical to defining a TMDL that will be equitable to all stakeholders.

TECHNICAL COMMENTS

Model Comments

The model used to develop the existing draft TMDL significantly oversimplifies the dynamics of the Harbor and may not accurately portray the impact of point sources on DO concentrations in the harbor. The following technical comments and observations involving specific areas are offered:

Re-aeration

It is our understanding that EPA has efforts underway to enhance the model that was used to develop the draft TMDL by addressing re-aeration concerns. International Paper fully supports these efforts to advance the utility and validity of this model as a tool to reflect the Harbor regime more accurately and in its entirety. Full disclosure of the supporting data to construct the model is requested.

BOD Decay Rates

We further encourage EPA to reassess the BOD decay rates that were used in the model as they oversimplify the fate of BOD in the Harbor. Since the current model uses a single decay rate, the loadings for many point source dischargers are either overestimated or underestimated. The model should be refined so it reflects the Harbor system as a whole allowing for the differing decay rates from individual point sources. Incorporation of multiple decay rates into the model should vastly modify the results. BOD decay rates are available for all dischargers and the model has the capability to handle multiple decay rates. Full use of the model's capabilities is imperative so as to provide maximum model accuracy. The actual decay rates, as measured for each discharger, can be incorporated into the model and provide a much more realistic picture of the Harbor's DO situation. It is premature to finalize the TMDL until the modeling process is complete and can be used to characterize the Harbor with a much greater degree of rigor and precision.

The paper industry has conducted a considerable amount of research on decay dynamics of oxygen-demanding substances from pulp and paper mill effluents. The data collected shows that these dynamics are relatively complex and that much of the BOD in paper mill effluents decays relatively slowly, on the order of 0.02/day. Additional studies have also indicated that de-oxygenation kinetics of CBOD from pulp and paper mill effluents are in some cases poorly represented by single stage first order decay expressions. In the case of the Savannah Harbor there are multiple sources of BOD to the system including pulp and paper, other point sources and non-point sources. The Savannah Harbor model applies a first order decay model and a coefficient of 0.09/day for the modeled reach from Clio to the ocean. This simplified decay rate constant has significant consequences for depicting an accurate model of BOD impacts on DO for the Harbor. Use of this overly simplified approach must be addressed. It is highly recommended that multiple rate decay coefficients be incorporated into another round of modeling prior to redrafting the TMDL so as to more accurately reflect the true decay dynamics of the system.

It is also unclear why the upstream river model uses a decay rate of 0.06/day until it enters the harbor and is reassigned a decay rate of 0.09/day. This may overstate the decay of upstream BOD in the harbor. This overestimate may need to be corrected by modeling it as a separate BOD component with a slower decay rate.

Deepening

As mentioned above, the harbor deepening events must be modeled to identify both pre-deepening and post-deepening impacts on the system as a whole. It is also recommended that a finer grid be used for the model prior to its use for developing a final TMDL.

Storm Water

The TMDL states that storm water is inconsequential as a contributing factor to the overall DO deficit as represented by the statement that storm water has "no measurable impact on DO levels in the critical areas of concern (p.13)." There is little to no data provided to support such a claim. However, it is noted that storm water did enter the system during data collection in 1999 and as such is implicitly included in the background data. This is a very important point and we suggest that storm water impacts be explicitly identified and incorporated into the TMDL. The State of Georgia has proposed new regulations for Industrial Storm Water Discharges that will impact business sites that discharge storm water to the Harbor. The TMDL needs to address how storm water dischargers will be impacted so as to maintain consistency between the TMDL and the requirements of the new General Industrial Storm Water Permit. We further reserve discussion on the allocation of storm water based on the insufficiency of data provided.

The draft TMDL describes the "vast majority" of non-NPDES loading of oxygen-demanding substances as derived from natural background sources, such as detritus and marsh outflow to the river. It is difficult to perceive how storm water, which would increase detritus inflow to the river and marsh outflow can be described as having "no measurable impact" on DO levels.

CONCLUSION

International Paper participates in two separate coalitions of dischargers representing the Savannah and Augusta areas. Respectively, these coalitions are the Savannah Harbor Committee and the Central Savannah River Area TMDL Group. Comments submitted by these individual coalitions are hereby incorporated by reference. The comments submitted by the American Forest & Paper Association are also incorporated by reference.

Although EPA's effort to expedite the development of this TMDL was predicated on achieving a judicially-driven timeline, we strongly recommend that EPA now take the necessary time to coordinate its efforts with stakeholders to determine an appropriate water quality standard and corresponding DO criterion for the Savannah River Harbor, redefine the TMDL based on the revised standard and resubmit the revised TMDL for review and comment. It is our understanding that EPA has initiated efforts to re-evaluate the model

used to develop the initial draft TMDL and we fully support this action, however, the numerous activities described above must be coordinated with the model review in order to assure the final TMDL is appropriate, scientifically defensible and achievable.

International Paper encourages EPA to refocus its efforts to collectively, with stakeholders, revise and redraft the TMDL based on an appropriate water quality standard that recognizes the protections necessary for an industrial port. To this end, International Paper encourages EPA to adopt the above recommendations and actions as their own and fully commit to assuring the development of a practical and attainable TMDL. To discuss these comments further or answer any questions that may arise, please contact me at (901) 419-3956.

Sincerely,



Jeffrey S. Lynn
Manager External Regulatory Affairs

The above comments are submitted and endorsed on the behalf of International Paper's Augusta and Savannah Mills. Should you have additional mill-specific questions please contact either Jeremy Pearson (706-796-5363) at the Augusta Mill or Donna Katula (912-238-7054) at the Savannah Mill.

Respectfully Submitted,



Steve Bowden
Augusta Mill Manager



Timothy M. Kean *DK*
Savannah Mill Manager



January 31, 2005

FILE COPY

Bob Scanlon
City of Savannah
P.O. Box 1027
Savannah, GA 31402

Regarding: **Information request for the SHER and SHEP Projects**
Screening Level DO Improvement Alternatives for Savannah Harbor
USACE SHEP/SHER Project
Project Number: 6301-05-0001

Dear Mr. Scanlon:

As components of both the Savannah Harbor Expansion Project (USACE, 2004) and the Savannah Harbor Ecosystem Restoration Study (USACE, 2004), the U.S. Army Corps of Engineers (USACE) has contracted with MACTEC Engineering and Consulting (MACTEC) to identify and conduct a screening level evaluation of alternative potential measures to seasonally improve dissolved oxygen (DO) concentrations in Savannah Harbor. Low DO levels in Savannah Harbor are the subject of an EPA Region 4 Draft Total Maximum Daily Load (TMDL) for Dissolved Oxygen (EPA, 2004). According to EPA, the particular harbor segment for which DO improvement is needed is an approximate four mile length between Talmadge Bridge and Elba Island and the critical season of the year for such DO improvement is the three-month period from June 15th through September 15th.

The EPA TMDL modeling attributes an approximate 0.5 mg/L critical segment DO deficit to all point sources of BOD (combined) with roughly one half of this point source deficit resulting from upriver point source BOD loads reaching the upper end of the estuary and the other half resulting from point source BOD loads directly to the estuary. This EPA finding means that total elimination of all point source BOD loads between Thurmond Dam and the sea could improve critical segment DO concentrations in Savannah Harbor by only 0.5 mg/L. The Draft EPA TMDL, based on meeting newly recommended DO criteria, calls for an approximate 30-percent overall reduction of point source BOD loading from the overall point source BOD loading experienced during the summer critical period of 1999.

The types of potential measures identified in the current harbor DO improvement screening for the Army Corps include: directly adding air or oxygen to low DO waters in the critical harbor segment; mixing low DO waters on the bottom of the harbor with higher DO surface waters; seasonally increasing flow releases from upstream reservoirs; seasonally reducing BOD loads from industrial and municipal discharges to the harbor and upriver. A potential benefit to point source BOD dischargers of the Corps' DO mitigation and restoration projects

is that the federal government may fund a portion of the costs for design and construction of whatever DO improvement measures may be authorized.

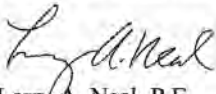
For purposes of screening the potential for seasonal BOD load reductions, MACTEC is contacting the larger point-source BOD dischargers seeking their ideas as to what measures might be considered for such screening. The objective is to identify potential means and general order of costs for reducing BOD discharges by about 30 percent or more during the three month critical season (June 15th through September 15th). Potential alternatives might include added effluent storage capacity, critical season land application or wetlands polishing, supplemental or short-term enhanced treatment, plant process changes, coordinated plant shut-down/maintenance schedules during the critical season, water conservation measures, or (in the estuary) piping BOD discharges farther seaward. Considering the limited impact of point sources on the critical DO deficit (only 0.5 mg/L according to EPA) it seems unlikely that point source BOD load reduction measures would prove to be a cost efficient means for significantly improving DO. Nonetheless, consideration of BOD load reduction alternatives is a required component of this DO improvement screening project.

To accomplish the screening level evaluation of potential BOD point source load reductions, MACTEC requests information relating to the wastewater treatment process at your facility. Specifically, waste stream generation process flow diagrams, wastewater treatment process flow diagrams, and unit operations information. Additionally, MACTEC recognizes that this information may be sensitive and will not include specific plans or diagrams in the final report and will only use them to identify the potential 'next steps' for BOD reduction. Representatives of MACTEC will be calling from February 2 through February 11 (or as necessary) to discuss this project and information with you for your facility.

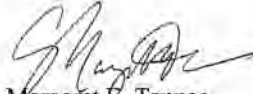
Thank you for your cooperation.

Sincerely,

MACTEC Engineering and Consulting



Larry A. Neal, P.E.
Senior Principal Engineer
Vice President



Margaret E. Tanner
Senior Engineer

References:

USACE, 2005. Savannah Harbor Expansion Project website.
<http://www.sysconn.com/harbor/>

USACE, 2005. Savannah Harbor Ecosystem Restoration Dissolved Oxygen (DO) website.
<http://www.sas.usace.army.mil/projects/projects/shdo.htm>



January 31, 2005

FILE COPY

Michelle Liotta
Georgia-Pacific
P.O. Box 828
Rincon, GA 31326-0828

Regarding: **Information request for the SHER and SHEP Projects
Screening Level DO Improvement Alternatives for Savannah Harbor
USACE SHEP/SHER Project
Project Number: 6301-05-0001**

Dear Ms. Liotta:

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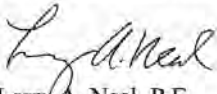
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Thank you for your cooperation.

Sincerely,

MACTEC Engineering and Consulting



Larry A. Neal, P.E.
Senior Principal Engineer
Vice President



Margaret E. Tanner
Senior Engineer

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<http://www.sas.usace.army.mil/projects/projects/shdo.htm>



January 31, 2005

Jeremy Pearson
International Paper--Augusta Mill
P.O. Box 1425
Augusta, GA 30903

FILE COPY

Regarding: **Information request for the SHER and SHEP Projects**
Screening Level DO Improvement Alternatives for Savannah Harbor
USACE SHEP/SHER Project
Project Number: 6301-05-0001

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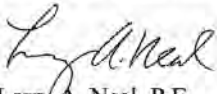
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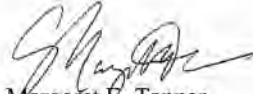
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Larry A. Neal, P.E.
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January 31, 2005

Brittany Robinson
International Paper-Savannah
P.O. Box 570
Savannah, GA 31402

FILE COPY

Regarding: **Information request for the SHER and SHEP Projects**
Screening Level DO Improvement Alternatives for Savannah Harbor
USACE SHEP/SHER Project
Project Number: 6301-05-0001

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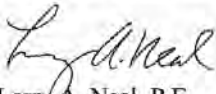
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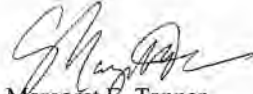
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Sincerely,

MACTEC Engineering and Consulting



Larry A. Neal, P.E.
Senior Principal Engineer
Vice President



Margaret E. Tanner
Senior Engineer

References:

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<http://www.sas.usace.army.mil/projects/projects/shdo.htm>



March 15, 2005

Rick Hamilton
Weyerhaeuser
P.O. Box 668
Savannah, GA 31402

FILE COPY

Regarding: **Information request for the SHER and SHEP Projects**
Screening Level DO Improvement Alternatives for Savannah Harbor
USACE SHEP/SHER Project
Project Number: 6301-05-0001

Dear Mr. Hamilton:

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The EPA TMDL modeling attributes an approximate 0.5 mg/L critical segment DO deficit to all point sources of BOD (combined) with roughly one half of this point source deficit resulting from upriver point source BOD loads reaching the upper end of the estuary and the other half resulting from point source BOD loads directly to the estuary. This EPA finding means that total elimination of all point source BOD loads between Thurmond Dam and the sea could improve critical segment DO concentrations in Savannah Harbor by only 0.5 mg/L. The Draft EPA TMDL, based on meeting newly recommended DO criteria, calls for an approximate 30-percent overall reduction of point source BOD loading from the overall point source BOD loading experienced during the summer critical period of 1999.

The types of potential measures identified in the current harbor DO improvement screening for the Army Corps include: directly adding air or oxygen to low DO waters in the critical harbor segment; mixing low DO waters on the bottom of the harbor with higher DO surface waters; seasonally increasing flow releases from upstream reservoirs; seasonally reducing BOD loads from industrial and municipal discharges to the harbor and upriver. A potential benefit to point source BOD dischargers of the Corps DO mitigation and restoration projects

is that the federal government may fund a portion of the costs for design and construction of whatever DO improvement measures may be authorized.

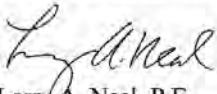
For purposes of screening the potential for seasonal BOD load reductions, MACTEC is contacting the larger point-source BOD dischargers seeking their ideas as to what measures might be considered for such screening. The objective is to identify potential means and general order of costs for reducing BOD discharges by about 30 percent or more during the three month critical season (June 15th through September 15th). Potential alternatives might include added effluent storage capacity, critical season land application or wetlands polishing, supplemental or short-term enhanced treatment, plant process changes, coordinated plant shut-down/maintenance schedules during the critical season, water conservation measures, or (in the estuary) piping BOD discharges farther seaward. Considering the limited impact of point sources on the critical DO deficit (only 0.5 mg/L according to EPA) it seems unlikely that point source BOD load reduction measures would prove to be a cost efficient means for significantly improving DO. Nonetheless, consideration of BOD load reduction alternatives is a required component of this DO improvement screening project.

To accomplish the screening level evaluation of potential BOD point source load reductions, MACTEC requests information relating to the wastewater treatment process at your facility. Specifically, waste stream generation process flow diagrams, wastewater treatment process flow diagrams, and unit operations information. Additionally, MACTEC recognizes that this information may be sensitive and will not include specific plans or diagrams in the final report and will only use them to identify the potential "next steps" for BOD reduction. Representatives of MACTEC will be calling from February 2 through February 11 (or as necessary) to discuss this project and information with you for your facility.

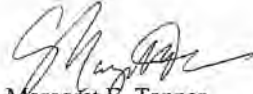
Thank you for your cooperation.

Sincerely,

MACTEC Engineering and Consulting



Larry A. Neal, P.E.
Senior Principal Engineer
Vice President



Margaret E. Tanner
Senior Engineer

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USACE, 2005. Savannah Harbor Expansion Project website.
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*Identification and Screening Level Evaluation of Measures to Improve
Dissolved Oxygen in the Savannah River Estuary
USACE Savannah District
Savannah, Georgia*

*FINAL
June 7, 2005
MACTEC Project 6301-05-0001
Contract No. W91273-04-D-0009, Delivery Order C/P1*

APPENDIX D

OXYGEN SUPPLEMENTATION TECHNOLOGIES

APPENDIX D

**OXYGEN SUPPLEMENTATION
TECHNOLOGIES**

(3/29/05)

Section 1. TMDL Compliance

Allowable BOD Loading

Regulations requiring that treated effluents be discharged to receiving waters at elevated D.O. concentrations are specified in some discharge permits. Conventional aeration techniques may achieve these higher concentrations but usually entail prohibitively high unit energy consumption and are limited in the D.O. levels that can be achieved. Using standard aeration equipment to increase the D.O. from 0 to 7 mg/L in water at 25°C would require approximately 2700 kwhr/ton of D.O. added, which is equivalent to over \$200/ton of D.O. for electricity rates of \$0.08/kwhr.

An efficient oxygenation system, on the other hand, can achieve the higher D.O. requirements both more easily and more economically. Technology is now available to produce heretofore impossibly high superoxygenation levels, allowing TMDL D.O. standards to be reached in many applications without the necessity for tertiary treatment.

TMDL Requirement Solutions

Reduction of pollutant loading, water augmentation in low flow situations and aeration are the methods traditionally used to reach TMDL levels. One aspect of the TMDL process mandated for surface waters is to establish the D.O. level appropriate for the resident fishery. This then leads to designation of the allowable BOD and/or nutrient-loading rate applicable to all entities discharging to the waterway. For impounded or slow flowing rivers with attendant low reaeration rate, k_2 , as found in the relatively flat terrain, the allowable pollutant loading rates are accordingly quite low, resulting in the need to achieve especially high pollutant removal rates by the contributing entities. Such advanced removals cause exponential increases in wastewater treatment costs for relatively small incremental removal of pollutants. At present secondary treatment is mandated in all states for all wastewaters, resulting in more than 90% removals commonly being realized, but tertiary removals with their attendant high cost may also be necessary to meet the TMDL levels in many cases. However tertiary treatment may no longer be necessary in most cases when using a newer method which supplements D.O. in very high concentrations sufficient to achieve TMDL standards for D.O.. However, as presented in this paper, a newer method of supplementing superoxygenation directly to the river, promises significant advantages not achievable in the past.

The rate of reaeration of a river is shown in the following equation by Thackston:

$$k_2 = 0.000025 [1 + 9 \{F\}^{0.25}] [(h S_e g)^{0.5}] / h$$

Where: u = velocity – ft/sec

h = depth – ft

S_e = slope – ft/ft

Fig. ___ depicts the k_2 corresponding to velocity and depth combinations.

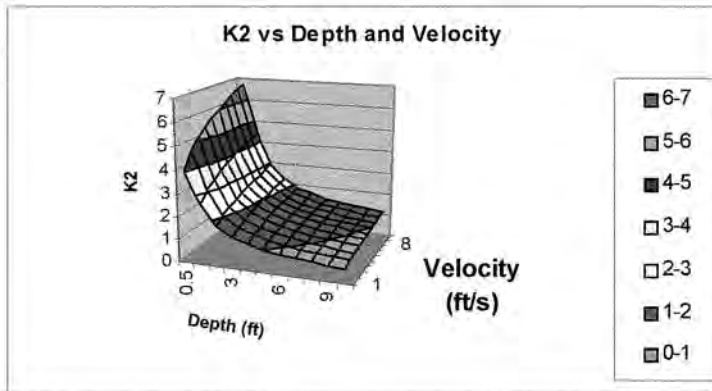
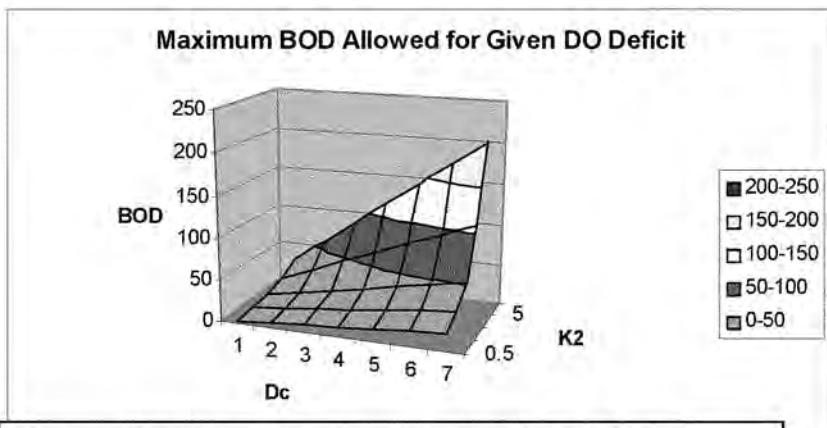


Fig. Reaeration rate vs velocity and depth



Maximum BOD Allowed for a Given D.O. Deficit at Sag Point

The allowable BOD loading in a segment of river is a function of the allowable D.O. deficit (or target D.O.) and the k_2 of that segment as shown in Fig. ___

Strategy for D.O. Supplementation:

- Add D.O. equivalent to ultimate BOD in discharge so no oxygen resources in the harbor are consumed in metabolizing residual BOD.
- Higher D.O. from oxygenation station permits increased spacing between oxygenation stations.
 - This permits economy of scale.
 - Cost to bring in electrical power much reduced
 - Delivery of LOX
- Propeller pumps to assist in D.O. transport away from oxygenation station.

D.O. Supplementation Trading for Advanced BOD removal

The allowable BOD loading on a river is a function of k_r , k_d , and k_2 . For example if River A has a depth of 10 ft and velocity of 1 ft/sec it will have a $k_2 = 0.65/\text{day}$ while River B, with a depth of 2 ft and velocity of 4 ft/sec will have $k_2 = 2.3/\text{day}$. Thus the allowable BOD loading at 25 °C for a D.O. deficit of 3 mg/L and for River A is 10 mg/L. By comparison, the allowable BOD loading for River B is 28 mg/L.

Lower aeration rated rivers should not be penalized if successful reaeration rates are reached by means of superoxygenation. When water quality trading is implemented locally, then, supplemental oxygenation of the receiving water body will also be an acceptable solution for meeting TMDL standards.

On Jan 13, 2003 EPA announced a new Water Quality Trading Policy to provide guidance on how trading can occur under the Clean Water Act while implementing regulations. Water quality trading is a market-based approach that is intended to provide greater efficiency in achieving water quality goals and watersheds by allowing one source to meet its regulatory requirements by using pollutant reductions created by another source that has lower pollution control cost.

Supplemental oxygenation of a river as a trade-off for non-point source pollution control measures has been used successfully. A study performed to remediate Snake River D.O. deficiency related to TMDL (caused by non-point source phosphorous loading) established that oxygen could be supplemented directly to the river for 3 % of the cost to reduce phosphorous from non-point sources to achieve comparable D.O. standards.

Ruane has postulated how the South Fork Holston River in Tennessee point/nonpoint-source pollutant trading within a watershed might be implemented. Although several hundreds of millions of dollars were invested for waste treatment facilities in the 1970s, nevertheless D.O. levels in the South Fork Holston River dropped to 2 mg/L under low flow conditions. D.O. concentrations were even predicted to range from 0 to 1 mg/L if industrial and municipal facilities discharged to the limits of their permitted waste loads.

TVA investigators considered a number of options for improving D.O. conditions in the South Fork Holston River, including advanced waste treatment for the dischargers, turbine aeration at Fort Patrick Henry Dam, various levels of flow augmentation at the dam, and in stream aeration. The results of this exploratory analysis indicated that D.O. standards of 5 mg/L in the river could not be attained using the advanced effluent treatments that were being considered by the industrial and municipal dischargers, but a

water quality trade off could meet the requirements. For example, it was predicted that state water quality standards could be met by augmenting flow releases from the dam, coupled with additional aeration by the hydroelectric project either at the dam or downstream. The annual cost of the trade off option would range from \$298,000 to \$395,000, compared to an estimated annual cost of \$44,000,000 for the industrial and municipal dischargers to operate advanced (but insufficient) waste treatments.

Superoxygenation provides a significant advantage by increasing river D.O. without processing the entire river. Also much smaller sidestream flows and civil works are required for superoxygenation than for aeration. Compelling cost comparisons favor use of this newest type of technology to achieve TMDL standards since pure oxygen is available for only \$60 to \$100/ton, depending on the usage rate. Successful superoxygenation can dissolve oxygen into water with 90% oxygen absorption efficiency for a total cost of approximately \$100/ton D.O. (which includes amortization of the capital cost @ \$10/ton D.O., energy consumption of 400 kwhr/ton D.O. @ \$0.05/kwhr = \$20/ton D.O., and the cost of oxygen at \$70/ton D.O.) while achieving 70 mg/L D.O. in a sidestream. When using pure oxygen vs aeration only about one tenth as much energy (300 kwhr/ton D.O.) is consumed per ton of D.O. supplemented than required for aeration yet D.O. concentrations in the river equivalent to air saturated D.O. can be easily achieved with these economies. The Chicago Canal sidestream aeration system, which moves the entire canal flow through the cascade aerators with an increase of only 1 to 3 mg/L D.O. involves energy consumption of over 3000 kwhr/ton of D.O. supplemented, which is ten times the energy requirement necessary for pure oxygen supplementation.

If the discharge has received secondary treatment there will be nil degradation of the river quality. Deep, slow moving rivers no longer need to be penalized in TMDL analyses when adopting superoxygenation technology. Advanced treatment will no longer be required.

Tertiary Removal of BOD

Tertiary treatment to lower the five-day BOD below 20 to 30 mg/L does little to improve the river habitat. The costs of tertiary treatment may exceed the cost of secondary biological treatment. If an increase in D.O. is a major need to improve the river habitat, then oxygen supplementation instead of tertiary removal of BOD should be implemented, especially with pooled rivers or harbors having very low aeration rates. For water quality limited harbors receiving secondary biologically treated industrial or domestic effluence. It is possible that an agreement could be reached with the state regulatory agency to allow oxygen to be supplemented directly to the harbor in order to maintain regulated D.O. concentrations.

As shown in the Figs. below, the health of a water body is directly correlated with the D.O. maintained therein.

Correspondence of Biocriteria to Environmental Gradients: Dissolved O₂

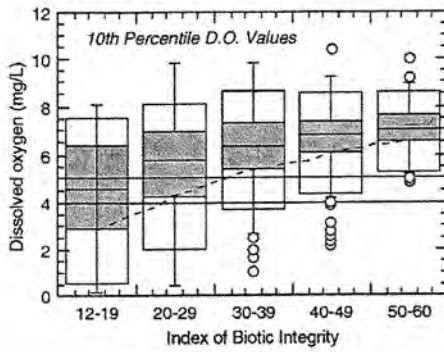
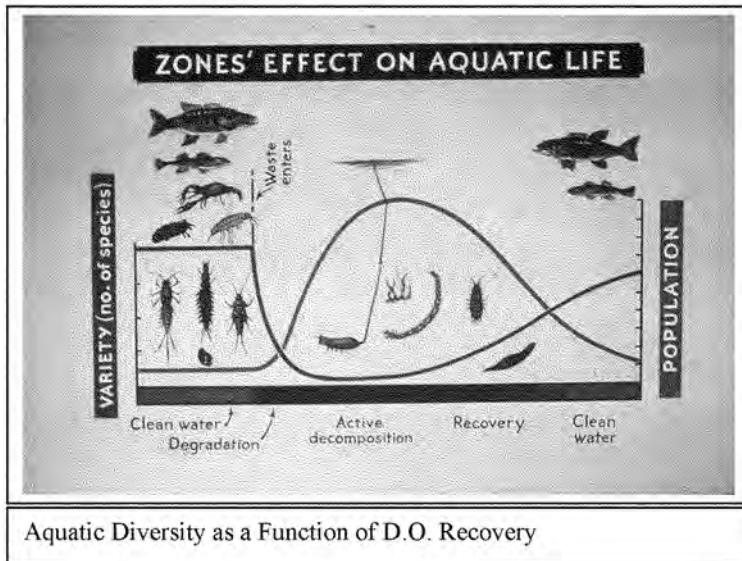
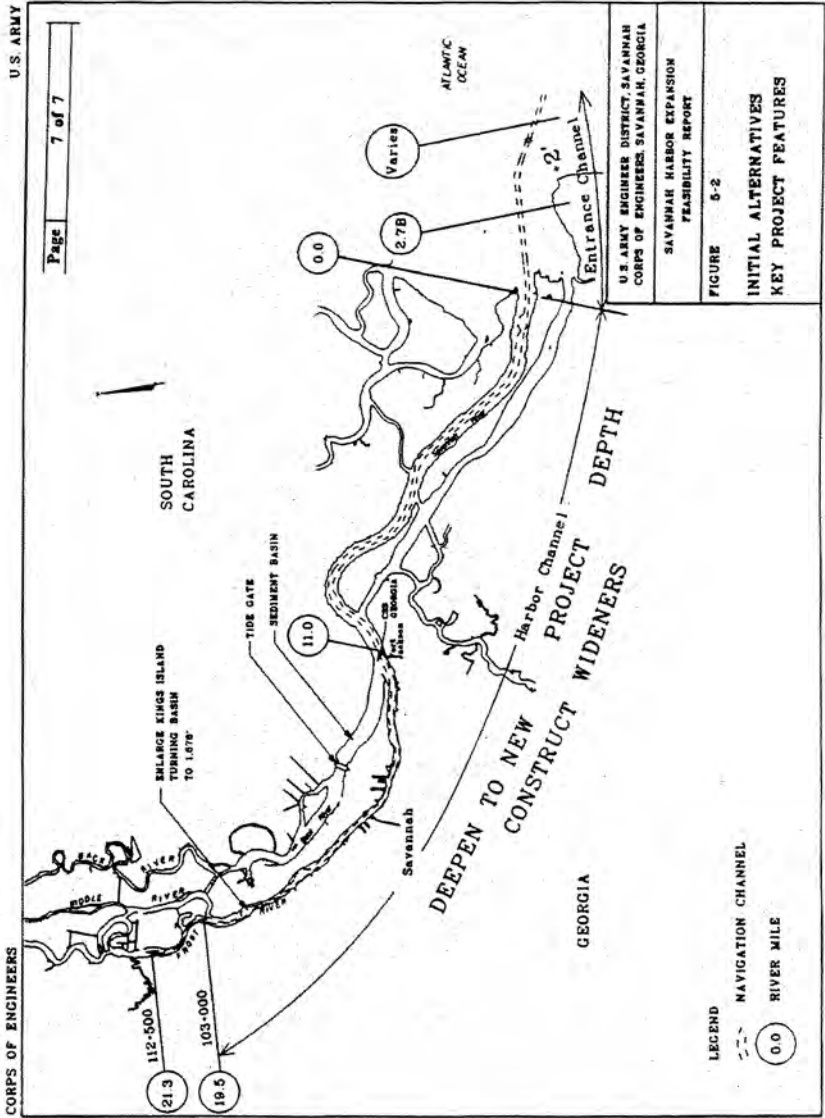
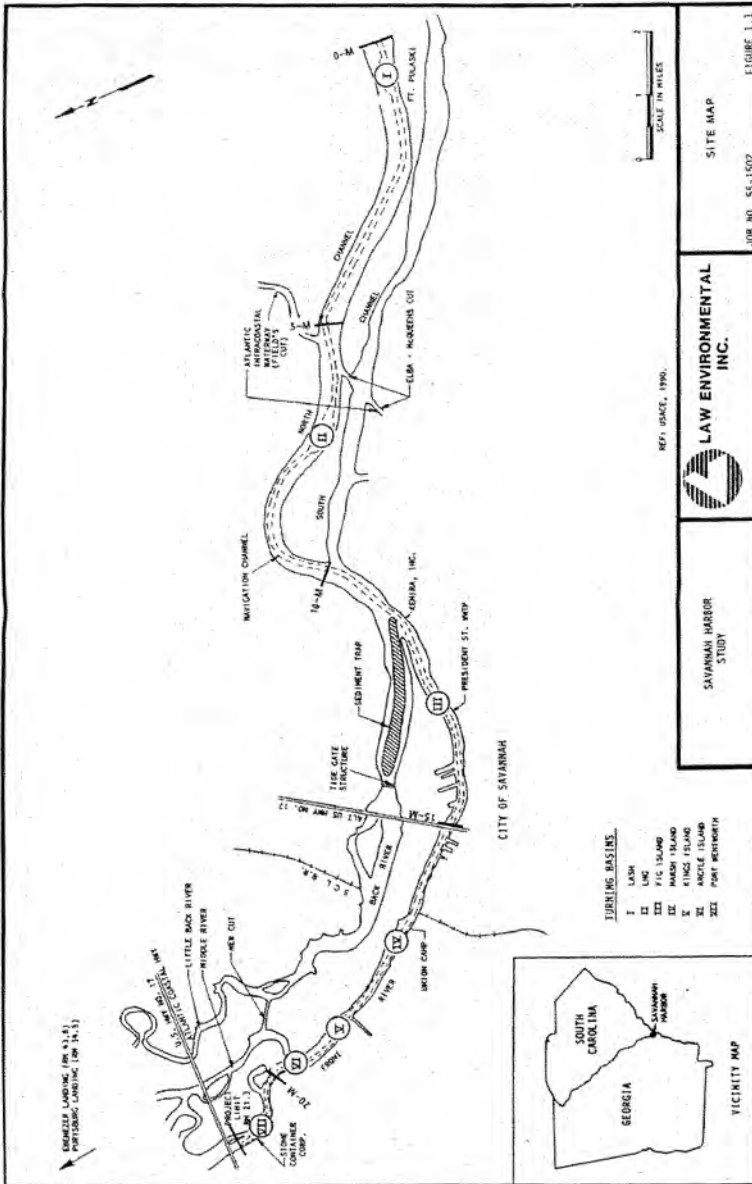


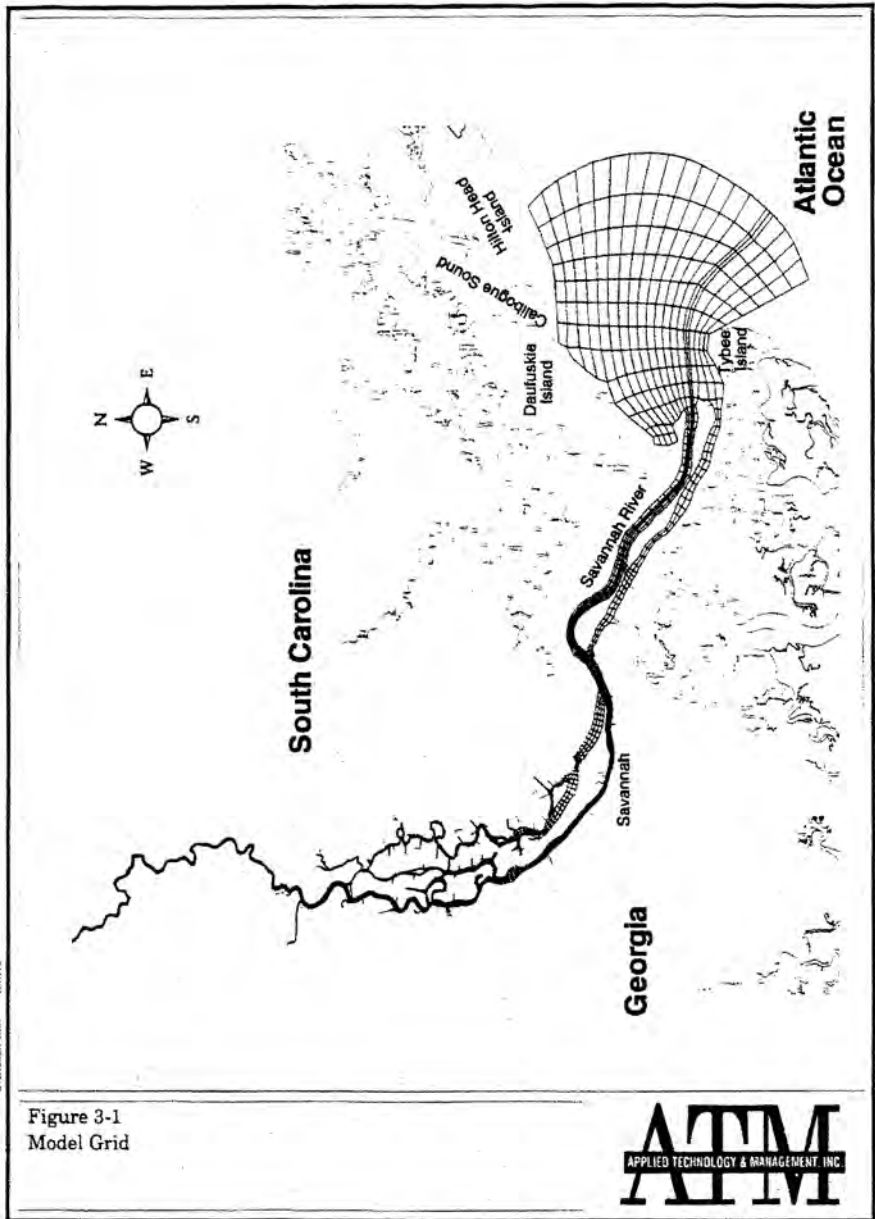
Fig. Correspondence of biocriteria to environmental gradients: dissolved oxygen



Aquatic Diversity as a Function of D.O. Recovery







Section 2. Worldwide Applications of Oxygen Supplementation to Rives, Lakes and Harbors

2. Existing Oxygenation System Installations.

I. Background.

Some of the world's most beautiful harbors and lagoons and its most heavily trafficked seaports face severe flooding problems during storm tide seasons. But remedial steps to minimize flood damage may in turn cause other water quality dilemmas, which must also be addressed at the same time.

Venice's magnificent architecture is being threatened by each successive flood season, yet its historic lagoon would also experience serious oxygen depletion if isolated by tidal gates. The busy Thames River's innovative tidal gates are successfully holding back potentially damaging flood tides at this time, but are accompanied by mobile oxygenation barges which alleviate consequent D.O. deficiencies.

Other oxygen poor harbors on the other hand, such as Shanghai Harbor, sustain serious pollution damage during dry seasons and the serious malodorous conditions which have plagued the city's inhabitants for decades have also caused the fish and shrimp to die until rehabilitation efforts were undertaken in 1988, and in 2001 when an oxygenation barge was deployed there with good results.

Savannah Harbor's main pollution source is decaying vegetation from the surrounding marshes. The Stockton, California Deepwater Ship Channel also must address constant new nutrient enrichment problems along with combined sewer overflows. Manchester Ship Canal in England has excessive algae growth, caused by heavy nutrient load and accumulation of sludges on the bottom, with consequent fish kills.

Ship traffic restricts equipment location, which precludes some types of aeration equipment. However, modern oxygenation designs using pure oxygen to raise the D.O. levels show great promise in solving worldwide harbor water quality dilemmas as well as those of rivers, lakes and bays.

II. Descriptions of oxygenation systems and specific equipment site data

Described below in approximate chronological order according to installation dates, are successfully operating installations which use HPO technology to achieve regulatory compliance and enhance resident fisheries.

Richard B. Russell Reservoir Georgia
 Newman Lake Washington
 Camanche Reservoir California
 Thames River England

Tombigbee River Alabama
 Logan Martin Dam Alabama
 Emscher River Germany
 Hallwilersee Lake Switzerland
 Patrick Henry Reservoir Tennessee
 Douglas Reservoir Tennessee
 Fontana Reservoir Tennessee
 Androscoggin River Maine
 Cardiff Bay Barrage England
 Amsterdam Canals, Netherlands
 Suzhou Creek, Shanghai Harbor

Richard B. Russell Dam, Georgia, Diffuser Systems

Richard B. Russell Dam is located on the Savannah River above Augusta Georgia. At Richard B. Russell Dam a first ever solution to D. O. depletion using fine bubble diffusers placed along the bottom of the 140 foot deep impoundment at approximately 1 mile in front of the dam. Oxygen supplementation was implemented within the hypolimnion from which layer the turbines withdraw water for power production and then discharge it downstream. Oxygen supplementation is practiced for approximately 7 months out of the year in order to maintain a downstream D. O. concentration of >6 mg/L for enhancement of the fishery therein.

During maximum power generation the dam release is over 60,000 ft.³ per second. Like all deep lakes in the Southeast, Russell Lake stratifies during summers. Warm light waters sit on a colder dense layer in the bottom. Only the top 30 feet, which is the epilimnion is circulated by wind action. With no means to replenish D. O. consumed in biological and chemical activity the D. O. levels in the depths of the lake, namely the hypolimnion layer, are gradually exhausted after stratification sets in. The water quality standards were set at 6 mg/L of D. O. in the reservoir releases. Since Russell Dam's waters needed D. O. improvement from 1 mg/L background to 6 mg/L in the discharge a more powerful oxygen enhancement system was needed than could be achieved by turbine venting or turbine oxygen injection. Proof of concept studies were conducted in the summer of 1975, 1976 and 1977 by a Drexel University team directed by Prof. Speece.

In order to generate absorption data for mass balance and efficiency studies an experimental system was suspended at the face of the dam. Fine bubble diffuser performance were evaluated by placing the diffusers at various depths below the water surface. An 11 foot diameter bubble collection of hood was placed at the surface above the bubble plume, so that the entire off gas from the bubble plume could be captured and quantified. Various diffuser loading rates were observed. Results from Phase 1 indicated that by using low porosity diffusers and O₂ loading rates of 0.5 to 2.0 feet per minute 90% of the oxygen was absorbed within a bubble rise of 100 feet. The next evaluation phase involved placing a rack of fine bubble diffusers 100 feet horizontally in front of the penstock intakes and measuring the D. O. in the discharge from those penstocks. When oxygen was injected in front of the hydropower discharge it raised the D. O. from a

background level of 2 mg/L to a discharge level of 8.1 mg/L. More than 90% oxygen absorption efficiency was achieved under these conditions.

The prototype diffuser system had two 1200 foot long assemblies of fine bubble diffusers and was suspended 5 feet above the impoundment bottom and located 100 feet apart in parallel. The fine bubble ceramic diffusers had a characteristic porosity of 2 feet per minute.



The first season of oxygen injection began with the onset of lake stratification on April 3, 1985 at an O₂ loading rate of 25 tons per day. A maximum oxygen loading rate of a hundred tons per day occurred in September and October of that year. Oxygenated water was shown to stay in the lower layer of the lake and a daily average of 6 mg/L was maintained. By the time injection was terminated in December, after the Fall turnover over 14,000 tons of oxygen had been injected.

In May to November of 1986. Some 10,000 tons of oxygen were injected, peaking at 90 tons per day. In 1987 only 7800 tons of oxygen were injected. Due to the natural aging of the lake the oxygen demand decreased.

This original fine, bubble system using ceramic diffusers was replaced after about 15 years by soaker hose technology.

In 2001 the original ceramic diffusers were replaced with a soaker hose diffuser design utilizing 10 - 4000 foot long lines along the old river channel upstream from the dam. High oxygen transfer efficiencies are achieved by spreading the diffuser hose over a larger area, (Mobley, Adams, Haynes and Sykes 2003).

They continued:

The diffuser installation in the reservoir was conducted from the surface without divers. The diffusers were assembled from a temporarily closed boat ramp and floated into final position in the reservoir in sections. Floating over a mile of diffuser pipeline at a time, across the popular reservoir required seven work boats, deep anchor points. Long rope spans and patrol boats to warn public boaters. The work boats and anchor points were used to maintain the diffuser location, despite changing wind directions. Once the diffuser was satisfactorily floating above the final location, the buoyancy chamber was pumped full of water to sink the diffuser in a controlled manner to the bottom. The process can be reversed to retrieve the diffuser for maintenance or repositioning.

The diffuser installation was completed with some preliminary testing in September 2001. Results indicated some disparity and individual diffuser line flows and difficulty in attaining full system design flow during test conditions that included temporary piping and flow control.

During 2002 the existing liquid oxygen supply facility was modified to reliably achieve the maximum design flow capacity, a new

oxygen flow control system was installed, and several diffuser lines were modified to provide better flow capacity. Start up testing was completed in August 2002 including operation of the system at over 200 tons of oxygen per day. The oxygen system was operated successfully for the remainder of the 2002 season.

Newman Lake, Washington, Speece Cone Oxygenation

Quoted from Barry C. Moore, Washington State University "Downflow Bubble Contact Aeration Technology (Speece Cone) for Sediment Oxygenation"

Internal phosphorus recycling during summer stratification has led to the accumulation of large amounts of organic sediments in the bottom of Newman Lake, which is the centerpiece of a residential area in western Washington state. The resulting anaerobic sediment water interface allows phosphorus recycling at rates several orders of magnitude greater than under aerobic conditions (Bastrom *et al.*, 1988, Funk and Morris, 1988).

A 1985 - 86, study concluded that 3000 pounds of oxygen per day would be required to meet the daily summer hypolimnetic oxygen demand, (McLean and Lean, 1986, Ashley *et al.* 1987). A Speece Cone was installed in 1992 to maintain oxic conditions with the view to eliminating unsightly algae growth visible to the residents and to restore the lake fishery.

Studies on Newman Lake conducted in 1985/1986 allowed calculation of a nutrient budget in which about half of the total net phosphorus loading was estimated to be associated with internal cycling (Funk and Moore, 1988). Therefore, intervention into processes leading to mobilization of sediment phosphorus was determined to be critical for reducing summer algae productivity and for restoring acceptable water quality. For Newman Lake, maintaining aerobic conditions during summer stratification offered the best means to reduce internal phosphorus recycling. Previous studies on sediment transport showed that, if the sediment/water interface is maintained in an aerobic state, then phosphorus solubility and mobility are greatly reduced (Bostrom *et al.*, 1988).

Over the years, export of materials of both natural and anthropogenic origin from the watershed, combined with plant materials produced within the lake basin itself, have led to the accumulation of large volumes of organic sediments on the lake bottom. During summer stratification, microbial breakdown of these sediments exerts oxygen demand that leads to depression and depletion of oxygen in the lake hypolimnion (bottom waters). The resulting anaerobic sediment/water interface allows phosphorus to be recycled into overlying waters at rates several orders of magnitude greater than under aerobic conditions (Bostrom *et al.*, 1988, Funk and Moore, 1988). High phosphorus

concentrations in Newman Lake have been determined to be the primary cause of excessive summer algae biomass, which is major water quality problem (Funk and Moore, 1988).

TABLE 1. System specifications for the Newman Lake Speece Cone.

Cone volume	11.1 m ³ (315 ft ³)
Cone height	4.6 m (15 ft)
Oxygen delivery	1,360 kg/day (3,000 lbs/day)
Dual Air/Sep O ₂ generators	680 kg/day (1,500 lbs/day) each
Dual rotary screw compressors	50 hp each
In-lake water pump	40 hp @ .73 m ³ /sec (21 ft ³ /sec)
Distribution manifold	100 ft (31 m) w/ 2" ports @ 2 ft spacing

In 1992, a Downflow Bubble Contact Aerator (DCBA) system, known as a Speece Cone, was installed in Newman Lake, Washington, USA. The principal purpose of the system is to provide sufficient oxygen to prevent hypolimnetic oxygen depletion and to maintain an aerobic sediment/water interface and is the first use of Speece Cone technology for lake restoration application. This later function was targeted to reduce recycling of nutrient compared to flux rates under anaerobic interfacial conditions. The system also contains other significant innovations, including pressure-swing molecular sieve technology for on-site oxygen generation, and a multi-ported exhaust manifold to reduce water velocities and prevent sediment entrainment. Compared to other available technologies, the system also represents significant savings in capital and operating costs. An evaluation of the Speece cone performance using a 17-year data set was made. When operated as designed, the system has been able to maintain elevated dissolved oxygen in the summer hypolimnion. Variations in operational and environmental parameters have provided a wealth of information on the Speece Cone, demonstrating that this is a economic and efficient technology that should receive wider application. Probably most significant are data that support the reality of a phenomenon known as induced oxygen demand, in which post-oxygenation O₂ demand rates exceed those observed prior to implementation.

Moore concludes his study with several recommendations for consideration of sediment oxygenation.

A recent review has concluded that improved water quality can be realized by hypolimnetic oxygenation, and that the method deserves more widespread application (Beutel and Horne 1999). In conclusion, it should be noted that the Speece Cone is an appropriate technology for delivering oxygen in water and sediment oxygenation applications. Methods that account for induced sediment oxygen demand are essential for predicting post-treatment oxygen requirements. Proper sizing of the system to meet that demand is crucial in order to realize environmental oxygenation goals.

When data on the range of environmental variability is limited, it should be understood that the associated high degree of uncertainty necessitates application of liberal safety factors to reduce risk of system under-sizing. For such situations, an economic analysis that balances risk versus cost of increasing system capacity may be an appropriate decision-making tool.



Camanche Reservoir, California, Speece Cone Oxygenation

Horizontal discharge of a super oxygenated sidestream is an important feature of the Speece Cone technology designed for Camanche Reservoir located in the foot hills of California, as may be seen in the photo (Figs -- --). During drought seasons the water depth, which usually varies up 135 feet, drops to only 25 feet. A yearly D.O. pattern of the hypolimnion is depicted in Fig. ---.

This reservoir discharges through a bottom pen stock during most of the stratification season and feeds a coldwater salmon fishery as well as a salmon hatchery immediately downstream from the dam. The discharge of 400 to 800 ft.³ per second during the stratification season is also used to generate power before discharge as the sole headwater of the Mokolumne River, which is a salmon habitat.

The river and hatchery require a coldwater discharge from the reservoir hypolimnion, so stratification must be carefully maintained. By mid June, the D.O. in the hypolimnion discharge is below 7 mg/L, which is the regulated D.O. for rivers in California classified for salmon. Therefore, at this time the hydropower generation must be bypassed and the water discharged through a Howell Bunger valve for aeration. Such cessation of electricity generation results in revenue losses of approximately \$5,000 per day per 400 ft.³ per second by-passing the generators.

By late June or early July anaerobic conditions are established in the bottom of the hypolimnion, where the discharge is located, causing iron and manganese to be

solubilized and hydrogen sulfide to be produced. Hydrogen sulfide is toxic to the fish, corrosive to electrical connections in the vicinity of the Howell Bunker valve where it is stripped during aeration, and eventually is offensive to personnel and visitors to the river below the dam.

In 1996, a Speece Cone hypolimnion oxygenator with horizontally induced flow, which dissolves 18,000 pounds of oxygen per day to the sidestream discharge from the oxygenation system back into 100 foot long diffuser, was installed on the bottom of the reservoir at the toe of the dam.

When the water is 100 foot deep, the oxygenated sidestream has a dissolved oxygen concentration of about 100 mg/L. A D.O. increase of 4 mg/L was observed in the hypolimnion 10,000 feet from the diffuser two weeks after the oxygen supplementation commenced operation.

Oxygen supplementation of the hypolimnion allows power to be generated, prevents hydrogen sulfide production, and meets river and hatchery D.O. criteria for the State of California. An additional advantage is that the equipment is hidden from public view at the bottom of the reservoir.

Thames River, England, Mobile Oxygenation Barge

An early network for the London sewer system was built in the 1850s with various catchments for drainage and pumping stations. Originally the design target was to intercept the dirty water coming down the river and divert it to London's east side, to minimize the pollution for the main part of the city. Both surface runoff and foul sewage enter the Thames. Two London areas, Becton and Crossness on the Eastside and Modem at the top of the tidal stretch of the river are the locations of the main sewage works. (Health and Public Services Committee, September 14, 2004 transcript).

During heavy rains, the system channels excess water back into the Thames. To avoid flooding in the city, according to the report cited above, the networks in London are so convoluted with its legacy that the normal rules do not apply. Therefore you need to have a rather individual approach to try to cure the problem.

The London sewage works are some of the largest in Europe, but when storm flows rise, untreated sewage as well as surface runoff are discharged into the Thames. Storm tank storage is limited so excessive flows cannot be contained. In order to avoid basement and house flooding, the sewage system must release storm runoff as frequently as 50 to 60 times a year, resulting in fish kills nearly every 10 to 16 weeks in the tideway.(*loc. Cit.* 2004).

A Thames Bubbler barge and a Thames Vitality barge authorized by the National Rivers Authority and the British government, containing venturi jets to diffuse the oxygen produced on board, have been deployed to prevent fish kills during storm tides. But even with these and the addition of hydrogen peroxide at the treatment works effluent, these oxygenation systems on the river failed to prevent fish kills in August and September of 2004. About 30 tons per day of oxygen are generated by each barge. Oxygen transfer efficiency is estimated to be about 65% from the venturi jets.

According to the report, it has always been recognized that the Bubbler barges were a temporary solution until something more permanent comes along.



Thames Bubbler

Tombigbee River Alabama, U-Tube Oxygenation

During periods of drought, the normally sufficient D.O. levels in the Tombigbee River, located near two paper mills in Alabama, dropped below minimum state standards. In times of prolonged drought after the 30 day treated effluent storage capacity of each

mill becomes full, mill production capacity had to be curtailed to maintain river D.O. levels, negatively impacting mill profits.

Both mills discharge efficiently treated waste water, so an agreement was reached with Alabama state authorities to add D.O. directly to the Tombigbee River. Since the Gulf States mill is located about 35 miles upstream from the James River mill, both mills impact the D.O. concentration downstream of the James River mill discharge. It was therefore a mutual benefit to design one common oxygen supplementation strategy. A D.O. water quality model of the river had demonstrated this oxygen supplementation strategy would allow both mills to operate at full capacity under the most critical low flow and high temperature conditions in the Tombigbee River.

The mutually beneficial agreement between the Gulf States and James River paper mills was reached on a solution for maintenance of the regulated D.O. concentrations in the Tombigbee River to minimize the fraction of river flow which must be moved through the oxygenation system. Therefore the D.O. concentration achieved had to be maximized.

The agreement allows 12,000 pounds per day of D.O. to be added to the James River mill effluent and 40,000 pounds per day of D.O. to be added 35 miles down river. One stipulation is that the D.O. in the river can never exceed 100% of air oxygen saturation, namely 7.9 mg/L at 28° centigrade, which is a typical hot summer river temperature during drought flows.

The James River effluent storage pond is located about 30 feet above the river level and flows by gravity through a U-Tube oxygenation device, where it is superoxygenated to 50 mg/L, and then passes into a diffuser on the bottom of the river. At the second location, called McCarty's Landing, 125 MGD of water must be pumped from the river through the U-Tube oxygenation device and back into a diffuser on the bottom of the river. Here again the D.O. is raised to 50 mg/L for discharge into the river diffuser.

A number of oxygenation systems and oxygen sources were evaluated. Air as an oxygen source was rejected because of the low potential D.O. concentration saturation and also potential dissolved nitrogen supersaturation problems in the river. Conventional surface aerators were rejected because of the excessive energy consumption per ton of D.O. supplemented to maintain the D.O. at 5 mg/L under summertime temperatures. Logistics due to barge traffic and policy considerations would not allow an oxygenation system to be located on the surface of the river, where it would obstruct barge traffic. Diffused aeration was rejected because of the low potential D.O. saturation, which would require pumping the entire river through the diffused aeration basin. Dissolved nitrogen gas supersaturation would result, possibly impairing the health of fish in the river. Again, excessive energy consumption per ton of D.O. supplemented was required to maintain a target D.O. of 5 mg/L.

Pressurized sidestream pipe reactor oxygenation was rejected because of excessive energy consumption per ton of D.O. supplemented and potential effervescent loss of supersaturated D.O. due to turbulence at the throttling valve used to maintain pressure in the reactor. Costs were considerable to supply 1000 feet of stainless steel pipe required to provide the required bubble contact time of over 100 seconds at the 10 fps water velocity necessary to maintain two-phase flow.

The overwhelming economical and practical advantages of using commercial oxygen emerged in the selection process, narrowing the search to two systems, the U-Tube and the Speece Cone technologies. Excessive cost to excavate deeply enough to withstand water levels in the 100 year flood disqualified the Speece Cone. The U-Tube oxygenation system was selected for its energy efficiency and capacity to produce very high D.O. concentrations of 50 mg/L with associated high oxygen absorption efficiency.

The U-Tube oxygenation system incorporates prolonged contact of the oxygen bubbles with the water as well as hydrostatic pressurization of the bubble water mixture



as it passes down through the U-Tube. Oxygen transfer is enhanced by the turbulence and extended contact time, but mainly by the hydrostatic pressurization as the water goes down the depth of the U-Tube and back up out the discharge. A depth of 175 feet was selected as the design depth for the U-Tube.

U-Tube oxygenation was selected for both of the two locations on the Tombigbee River. The U-Tube with

oxygen injection produced an affluent D.O. of 50 mg/L at 28°C with an oxygen absorption efficiency of 80 to 90% for a unit energy consumption and 94 kWh per ton of D.O. The oxygenation capacity was 5400 mg/L of D.O. per cubic feet per hour and the head loss across the 175 foot deep U-Tube was 5 feet.

A bubble harvester was incorporated to harvest any undissolved bubbles and recycle them back to the influent of the U-Tube. By discharging a highly elevated D.O. sidestream into the river through a diffuser in the bottom, advantage was taken in the hydrostatic head to prevent effervescent loss of D.O. and a high D.O. discharge was mixed throughout the river cross-section within a short distance downstream.

A schematic diagram shown in (Figs. ____) of both a gravity fed U-Tube which puts in 12,000 pounds of D.O. per day, as well as a schematic of the U-Tube where 125 MGD of water is pumped from the river through the U-Tube and then discharged back into the river with 50 mg/L of supersaturated D.O. concentration, resulting in 40,000 pounds per day of D.O. supplementation.

1.6

INTRODUCTION

CUTAWAY DIAGRAM

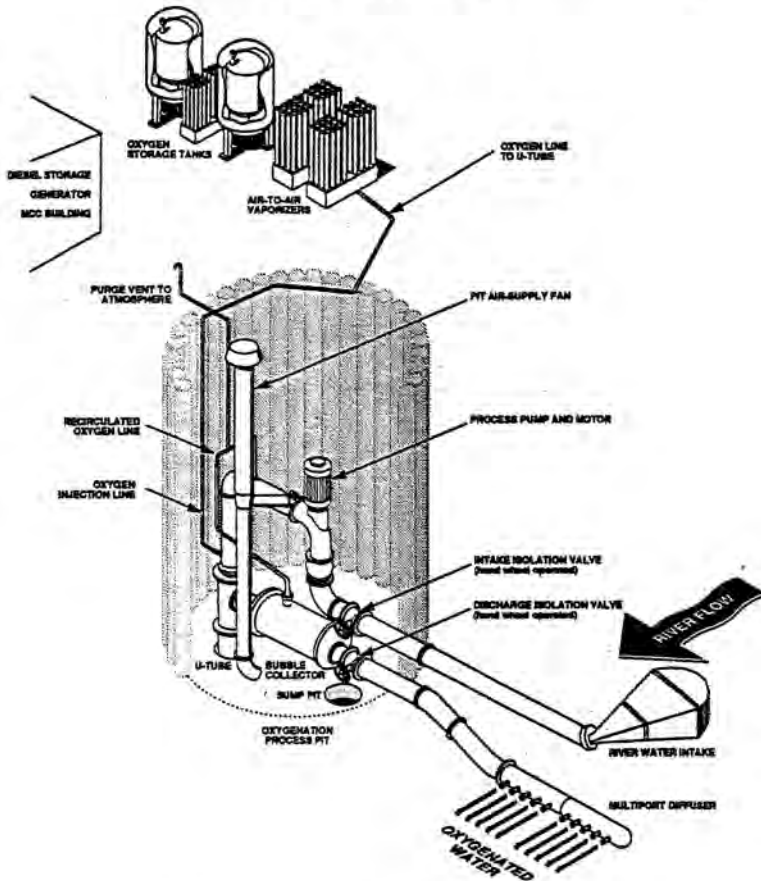


Figure 1.4 River Oxygenation Equipment Diagram



Module Two - Foundations
RIVER OXYGENATION SYSTEM - MCCARTHY'S SITE
Rev 0 - October, 1992



1.6

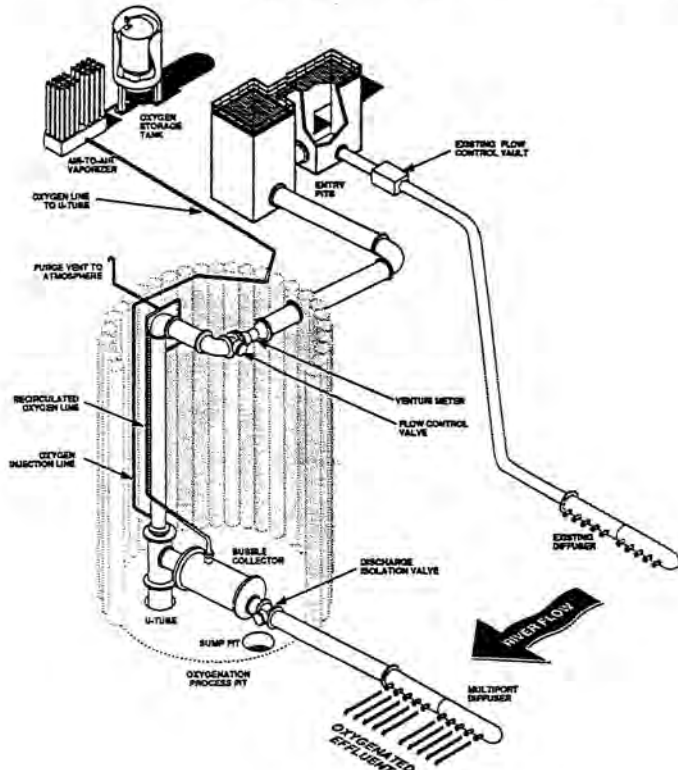
INTRODUCTION
CUTAWAY DIAGRAM

Figure 1.4 River Oxygenation Equipment Diagram



Module Two - Fundamentals
RIVER OXYGENATION SYSTEM - MAHEOLA SITE
Rev 0 - October, 1982



Field testing of the oxygenation system performance of the U-Tube installation which oxygenated the treated James River Mill effluent on the Tombigbee River yielded the following data:

- up to 50 mg/L discharge D.O. at 25°C in the water
- 5.3 foot head differential across the U-Tube
- up to 18,000 pounds of D.O. per day oxygen transfer
- 80 to 90% oxygen absorption efficiency

Logan Martin Dam, Alabama, Speece Cone Oxygenation

Logan Martin Dam, owned and operated by Alabama Power Co., is located on the Coosa River and was constructed on a karst stone geological foundation, 60 feet deep near the dam. The river flows 35 miles downstream past a paper mill, with less than 4 mg/L of D.O. on the weekends due to hydropower turbine shut down. Since it is operated as a peaking power dam, water is only released through the turbines between 9 a.m. and 10 p.m. on weekdays, causing approximately 900 cfs of water to leak out through the conduits in the karst foundation, in spite of extensive grouting to prevent it.

These conduits in the rock below the dam are somewhat similar to biological trickling filters in that a biological slime develops on the surface of these conduits. Consequently, even though the water contains about 8 mg/L of D.O. in the reservoir behind the dam, by the time the water leaks through these conduits beneath the dam, essentially all of the D.O. is removed. Then on weekends when water is not released to the hydropower turbines, the only water passing into the tail water zone is comprised of this 900 ft.³ per second of leakage water, which contains essentially zero D.O..

The resident fishery in the tail water below the dam is noticeably stressed during these weekend periods of low D.O. Fish by the dozens can be seen standing on their tails gulping air in an attempt to compensate for the low D.O. in the tail water. By Monday when the water now containing less than 1 mg/L of D.O., slowly passes the paper mill discharge point, the mill must curtail operation until the D.O. level again reaches about 4 mg/L.

In 1990 a Speece Cone oxygenation system was installed to meet one third of the 18,000 pound per day of oxygen required to raise the D.O. in the leakage flow to the required level. The 21 ft.³ per second system also incorporated into the final design an additional system capable of handling another 42 ft.³ per second.

This oxygenation system receives 21 ft.³ per second of water from a pipe connected to the pool above the dam. The Speece Cone oxygenation system was installed at the base in the dam so that the water from above the dam passes through the



Speece Cone oxygenator and discharges about 30 foot below the tail water surface. A throttling valve is located at the discharge in the tail water to allow pressurization of the oxygenation system. This pressure corresponds to the difference in water elevation between the upstream pool and the tail water.

The water pressure in the Speece Cone is advantageous because it allows oxygen transfer to take place at a pressure of 50 foot of hydrostatic head above ambient pressure. Consequently, the discharge D.O. has a concentration of approximately 50 mg/L. Approximately 5000 pounds of D.O. is added to the tail water each day by this supplemental oxygenation system. There is a D.O. rich zone in the vicinity of the Speece

Cone discharge into the tail water of Logan Martin Dam which can provide a respite for fish when the bulk of the tail water is very low in D.O.

The performance characteristics of the Logan Martin Dam oxygenation system have been thoroughly evaluated. When the water throughput is at the design level, over 90% oxygen absorption efficiency is realized within the Speece Cone. Maximum oxygen absorption efficiency occurs at a water flow rate of 21 to 25 ft.³ per second through the system. A slight reduction of oxygen absorption efficiency occurs below this range and a more rapid decline at higher velocities.

The pressure at the oxygenation discharge with no flow through the system is 52 feet, reflecting the static head of water above the dam with respect to the location of the oxygenation cone. With no oxygen injection the discharge pressure registers 44 and 42 feet at water flows of 22 and 25 ft.³ per second, respectively and an oxygen to water injection rate of 4% results in discharge pressures of 38 and 37 feet. It is to be noted that the total head loss across the oxygenation cone is nearly constant at 6.2 feet regardless of water flow through the system when oxygen is subjected at 4% oxygen water ratio.

At the design flow of 21 ft.³ per second and 4% oxygen water ratio, the system added 48 mg/L of D.O. to a background influent D.O. of 3.6 mg/L for a total of 5600 pounds of D.O. per day or 9 pounds of D.O. per cubic feet of reactor per day, which is 100 mg/L per minute at 90% oxygen absorption efficiency. The average pressure in the Speece Cone is approximately 29 feet at the centerline of the cone and the water temperature is 86°F. At this pressure and temperature the saturation D.O. concentration would be 66 mg/L, if the gas phase is 100% oxygen. The discharge D.O. was 51 mg/L and the oxygen content of the bubbles within the oxygenation cone was approximately 83% as measured and with a 4% oxygen to water injection rate, indicating the oxygenation system is able to achieve 94% of theoretical saturation under these conditions. These results are indicative of an excellent oxygen transfer system since the hydraulic retention time is only about 30 seconds.

In the flow range of 22 to 25 ft.³ per second with an oxygen ejection ratio of 3%, the discharge D.O. was 42 mg/L for a net increase of 38 mg/L over the background level. Under these conditions, the absorption efficiency was 95%.

The Logan Martin Dam with its full-scale application of Speece Cone technology has been in operation for over 10 years.

Emscher River, Germany, UNOX Oxygenation

Located in the Ruhr District of Germany, and a tributary of the Rhine, the Emscher River receives untreated and mechanically treated wastewater from a catchment area of 768 square kilometers. Industrial loading, mainly from chemical and food industries, makes up about 50% of the organic pollution. Up to 80% of the river flow is wastewater during dry weather conditions. (Bjerre, Jacobson, Teichgraber and te Heesen 1995).

At one point along the Emscher the river is diverted through primary clarifiers and farther along it enters a biological treatment plant for removal of dissolved and colloidal organic matter and phosphorus precipitation, before discharge into the Rhine. However hydrogen sulfide problems in transit are an indirect effect of anaerobic processes occurring in the river. An oxygenation station is being used to remediate foul odors experienced by populations living near the river.

The attached photos show the channelized Emscher River. Note the concrete structure, which is similar in concept to the UNOX pure oxygen transfer system with baffles at the beginning and end to enclose a headspace for oxygen enriched gas to be trapped above the river level.

Surface aerators splash the river water in contact with the enriched oxygen to achieve elevated D.O. concentrations so as to avoid odor generation before the water enters a 10 km stretch before reaching the secondary wastewater treatment plant. Dry season flows into the treatment works inlet vary from 9 to 13 m³ per second, and the detention time is approximately 2 days.

The oxygenation system raises the D.O. in the entire river about 15 mg/L and supplements about 30,000 pounds of D.O. per day to the river.



Halwilersee Lake, Switzerland, Tanytarsus Oxygenation

In 1986, a tanytarsus diffuser system was installed in a medium-size lake in the Swiss plateau, which had experienced anoxia for a century. Lake Halwiler was eutrophic, due to excessive phosphorus loading characteristics of lakes and reservoirs in Switzerland and required deepwater oxygen bubble plume injection to prevent intrusion of hypolimnion water into the thermocline. As described by McInnis, Lorke, Wuest, Stockli and Little 2004, this system can be switched between artificial mixing using coarse air bubbles and hypolimnion lake oxygenation using fine oxygen bubbles. The six diffuser racks are 6 1/2 meters in diameter and are in a 300 m diameter circular configuration near the center of the lake.

The accompanying figures show the whole lake contour plots of typical oxygen distributions with the plume operating with pure oxygen. Of particular note is the observation that this free bubble rise system is unable to oxygenate below the diffuser system. This results in great areas of the sediment water interface, which remain anaerobic even though the water column higher in the hypolimnion is well oxygenated.

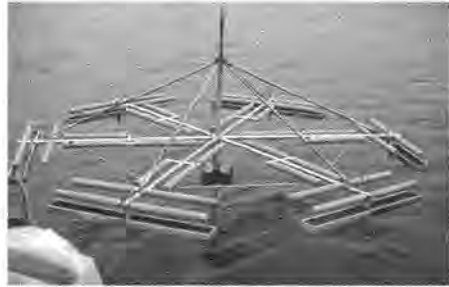


Figure 3. One of the six 6.5-m diameter Tanytarsus diffusers.

Patrick Henry Reservoir, Tennessee, Ceramic Diffusers

Liquid oxygen and ceramic diffusers, mounted on frames supported by columns anchored on the reservoir bottom, were installed from 1973 to 1976 as a pilot demonstration study (Fain 1978), following Ruane and Vigander's 1972 research on reservoir diffuser systems for hydropower sites for the Tennessee Valley Authority in Tennessee.

Later, following laboratory tests and comparison of diffuser equipment prices, a standard alumina tube with pore sizes of 15 to 20 μ was chosen to be installed on frames about 8 feet above the bottom. Transfer

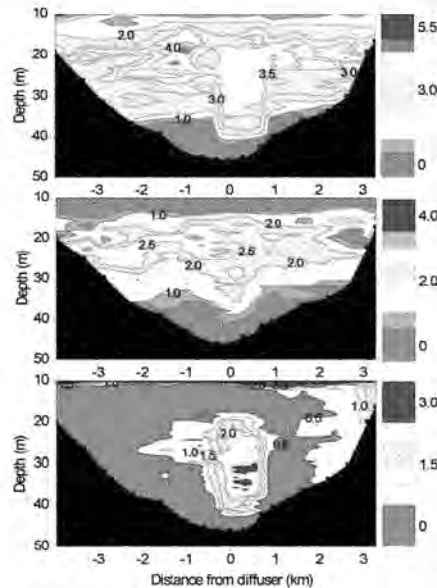


Figure 8. The (top) 24 July, (middle) 16 August, and (bottom) 27 September 2001 DO contours (g m^{-3}). Note different scales. The x-axis zero point is located at the center of the 300-m-diameter diffuser ring. The contours were interpolated from 18 CTD profiles (locations indicated by black squares at the bottom of the plots) sampled along the centerline of the lake (see Figure 2 map showing 18 sampling stations).

efficiencies were not as high - 30 to 90%, as had been recorded in laboratory tests -- 80 to 90%. However smaller pore size diffusers were found to achieve higher transfer rate (Ruane, Vigander and Nicholas, Journal of Hydraulics Division of the American Society of Civil Engineers, October 1977.

Douglas Dam, TVA, Membrane and Soaker Hose Diffusers

An early hydropower installation using a membrane diffuser was chosen for Douglas Dam in 1988 by the Tennessee Valley Authority. A 20 foot by 33 for diffuser frame was placed on adjustable legs to fit the bottom topography in front of one of the intakes. Oxygen transfer efficiencies of about 72% were measured late in the D.O. season of 1988, when weak stratification conditions existed (Mobley, 1989). D.O. improvements in the releases were about 2 milligram per liter. However, during the peak of the 1989 D.O. season, the oxygen improvement in the releases dropped to nearly 0 mg/L. This was attributed to oxygen demand stirred up from near the reservoir sediments and mixed by the strong plumes induced by the diffusers. No clogging of the membrane diffusers was experienced, but the Unit 4 generator cooling system was clogged with sediment and organic growth due to the pumping action of the diffuser plumes. This necessitated outages for cleaning and chemical treatments to reduce organic buildup. This experience indicated a clear need for a means to spread the bubbles over large areas to reduce mixing and entrainment of the sediments.

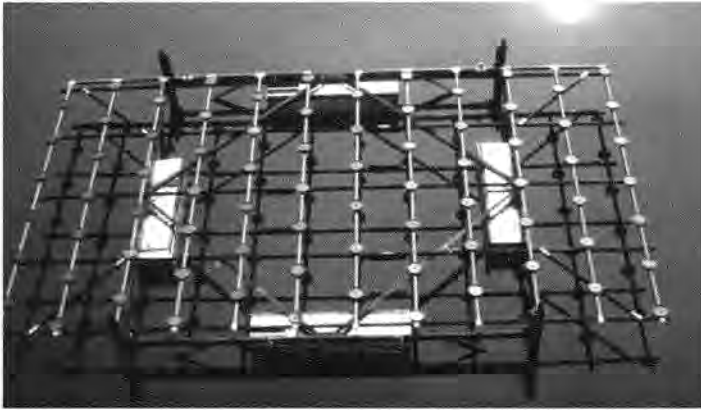
Sixteen smaller PVC diffuser frames, measuring 100 foot by 120 feet, are shown in the accompanying figure and were successfully deployed in the Douglas Reservoir in 1993. There were 80 hoses per frame for a total of 12 miles of porous hose. The system capacity was 3000 m³ per hour or 110 tons per day of oxygen. The redesigned oxygen distribution header was made of flexible hose. These diffusers have been used since 1993, to provide up to 2 mg/L of D.O. improvement in 16,000 ft.³ per second power discharges from the four turbines at Douglas Dam. Although these diffusers are effective and are still in use, the frames and buoyancy connections were too unwieldy and expensive for future designs.

In 1991 soaker hose equipment measuring 400' x 100' suspended on a PVC diffuser frame was built to support 50 foot long porous hoses. The common garden-variety soaker hose stretches slightly under pressurization so that O₂ diffuses out through the walls. This was an attempt to distribute the oxygen bubbles more extensively to reduce mixing and oxygen demand from the sediment layer.

Early Hydropower Installations Using Membrane Diffusers

Douglas Dam, TVA: 1988

In 1988, a pilot oxygen diffuser system was installed on Unit 4 at TVA's Douglas Dam. Three bottom-anchored, steel diffuser frames with adjustable legs to fit bottom topography were lowered from a catamaran crane in front of the intake of Unit 4. Each 6-meter by 10-meter (20-foot by 33-foot) frame supported 78 membrane diffusers, as shown in Figure 2. Oxygen transfer efficiencies of about 72% were measured late in the DO season of 1988 when weak stratification conditions existed (Mobley, 1989). DO improvements in the releases were about 2 mg/L. However, during the peak of the 1989 DO season, the oxygen improvement in the releases dropped to nearly zero. This was attributed to oxygen demands stirred up from near the reservoir sediments and mixed by the strong plumes induced by the diffusers. No clogging of the membrane diffusers was experienced, but the Unit 4 generator cooling system was clogged with sediment and organic growth due to the pumping action of the diffuser plumes. This necessitated outages for cleaning and chemical treatments to reduce organic build-up. This experience indicated a clear need for a means to spread the bubbles over large areas to reduce mixing and entrainment of oxygen demands from the sediments.



Installations using line diffusers

The following excerpts were taken from reports by Mark Mobley.

Normandy TVA 1994.

The next diffuser application at TVA was for a nonpower reservoir where aeration was desired to remove dissolved metals and hydrogen sulfide in the reservoir by aeration and precipitation. This system was supplied with compressed air. This installation was the first for the line diffuser design, and the clamps on saddle shoes for hose connections were

found to be expensive and leaky. The drilled holes to provide an orifice for flow control, were also found to be expensive and unnecessary.

Blue Ridge TVA 1994,

A linear arrangement of four, 1800 foot long diffuser lines were deployed in the fore bay to provide a 3 mg per liter dissolved oxygen improvement using 24 tons of oxygen system capacity per day. The design used small check valves at hose connections that were determined to be ineffective since the diffusers sank anyway, when left overnight. The long linear arrangement of the diffusers was found to provide insufficient oxygen to the small minimum flow turbine so an additional diffuser was installed immediately upstream of the intake tower.

Cherokee TVA 1994-1995.

Peak hydropower water flows at Cherokee dam can approach 20,000 ft.³ per second and despite having operational installations of both turbine venting and surface water pumps can require up to 2 mg per liter of additional dissolved oxygen improvement for the line diffuser system to meet 4 milligram per liter in the releases. The system capacity was 150 tons per day, with 48,000 lineal feet of line diffuser in the four bay. The system has automatic valves open to provide a high rate of oxygen flow while the turbines are in use. When the turbines flows are often small, oxygen bypasses the valves to maintain a background buildup of D.O. in the reservoir. The oxygen input from the diffusers provided oxygenated cold water in the fore bay that created a striped bass habitat during the warm summer sessions. High concentrations of fish lead to intense fishing pressure. But despite the repeated anchoring of boats in the area, no significant damage to the diffusers has been experienced. At this installation, the elastic cords for anchor attachment failed, allowing sections of the diffuser to float to the surface, creating a boating hazard. A new anchor connection using stainless steel cables was retrofitted by refloating each diffuser.

Fort Loudoun TVA 1995.

This mainstream, Tennessee River dam has hydropower flows approaching 38,000 ft.³ per second. But require only a small boost in D.O., mostly associated with reduced flows during weekends. The Fort Loudoun application included a single 10,000 foot long line diffuser used to spread oxygen input over the reservoir volume of an average day's generation. The diffuser was equipped with progressive orifice sizes at the hose connections to obtain uniform flow over the entire length. The installation was complicated by intense recreational boat use and

commercial navigation traffic. The elastic cord anchor connections were redesigned during this installation and retrofitted on the first diffuser.

Hiwassee Dam TVA 1995.

The original designs for the Hiwassee reservoir diffuser system were to use air but the total dissolved gas limitations in the tailrace shifted the design from air to oxygen. The installation of an on-site pressure swing absorption oxygen generation system was attempted for this application with unsatisfactory results. The diffusers are now supplied with liquid oxygen storage tank.

Watts Bar TVA 1996.

Watts Bar is another mainstream hydropower project with flows and oxygen requirements similar to Fort Loudoun. The diffusers were deployed to oxygenate an average daily flow volume and a more compact diffuser placement was utilized immediately upstream of the dam to provide for the increased oxygen needs during initial or single turbine operations. The multi-diffuser design used in the immediate fore bay, proved to be difficult to deploy and retrieve.

Buzzard Roost Hydroelectric Station, Duke Energy 1997.

The line diffuser at Buzzard's Roost was installed to provide enough oxygen input to allow Duke Energy to meet the FERC water quality requirements at the site. This installation included 9000 feet of line diffuser in the shallow excavated hydropower intake channel. The diffuser lines were placed within 20 m of each other in only 40 foot of water as compared with a typical spacing of 100 foot gaps.

Summary of existing line diffuser installations.

A total of 153,000 feet of line diffusers have been installed at the eight reservoirs described above and three other applications. The diffusers have required no maintenance of the inspection of the bubble pattern at the beginning of each season. Reservoir diffuser installations and other aeration applications have resulted in improved conditions in the hydropower tail waters, according to Scott *et al.* 1996. Installation costs of line diffusers have been \$25-\$30 per foot.

Androscoggin River, Maine, Bubble Diffusers

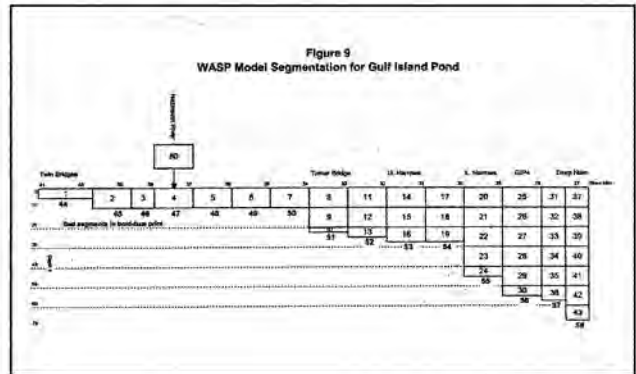
The Androscoggin River in Maine has a minimum flow of 1700 ft.³ per second and requires supplemental oxygenation from June the first until September the 30th, the deepest part of the forebay is 60 feet, and the oxygen transfer requirements are 40,000 pounds per day. The ambient D.O. is 5 mg/L and the design D.O. minimum is 6.5 mg/L. Additional mechanical aeration of Gulf Island Pond is a critical component of the overall plan to bring the Androscoggin River into D. O. attainment. The current model indicates that a total of 150,000 pounds per day to 210,000 pounds per day of oxygen must be supplied based on the current transfer efficiency of about 30%. This is in combination with additional controls at the paper mills in order to bring Gulf Island Pond into attainment for D.O.. In addition, the model indicates that attainment of D.O. criteria everywhere in Gulf Island Pond cannot be attained with a single point injection system at its current location. Multiple point oxygen injection systems are needed, unless there is sufficient proof to show that the attainment can be met using a different configuration.

The present oxygen supplementation system injects pure oxygen into fine bubble diffuser plates located at a depth of approximately 30 feet within the Androscoggin River. The diffuser loading rate is about 2 feet per minute. Coalescence of fine bubbles occurs and fouling of the diffusers has been noted over time.

Due to the biological oxygen demand in wastewater discharges from the three paper mills located on the Androscoggin River and the sediment oxygen demand of the river due to the impoundment of the Androscoggin River created by the Gulf Island dam, the D.O. content that is required for class C waters may not be achieved during the summer months of July, August and September. Consequently the paper companies and Central Maine Power Company entered into an agreement to oxygenate the river.

The State of Maine, Department of Environmental Protection board requires that 27,000 pounds of oxygen per day be dissolved into the river water column. This requires a minimum 73,000 pounds per day of oxygen delivered to the river by the oxygen plant based on 35% O₂ absorption efficiency. It is expected that this level of oxygen will meet water quality standards over most of Gulf Island Pond during July, August and September. A system was designed to introduce oxygen approximately 4 miles north of Gulf Island Pond through fine bubble porous ceramic diffusers which are located along the river bottom approximately 30 feet below the surface of the water.

Future oxygen supplementation requirements are from 40,000 to 70,000 pounds of oxygen per day to Gulf Island Pond. It is proposed to use 12 foot diameter by 18 feet



high Speece Cones, each capable of dissolving 10,000 pounds of oxygen per day. A 100 HP submersible pump will move water through the oxygenation cones. The water flow will be 30 ft.³ per second against 25 foot of head and contain 60 mg/L of D.O. in the discharge. Oxygen absorption efficiency of over 90% is specified and the unit energy consumption will be approximately 400 kWh per ton of D.O.. The discharge will be diluted quickly by a combination of diffuser and banana propeller pumps.

In order to transport the oxygenated discharge from the oxygenation cones at the dam to the upstream pond area, each will be equipped with a 7 foot diameter 10 HP banana propeller pump capable of moving about 200 ft.³ per second horizontally under negligible head.

Life Cycle costs are strongly affected by the O₂ absorption efficiency achieved in the oxygenation system as shown in the following table.

Table. Comparison of % O₂ Absorption and Costs for 40,000 lb D.O./day

<u>%O₂ Absorp</u>	O ₂ Added	O ₂ Lost	Cost of O ₂ Lost	Present Worth O ₂ Lost
	ton/yr	ton/yr	\$/yr	\$
100	2000	0	0	0
90	2200	200	66,000	693,000
75	2670	666	222,000	2,310,000
60	3330	1330	444,000	4,620,000
50	4000	2000	666,000	6,930,000
40	5000	3000	999,000	10,400,000
25	8000	6000	2,000,000	20,800,000

Amsterdam, Netherlands, Canal Mobile Barge Oxygenation

There is at present no complete sewer system operating in the lovely concentric canals of central Amsterdam, which therefore continually receive raw sewage directly. The low flow velocity in addition to deep waters, and the pooled nature of the canals, all contribute to low reaeration rate and zero D.O. levels. Hydrogen sulfide generation thus mars the historic

picturesqueness of the area and assaults the urban population.

A motorized barge, containing a liquid oxygen storage tank and an oxygen injection system was deployed to withdraw canal water, super oxygenate it under elevated pressure,



and then discharge it back into the canal. The barge system has been successful in increasing D.O. concentrations in the canals sufficiently to prevent hydrogen sulfide production.

Shanghai Harbor, Suzhou Creek, China, Mobile Oxygenation

As Shanghai has grown commercially to become China's largest industrial center, Suzhou Creek has suffered increasingly severe pollution. From the 1920s the river began to smell and turn a blackish color, causing the extinction of fish and shrimp in the river. Until 1978, the entire Shanghai section of the Suzhou Creek was thoroughly polluted.

Stretches of the 125 km Suzhou Creek have experienced anaerobic conditions, which means there are insufficient levels of oxygen to support fish or other aquatic life. Pumping oxygen into the water, by means of the barge, will assist the natural process of decomposition of pollutants and the restoration of oxygen levels needed to prevent H₂S odors and sustain aquatic life.

A decade later, the Shanghai municipal government started a cleanup project to restore the river. A total of 8.7 billion yuan i.e. one billion US dollars, was spent completing the first stage of work on the project. The plan to clean up Suzhou Creek was launched in 1998, with the creation of the Shanghai Suzhou Creek Rehabilitation and Construction Company (SSCRCC). Its goal was to rehabilitate Suzhou Creek, to enable it to reestablish an ecosystem and raise public health standards for nearby residents.



British Oxygen Corp. designed and supplied the environmental technology for China's first mobile oxygenation barge. The self-sufficient barge represents the first step in a 12 year plan to rehabilitate Suzhou Creek. The Suzhou Creek project is China's most ambitious water reclamation project to date. The mobile oxygenation system is capable of generating 5 tons of oxygen per day and injecting it into venturi jets which discharge into the water at 20°C with a concentration of 6 mg/L D.O.

The oxygenation barge, which was officially handed over to the Chinese government in November 2001, contains a BOC Novox TM oxygen generator and two Vitox TM venturi oxygen injectors. Water from Suzhou Creek is withdrawn from the river, oxygenated on the barge at a rate of 5 tons per day, and then returned to the river via 20 Vitox venturi distribution nozzles mounted on each side of the barge.

This is the latest version of Thames Bubbler and Thames Vitality technology that BOC had developed for use in two barges used on stretches of the Thames River in England. Two delegations from SSCRCC, visited Vitality and talked with BOC engineers in Guilford, UK before BOC was awarded the contract for the Suzhou Creek project.

At the official dedication ceremony, which took place in Shanghai on November 2, 2001, Chinese environmental officials said they had originally planned to build several land-based oxygenation stations along the banks of Suzhou Creek, but decided it would be more effective to use a mobile oxygenation station to deal with shock pollutant loads during emergencies. An SSCRCC representative said, "the barge can go wherever it is needed to improve the oxygen level quicker and cultivate beneficial aerobic bacteria."

The \$1,600,000 barge will be working on a one-month trial basis. More barges are expected to be built to improve Harbor water quality even more.

II. Proposed Appropriate Sites for Oxygen Supplementation to Water Bodies

Oxygenation technology is being considered to remediate D.O. depleted waters in the following locations:

- Cardiff Bay, England
- Stockton, California Deep Water Ship Channel
- Onondaga Lake, New York
- Chicago Canal System, Illinois
- Brownlee Reservoir, Snake River, Idaho
- Hood Canal, Washington
- Manchester, England Ship Channel.
- Jamaica Bay, New York.
- San Diego water reuse reservoir.
- New York City water supply reservoirs.
- Venice Lagoon, Italy.

Cardiff Bay, England, Speece Cones on Oxy/Cat Mobile Barges

The barrage erected across Cardiff Bay in about 1995 to isolate tidal activity outside and maintain a constant pooled water surface inside the barrage has impounded approximately 440 acres of water in a permanent pool behind the dam. The pool prevents the tidal mud flats from being exposed and their associated bad odors are avoided. It has resulted in a real estate boom on the water front. However characteristically the pooled water is deficient in D.O.

An air diffusion system designed by Ken O'Hara was adopted, but it could not satisfy D.O. standards in the harbor under all conditions. Therefore a mobile oxygenation unit was proposed to serve the impoundment that could be moved to remediate specific oxygen depleted areas. A system was proposed, which incorporated Speece Cone oxygen

transfer technology in combination with a twin hauled barge. The design features an adjustable discharge boom, which can deliver a super oxygenated sidestream horizontally through this diffuser to variable depths of between 1 to 8 m in the water column.

More than 90% oxygen absorption can be achieved, while consuming 1100 kWh per ton of D.O. added from an on barge oxygen storage tank. The Oxy/Cat dimensions are 15 m length and 7 1/2 meters width with a loaded draft of 0.75 m and light air draft of 3.5 m. The system is comprised of two Speece Cones, a LOX tank capable of holding 6 tons of liquid oxygen and two Perkins, 185 D diesel engines which drive two 12 inch pumps to move the water through the oxygenators.

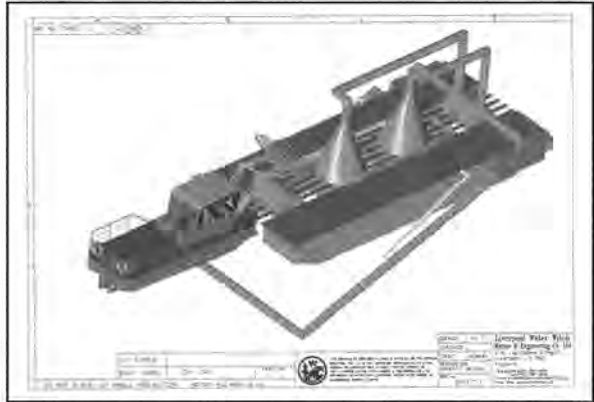
A comparison of the Liverpool Water Witch Marine and Engineering Co. Ltd.'s/ECO2 Oxy/Cat system with the BOC Vitox oxygenation barge reveals several important differences:

Speece Cone oxygenation system.

- 90 % oxygen absorption regardless of the depths to which the water is discharged.
- Gas transfer accomplished **before** discharge into the bay.
- Closed system readily monitored using a flowmeter to determine flow rate in inlet armeter to measure D.O. prior to discharge.
- No effervescent loss of D.O. due to instant dilution.
- Absorption efficiency not dependent upon water column D.O. concentration.

Vitox System.

- Percent absorption dependent upon deeper depths.
- Gas transfer occurs after discharge into the baying causing turbulence.
- An open system, not easily monitored for flow rate and D.O. levels.
- Dissolving takes place during rise of bubbles to the surface in the water column.
- Absorption efficiency depended upon D.O. concentration in water column.

**Stockton Deep Water Ship Channel****Evaluation of Aeration Technology for the Stockton Deep Water Ship Channel.**

Report to CAL FED Bay Delta Program.

Sacramento, California.

Dr. Russ Brown.

April 19, 2002.

Quoted from the Executive Summary

This report describes the scientific background for quantitatively understanding aeration processes that transfer oxygen between the atmosphere (gas) and a water volume (dissolved gas). Although water (H_2O) is composed of 89% oxygen, fish and aquatic organisms require D.O. gas (O_2) for respiration and cannot utilize the oxygen in the water molecules. The natural reaeration that occurs at the surface of the San Joaquin River and the Stockton Deep Water Ship Channel (DWSC) is described to introduce the equations and coefficients that are used to quantify this process.

The basic methods that have been used to augment or artificially increase this oxygen gas transfer process in rivers and lakes (or reservoirs) are then described. The performance of the existing Corps of Engineers jet-diffuser device is summarized, and the engineering feasibility of alternative methods to increase D.O. (DO) concentrations in the DWSC with aeration technology are compared. Each alternative is described for possible application to the DWSC worst-case summer design condition where the DO recorded at the Rough & Ready DO monitoring station is assumed to be 2 mg/l below the DO objective for the DWSC.

Figure 1 shows the location of the City of Stockton River water quality stations within the DWSC. The Department of Water Resources (DWR) continuous DO monitoring station is located at the downstream end of Rough & Ready Island, near the R5 sampling station. Data from these stations are used to estimate the DO deficit below applicable water quality objectives for the DWSC (i.e., 5 mg/l from December through August and 6 mg/l from September through November). This DO deficit is the necessary amount of DO augmentation that would be necessary to meet the DO objectives in the DWSC. Based on the daily minimum DO concentrations at the Rough & Ready monitoring station, a total of about 1,000,000 pounds of oxygen would have been needed in the summer of 2001. An aeration device that delivered about 10,000 lb/day would have satisfied the measured DO deficit during the summer of 2001. The required amount of DO supplied by aeration in 1999 and 2000 would have been somewhat less, although the 10,000 lb/day capacity would likely have been needed in each year. For an assumed DWSC reaeration transfer distance of 0.5 m/day with a DO deficit of 4 mg/l, reaeration will supply about 18 pounds of oxygen per acre per day. There are about 250 acres between R3 and R5, so the reaeration in this portion of the DWSC would be about 4,500 lbs/day. The DO concentration increase from one day of reaeration would be about 0.25 mg/l (i.e., 0.06×4 mg/l). This is only a moderate reaeration term compared with the RWCF and SJR river loads of BOD, and the assumed transfer velocity of 0.5 m/day is uncertain.

D.O. Concentration Pattern in the DWSC

The DO concentration patterns in the DWSC are controlled by reaeration and algae production of DO as well as BOD (and SOD) decay processes. The BOD loads originate from the Stockton RWCF effluent and from upstream SJR sources, as well as from sediment oxygen demand and algae biomass growing within the DWSC. The City of Stockton water quality model uses a typical first-order DO sag equation coupled to the governing hydrodynamic equations for tidal flow within the DWSC. The current model does not include effects from stratification on algae growth and reaeration (i.e., mixed depth dynamics). The DO modeling simulates the longitudinal DO pattern and identifies the location of the lowest DO concentration (greatest DO deficit).

Figure 2 shows the measured minimum and maximum DO concentrations at the DWR Rough & Ready monitoring station during 2001. The minimum DO concentrations were generally about 3 mg/l during the worst-case episodes. The saturated DO concentration is shown for comparison to indicate that the minimum DO concentrations were generally 4-5 mg/l less than saturation during the summer period. The minimum DO concentrations were therefore about 2 mg/l less than the DO objective of 5 mg/l during these worst-case episodes. The maximum DO concentrations measured during the afternoon are influenced by algae photosynthesis and are usually about 2-3 mg/l higher than the minimum DO values, and may approach saturation concentrations on some days. The reaeration rate, which is controlled by the DO deficit, is therefore less during these afternoon periods. A DO sag may also occur after September 1 when the DO objective changes to 6 mg/l. The pattern and magnitude of DO sag in September is similar to conditions prior to September because water temperatures are slightly cooler and the saturated and measured DO concentrations are slightly higher.

Figure 3 shows the minimum DO pattern measured in 1999 along with the UVM net flow estimates during the year. The daily calculated DO required to satisfy the DO target concentration (DO objective + 0.5 mg/l) are also shown. The DO concentration was below the DO target concentration from about July through September of 1999 (although the DO in October was not recorded). The daily DO deficit was often 10,000 lb/day with a few peaks of 15,000 lb/day. An aeration device with a daily DO delivery of 10,000 lb/day would likely have maintained the DO concentration in the DWSC at the DO target during 1999. The total DO deficit in 1999 was at least 650,000 pounds, although a deficit might have also occurred in October. The total cost for oxygen (at \$0.10/lb) in 1999 (including some in October) would have been about \$75,000.

Figure 4 shows the minimum DO pattern measured in 2000 along with the UVM net flow estimates during the year. The DO concentration was below the DO target concentration from about mid-June through September of 2000 (although the DO in October was again not recorded). The daily DO deficit was often 10,000 lb/day with a few peaks of 15,000 lb/day. An aeration device with a daily DO delivery of 10,000 lb/day would have maintained the DO concentration in the DWSC at the DO target during 2000. The total DO deficit in 2000 was at least 475,000 pounds, although a deficit might have also occurred in October. The total cost for oxygen in 2000 would have been about \$50,000.

Figure 5 shows the daily calculated DO source required to satisfy the DO target concentration in 2001. The DO concentration was below the DO target concentration from early June through early October of 2001. The daily DO deficit was often 10,000 lb/day with a few peaks of 15,000 lb/day. An aeration device with a daily DO delivery of 10,000 lb/day would have maintained the DO concentration in the DWSC at the DO target during 2001. The total DO deficit in 2001 was about 1,000,000

pounds. The total cost for this oxygen would have been about \$100,000 in 2001.

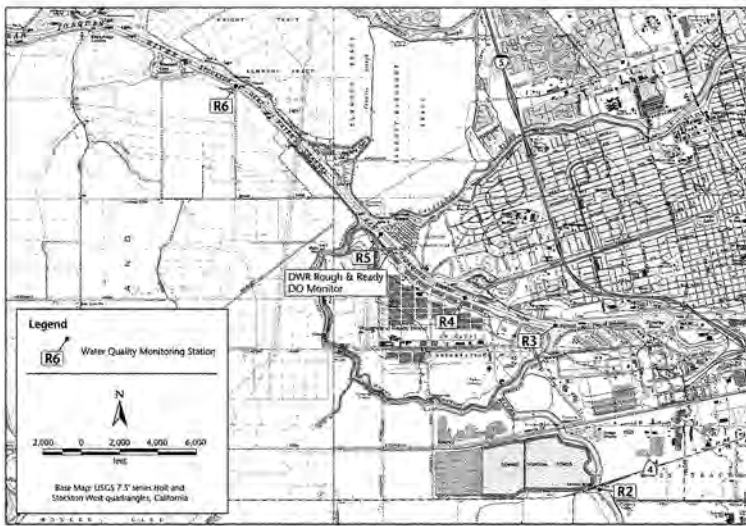
Aeration Design Conditions

These worst-case summer conditions have been previously characterized with the results from DWR Rough & Ready Island DO monitor as well as City of Stockton water quality monitoring results (Jones & Stokes 1997, 2001). Net SJR flows through the DWSC during low flow summer period of about 500 cfs can be expected to occur on a routine basis, and the travel time for water between R3 and R6 at 500 cfs is about 10 days (because the DWSC volume from the turning basin to R6 is about 10,000 acre-feet). Monitoring data indicates that similar DO sag concentrations can occur to a flow of about 2,000 cfs. Generally, the maximum DO sag is located further downstream in the DWSC as flows increase. When flows exceed 2,000 cfs, the magnitude of the DO sag within the DWSC is reduced due to shorter residence times, higher natural reaeration rates, or lower BOD concentrations entering the DWSC. As hydraulic residence time decreases with increasing flow, the time available for BOD decay is reduced. At higher streamflow rates, a greater portion of the BOD load passes through the DWSC out to the other Delta channels. Higher flows may reduce the SJR concentrations of BOD and dilute the RWCF effluent BOD loads.

At a flow of 1,000 cfs, a 2 mg/l DO decline below the 5 mg/l objective is equivalent to a daily DO mass deficit of 10,800 lb/day (i.e., $5.4 * 1,000 * 2 = 10,800$). This is the quantity of oxygen that needs to be added into the DWSC on a daily basis to result in average DO concentrations near the DO sag location that meet the Basin Plan DO objective of 5 mg/l. This is taken as the worst-case design capacity for the alternative DWSC aeration devices.

Figure 6 illustrates the major factors and processes that influence the DO concentration pattern within the DWSC. The initial BOD concentration (and BOD decay rate) along with the sediment oxygen demand (SOD) govern the DO losses along the DWSC. The reaeration is the major source of DO and depends on the DO deficit (below saturation). The net flow controls the travel time as the water moves through the DWSC from R3 to R6. An estimate of worst-case total BOD concentration is about 10 mg/l (equivalent to a 5-day BOD measurement of about 4 mg/l). At a flow of 1,000 cfs, this is a total BOD load of 54,000 lb/day. The City of Stockton RWCF and the SJR are the sources for this BOD load. SOD has been estimated to range from 0.5 to 1.0 g/m²/day and is assumed to be uniform throughout the DWSC (Litton 2001). This range of SOD exerts a daily oxygen demand of about 1,115 lb/day to 2,230 lb/day based on the channel bottom area (i.e., 250 acres) between stations R3 and R6. The origin of this SOD, however, may be settling of some of the total BOD from the river and RWCF discharge.

- 1) Reaeration depends on the estimated transfer velocity (i.e., 0.5 m/day) and the DO deficit. For an average deficit of 4 mg/l, the reaeration between R3 and R6 would add only about 4,500 lbs/day. However, the intermittent development of stratification near the water surface may restrict the reaeration of the DWSC. Algae photosynthesis in the surface of the DWSC will add DO but also increase the BOD concentration. Although the net effect of algae growth and respiration in a closed tank would be no change in DO concentration, the effects of algae growth in the DWSC are not well documented. It is apparent from this simple comparison that the BOD loading far exceeds the oxygen source from natural reaeration (with algae growth and respiration assumed to provide no net increase in DO). Artificial aeration or oxygenation will be needed to provide a balance in the DO budget within the DWSC.
- 2) One problem with the bubble devices is that the aerated water ends up on the surface where the DO may already be high, rather than in the bottom layer where the DO is lowest.



Jones & Stokes

Figure 1
Stockton Deep Water Ship Channel Water Quality Stations

and Maximum Measured at Rough & Ready DO Monitor During 2001

Figure 2. DO Minir

Minimum and Maximum DO at Rough & Ready Monitor

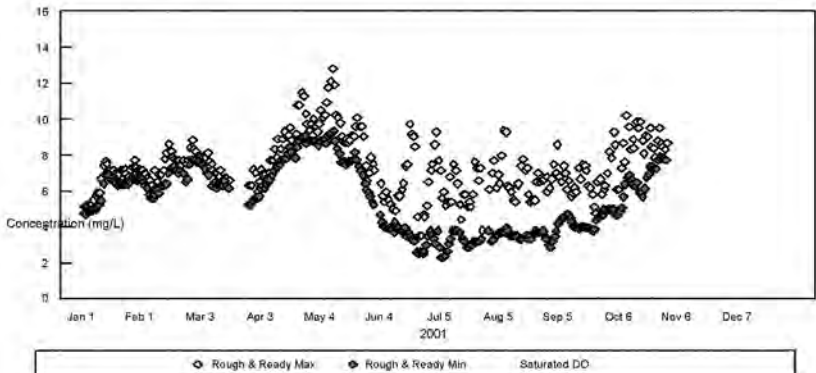
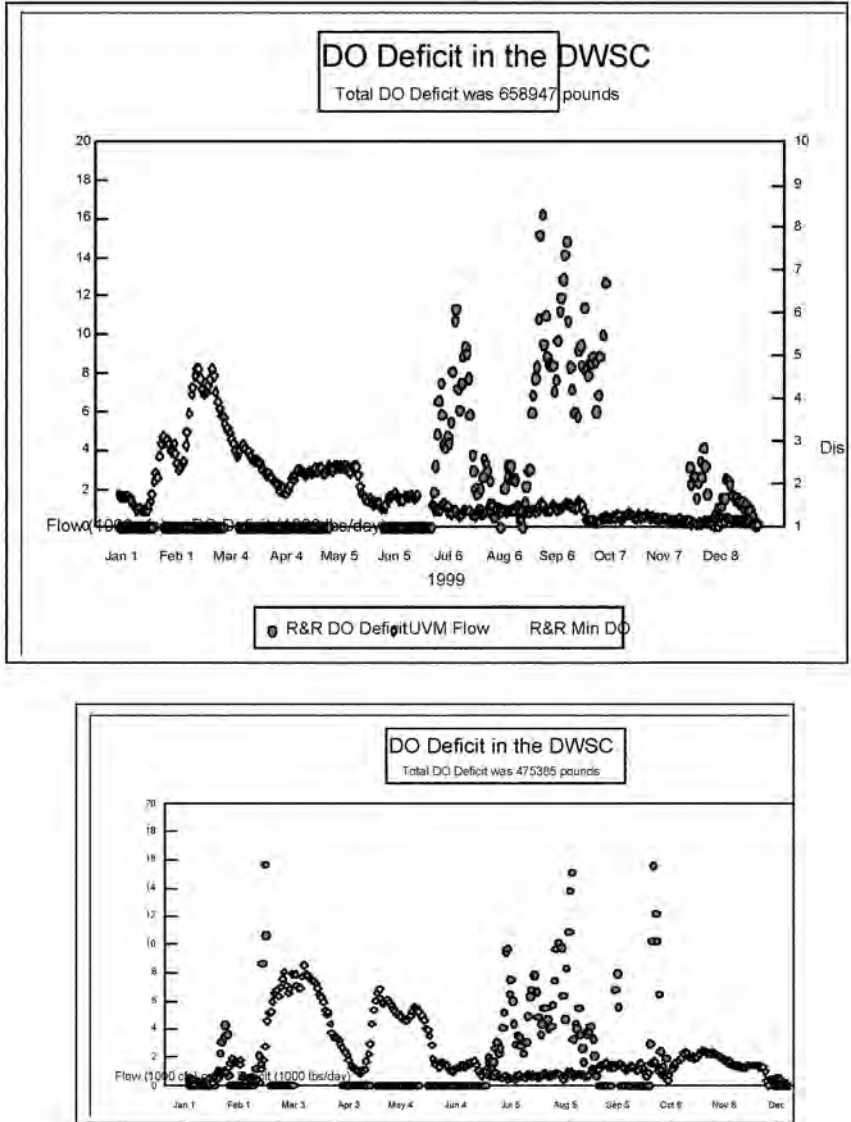


Figure 3. Calculated DWSC D.O. Deficit During 1999.



Onondaga Lake Hypolimnion Oxygenation, Syracuse NY

Taken from US Army Contract Description

Onondaga Lake an urban lake located in metropolitan Syracuse, NY is approximately 4.6 miles long by 1 mile wide has mean and maximum depths of 35 and 63 feet respectively and a drainage basin of 248 square miles. The major hydrologic inputs to Onondaga Lake are several creeks and the Syracuse Wastewater treatment plant. The lake outlet is located at the northern end of the lake where it empties into the Seneca River. Onondaga Lake's present water and sediment quality and biological conditions are the result of more than a century of waste inputs. Contributing factors include extensive quantities of treated domestic wastewater, combined sewage overflows, various industrial wastes, runoff from urban and agricultural land and leaching of various substances from hazardous waste sites around the lake. Another likely factor is the probable release of mercury, phosphorous and other contaminants from the lake's bottom sediments. Fishing was banned in 1970 because of mercury contamination and currently, a fish advisory exists which severely limits fish consumption. Some of the water quality problems in Onondaga Lake result from the fact that the effluent from the municipal wastewater treatment plant represents approximately 20% of the annual inflow to the lake and 60 to 70% of the total inflow during low flow conditions. Pollutant loading in this effluent may contribute to low hypolimnetic D.O. concentration. In addition, during late summer and early fall turnover, Onondaga Lake has undergone temporary lake-wide D.O. depletion resulting in violation of NY State's minimum D.O. concentration of 4 mg/L for several weeks.

The hydraulic residence time in Onondaga Lake is about 3 months. During stratification the hypolimnion waters are basically stagnant while the inflow water flows over the top of the lake and out.

Preliminary recommendations are to supplement approximately 30 tons of D.O. per day to the lake hypolimnion for the next decade to satisfy the accumulated oxygen demand in the sediments and reduce the rate of mercury methylation.

Chicago Urban Canals Supplemental Oxygenation

The urban canals of Chicago receive storm runoff and combined sewer overflows. Their impounded flow prevents periodic scouring of benthic deposits and also results in very limited reaeration capacity. Consequently prior to about 1990 the D. O. was often near zero for extended periods. Chicago's urban canal system is used for barge transportation as well as conveyance of treated waste waters away from the metropolitan area. Lake Michigan is a high-quality water resource that serves as the water supply for Chicago. By federal decree, only an annual average of 90 m³ per second of water could be diverted from Lake Michigan. A proposed system of 10 strategically placed diffused aeration stations having a combined reaeration capacity of 134,000 kg of oxygen per day was proposed to maintain minimum D. O. concentrations. However, 18 m³ per second of Lake Michigan water would have still been required as an integral part of this supplemental reaeration scheme.

An economically competitive supplemental reoxygenation system utilizing pure oxygen and a system of five reoxygenation stations was proposed which would maintain the D. O. standards and require no diversion of Lake Michigan water. The diverted water thus saved was freed to serve as a much-needed water supply for communities in the metropolitan area. The reoxygenation stations proposed were two U-Tubes of 75 m depth and capable of raising a sidestream from the canal up to 35 mg/L D. O. This sidestream would then be blended with the canal flow to raise the canal D. O. to approximately 15 to 25 mg/L. Negligible stripping of this supersaturated canal D. O. would have occurred because of the low reaeration rate of this pooled canal. Yet the number of required reaeration stations was markedly reduced from 10 to 5 over the case where air would be used as the oxygen source. Only two reoxygenation stations were required on the canal using U-Tube oxygenation and pure oxygen injection versus 10 for diffused aeration station. Three U-Tube pure oxygen stations were to be located on the outfall of the three major wastewater treatment plants.

The Chicago Canal system consists of three segments, North Shore 12.8 km long, Main 48 km long main and Calumet Sag 26 km. These canals connect with the original river channels to form a 130 km system. The average depth varies from 3.6 m in the North Shore Canal to 7.6 m in the main with width varying from 21 m in the North Shore Canal to 60 to 90 m at places in the Main and Calumet sag segments.

Dry weather flows result in extended travel times of four days in the North Shore, five days in the main and four days in the Calumet sag canals. Combined sewer overflows discharge into the canal system to prevent local flooding. The average frequency of combined sewer overflows was once per four days before the large tunnels were constructed for storage of storm overflows. The average BOD of the overflow events is 273,000 kg. The long-term effects of these combined sewer overflows is the accumulation of sludge deposits of 1 to 2 m depth in the canal system, causing the benthic deposits to exert an oxygen demand of 64,000 kg per day.

The stations would pose no interferences to navigational use of the waterways. Each would be designed to oxygenate a sidestream effluent of canal water drawn out of the main flow through a screen into a pump. The flow to be oxygenated would be pumped into the U-Tube against approximately 4 m of head by a low lift pump station. Pure oxygen would be injected in the down flow leg of the U-Tube at a rate required to

produce the desired discharge D. O.. The upflow leg of the U-Tube would discharge into a diffuser pipe located on the bottom of the canal at right angles to the direction of flow and approximately 20 meters downstream from the intake screen.

Main canal. The low flow at the head of the main canal is approximately 19 m³ per second. By raising the dissolved oxygen concentration from 4 to 14 mg/L. The D. O. standards would be satisfied with no discretionary diversion from Lake Michigan until the flow reached the West Southwest sewage treatment plant. The U-Tube would add 34 mg/L of D. O. to a flow of 7 m³ per second.

Brownlee Reservoir on the Snake River, Idaho

Taken from "Application for Certification Pursuant to Section 401 of the Federal Clean Water Act for the Relicensing of the Hells Canyon Hydroelectric Complex. FERC No. 1971 Submitted to Oregon Administrative Rules Chapter 340, Division 48, July 2003

Brownlee Reservoir is on the Snake River between Idaho and Oregon and is part of the Hell's Canyon Complex of hydropower dams. The water quality standard is 6.5 mg/L. Currently D.O. levels in Brownlee Reservoir do not always meet the D.O. targets nor are they adequate to support all designated beneficial uses. D.O. in Brownlee Reservoir can become severely degraded, especially during summer, a condition that has occasionally caused fish mortality.

The D.O. was below this target 55% of the time in Brownlee Reservoir and the metalimnion had the highest number of measurements below target. Excessive algal proliferation is reported to be the cause of the D.O. deficiency and a phosphorous reduction has been recommended.

To fulfill regulatory requirements it is proposed to supplement 1450 tons of O₂ per year into Brownlee Reservoir into the transition zone or the upstream end of the lacustrine zone.

Percy Priest Lake

The basic purpose of the Percy Priest Lake oxygenation system is to meet the water quality discharge criteria in the hydropower discharges. This involves D.O., Fe, Mn, and H₂S. Is it possible to leverage the engineering solution such that significant additional benefits can be realized without additional costs? It seems kind of a shame to just meet the letter of the law when significant environmental enhancement of the hypolimnion could be realized for not additional cost. In this proposed oxygenation design there are even considerable savings in capital costs as the hypolimnion is enhanced and the discharge water quality criteria are still achieved.

The real burden of the oxygenation system for Percy Priest lies in accommodating the peaking power releases - which may occur only once or twice a summer. An oxygen demand of 37 tons/day is required in the dam vicinity where it will have least enhancement to the fishery habitat. So much oxygen is put into the reservoir for so little

time - perhaps a few hours! Two thirds of the total oxygen transfer capacity is required just to meet these sporadic releases.

Why does so much oxygen have to be added at the dam vicinity? Because it is *not* in the water already. If it was already in the water, there would be no need for such large instantaneous oxygen dissolution capacity.

If it is assumed that a given amount of oxygen is required per season, why not buy it a few months early and store it in the hypolimnion? This would require that oxygen injection would have to be initiated about one month earlier than normal when the hypolimnion D. O. dropped to 5 mg/L to maintain it at that level. In such a case there would be no need to instantaneously meet a sporadic discharge event. Maintenance of 5 mg/L of D.O. in the water column does not cause a significant increase of oxygen demand from the sediments or the water column.

To avoid high peaking oxygen demands, it is necessary to determine the maximum discharge-duration event. If it is assumed the maximum discharge would be 4600 cfs for 7 days, this would be 9000 acre-ft per day of which 80% comes from the hypolimnion or 7200 acre-ft per day times 7 days = 50,000 acre-ft. Since the hypolimnion has a volume of 178,000 acre-ft (below elevation 470 ft.) there is sufficient hypolimnion volume to meet this design event. A volume of 50,000 acre-ft contains 340 tons of oxygen at 5 mg/L.

If it is assumed that the projected oxygen use per season is 2500 tons and the season is 170 days, the base rate of oxygen supplementation is 15 tons per day.

If it is not sufficient to just dissolve the oxygen, it needs to be moved throughout the hypolimnion. The major cost of this oxygen supplementation project is getting the oxygen in solution. A relatively minor cost is involved in moving it horizontally throughout the hypolimnion. To accomplish this function, it is proposed to utilize 3 - 10 HP 8 ft diameter, horizontal axial flow pumps capable of mixing 200 cfs each. The mixing characteristics of such a pump are that it will reach 3 km away in 1 day and 6 km away in 6 days.

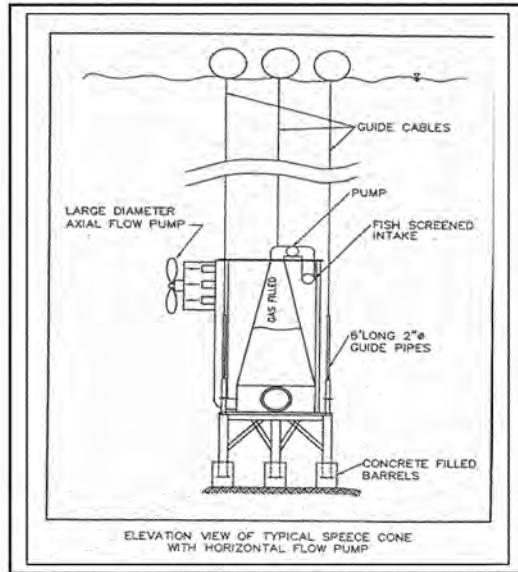
PROPOSED OXYGENATION LAYOUT

A Speece Cone is proposed to be located at the Corps boat dock and has the flexibility of delivering the highly oxygenated side stream in the direction of the dam, in the direction parallel to the dam across the reservoir or upstream in the reservoir in the direction opposite to the dam. Its "zone of influence" can be enhanced over 6 km away within a week by the use of the aforesaid pumps.

It is recommended for this design that a Speece Cone be placed in the old river bed channel near the Corps boat dock. A 10 ton/day Pulsed Swing Adsorption (PSA) oxygen generator would supply this Cone.

An addition Speece Cone is recommended at approximately 5 miles upstream (below Hobson Pike) and having a capacity of 5 tons/day of oxygen dissolution capacity. It would be fed by a PSA oxygen generator of 5 tons/day capacity.

There would be 3 locations where a 200 cfs 10 HP large diameter, horizontal axial flow pump would be located. One would be located at each Speece Cone location and a third would be located above Elm Hill Marina. This third large axial flow pump would move oxygenated water pumped from the Cone at the Corps boat dock and move it further upstream.



Gowanus Canal New York City

Following is a proposal for supplemental oxygenation of the Gowanus Canal. It is understood that 6100 lbs of D.O. is to be supplemented each day and that a D.O. of 8 mg/L is to be maintained in the canal under summer temperatures of 25 °C. The canal is assumed to be 20 ft. deep. D.O. C_{sat} for air at mid-depth would therefore be 10.4 mg/L (1.3 atm at mid-depth $\times$ 8 mg/L C_{sat} at 25 °C.) The D.O. deficit at which an aeration process would be working would therefore be $10.4 - 8.0 = 2.4$ mg/L.

Super oxygenation technology for discharge horizontally through a diffuser located off the bottom of the canal (to prevent sediment suspension) where it is rapidly diluted down to 8 mg/L D.O. is recommended. This also accomplishes mixing and transport of the D.O. along the canal. A system would raise the D.O. in a sidestream to about 90 mg/L and guarantee over 90% dissolution and retention in the water. The size of this Speece Cone system would be nominally 8 ft in diameter and about 20 ft tall supplied with a 200 HP pump.

The system has an energy consumption of about 1000 kwhr/ton of D.O. added. This would be about \$300/day for electricity at \$0.10/kwhr to add 6100 lbs D.O. per day. The entire system can be mounted on a barge moored on the side of the canal or placed on land where space is available.

For a permanent solution, the oxygenation vessel could be placed in an excavated caisson about 40 ft deep so that it could use the hydrostatic pressure instead of pumped pressure to achieve superoxygenation. This would reduce the energy consumption to less than 300 kwhr/ton of D.O. as has been done for an industrial client in Oklahoma. In this case 30 cfs was pumped through an oxygenator and raised the discharge D.O. to 60 mg/L in water that was 25 °C. It then entered a 5-mile long pipeline flowing full to prevent any hydrogen sulfide formation during transit. This system dissolves about 10,000 lbs of D.O. per day. A 40 HP pump is used to move water through each oxygenator.

New York Water Supply Reservoirs

The New York City Water Department withdraws cold hypolimnion water from stratified New York State reservoirs except during summer months when complete D.O. depletion occurs in some of the reservoirs caused by algae proliferation in warm surface waters. Under such anaerobic conditions, Fe, Mn and H₂S production is exacerbated by algae decay, consuming all the D.O. Since no subsequent treatment has been provided to date, these reservoirs must be taken off line until colder weather results in destratification.

Direct supplementation of oxygen to the hypolimnion, however, would avoid this problem while not destratifying the reservoir. In addition the potential problem of dissolved nitrogen supersaturation which often arises when using air may be avoided when superoxygenation is utilized as the treatment protocol.

For stratified reservoirs with D.O. deficiency in the hypolimnion, oxygen can be dissolved directly into the hypolimnion to effectively offset the oxygen demand from algae settling down from the euphotic zone as well as sediment oxygen demand. This would be

similar in concept to the Camanche Reservoir hypolimnion oxygenation system utilizing the Speece Cone.

San Diego Water Reuse Reservoirs

One novel application of hypolimnion oxygenation with induced horizontal flow propagation is in regions which have a chronic summer water shortage. Reuse of treated wastewater to augment the water supply is being considered in San Diego. It is desirable to have a storage period delay of over a month after the wastewater is treated before it is used as a water supply. The treated warm wastewater would be discharged and stored in the epilimnion providing the requisite storage delay before reuse and the hypolimnion would have to be supplemented with oxygen to prevent water quality deterioration throughout the stratification season.

Manchester Ship Channel England

Presently supplementation of D.O. is practiced in this ship channel with aeration techniques that incorporate air aspiration into Venturi ejectors. Due to the inability to meet the target D.O. criteria, superoxygenation has been recommended.

Hood Canal Washington

Hood Canal is a long narrow branch off Puget Sound. It is about 50 km long, 2 km wide and an average of 100 m deep with an entrance sill of 50 m. Maximum depth is about 200 m. Persistent stratification is maintained from gradients in both salinity and temperature. There is a strong density difference located at 5 to 10 m depth. Strong water column stratification with low dissolved oxygen levels are typical throughout the year but are more pronounced in the southern portion of Hood Canal and during the Fall. Because of the canal's depth and shape, the water exchange is slow, taking about a year for the canal to exchange its waters with Puget Sound. Fish and invertebrate mortalities are believed to be due to low dissolved oxygen. ("First Record of a *Heterosigma* Akashiwo Bloom in Hood Canal Washington, USA. By Connell, L.B., Newton, J.A. and Craig, S. D.

Weather conditions can cause upwelling in the ocean so that the water flowing into the Puget Sound is also lower in oxygen and higher in nutrients. The daily D.O. demand in the lower regions of the canal is in the order of 100 tons per day.

Venice Lagoon Italy

Storm tides which sometimes flood the beautiful city of Venice, Italy are gradually undermining its magnificent architecture. Future efforts to prevent flood damage, however, must accommodate an additional set of problems. Since the city still has no sewerage collection and treatment system, should tidal gates be built to isolate the lagoon during high

tide emergencies to prevent further architectural and artistic deterioration, severe oxygen depletion could soon occur in the lagoon. In the absence of flushing tides the undesirable visual spectacle of algae scum forming and the possibility of serious fish kills occurring would have to be addressed in the design criteria for tidal gate use. This lagoon is an excellent candidate for superoxygenation to achieve water quality objectives.

Jamaica Bay, New York

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Section 3. Air as a Supplemental Oxygen Source

3. Aeration Technology

I. Supplemental Aeration Characteristics

A. Selecting Tertiary Treatment Alternatives

After it has become evident that a more cost-effective solution than tertiary treatment is necessary for removal of a small increment of residual BOD in the treated wastewater, selecting the best oxygenation equipment available is advisable.

The objectives of oxygen supplementation to a harbor differ substantially from ordinary aeration of wastewater. The dissolved oxygen deficit in a harbor is about 4 mg per liter (8 – 4 mg/L), or about half of that found in wastewater treatment (9 – 1 mg/L). The 4 mg per liter dissolved oxygen level must be maintained even during the warmer temperatures in the summer, which reduce the air saturation concentration to 8.2 mg per liter, which constitute the critical seasonal conditions.

The cost of electricity has risen in many areas and must be factored into equipment selection. Since the unit energy consumption of conventional aeration is inversely proportional to the dissolved oxygen deficit driving force, a doubling of energy consumption will result if the D.O. deficit is halved, adding \$60 to \$120 per ton to the other costs of dissolved oxygen supplemented. At \$0.06 per kilowatt hour and in water that has only 2 mg per liter of dissolved oxygen, 1000 to 2000 kWh per ton of dissolved oxygen is required.

Aeration technology utilizes various generic designs for dissolving oxygen from air into water such as surface aeration devices, coarse or fine bubble diffusers, Venturi aspirators and cascade/weir aeration equipment. Each of these systems can effectively dissolve oxygen from air into water if target D.O. in the water is low and the cost of electricity is minimal.

B. Inherent Disadvantages of Aeration in Many Applications

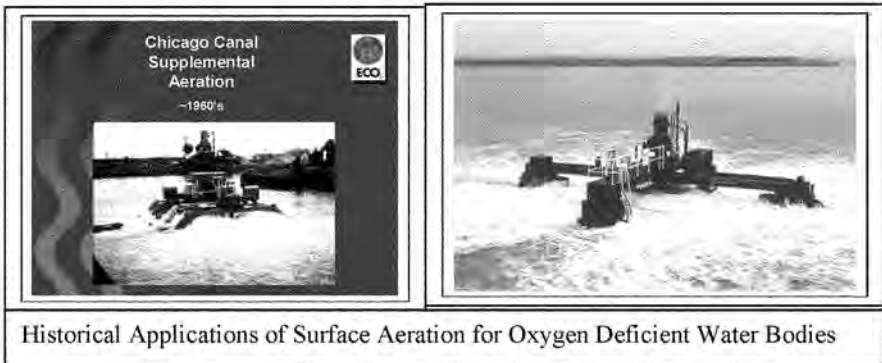
Traditionally aeration technology was developed to meet the need to dissolve a large quantity of dissolved oxygen into wastewater to support the aerobic microbial metabolism of organic pollutants. Therefore the most commonly used aeration techniques were optimized for this purpose. However, it should be recalled that the systems were developed when electricity was still cheap, required bulk D.O. concentrations were 1 to 2 mg/L and compact aeration equipment was not necessary.

Air as a supplemental oxygen source has distinct disadvantages. Since air is composed of 79% nitrogen, the accompanying nitrogen gas can cause serious supersaturation problems if it comes into contact with water at above ambient pressure, which occurs in diffused aeration systems (not a problem with surface aerators). Nitrogen gas supersaturation can impair fish health, and even be lethal to them, (see a more extensive discussion later in this report).

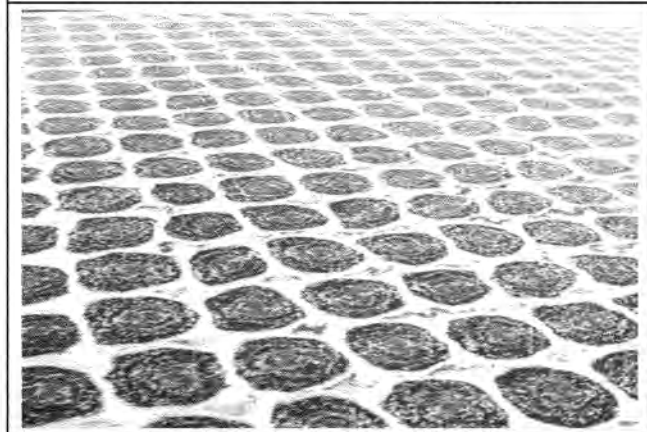
Another disadvantage is that with the air as the oxygen source, if a discharge concentration of less than 5 mg per liter dissolved oxygen is produced by the aeration system, almost 100% of the harbor flow must be moved through the oxygenation system. Significant pumping and river diversion problems must then be addressed.

C. Historical Attempts to Use Surface Aerators for Supplemental Aeration

Shown in these photos are prototype installations which attempted to achieve supplemental aeration in shipping channels. They proved to be rather ineffective and quite energy intensive. The projects were abandoned.



The following photos show the close spacing required of conventional surface aerators in wastewater treatment. This type of equipment placement is not appropriate for the Savannah Harbor shipping channel, which must remain unobstructed.



Conventional Aeration Systems Occupy Entire Volume of Aeration

II. Impact of Changing D.O. Requirements on Aeration Technology Applications

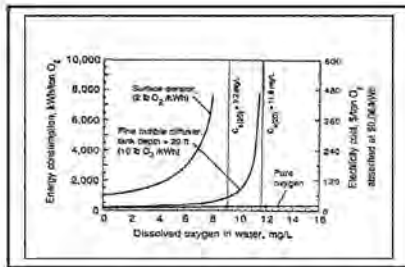
A. Aeration Technology Cost Effectiveness

Nowadays the increased cost of electricity has caused conventional aeration technology to become impractical if D.O. standards are set above 4 mg/L. Should dissolved oxygen standards for Savannah Harbor be raised in the future, many systems

may even be rendered obsolete. Table I indicates the approximate electricity consumption per ton of D.O. for surface aerators, coarse bubble diffusers or cascade weir aeration at 25 °C.

Table I. Unit Energy Consumption and Costs for Surface Aeration, Coarse Bubble and Cascade Weirs

D.O. (mg/L)	D.O. Deficit (mg/L)	# O ₂ /kw-hr	kw-hr/ton D.O.	\$0.05 (Dollars/Ton of D.O.)	\$0.08 (Dollars/Ton of D.O.)	\$0.11 (Dollars/Ton of D.O.)
0	8.2	2.6	770	38	62	85
1.2	7.0	2.0	1000	50	80	110
2	6.2	1.8	1100	55	88	120
3	5.2	1.5	1300	65	104	143
4	4.2	1.2	1700	85	136	187
5	3.2	0.9	2200	110	176	242
6	2.2	0.6	3300	165	264	363
7	1.2	0.35	5700	285	456	630



The waterfall height required to achieve indicated dissolved oxygen levels, along with attendant unit energy consumption at 25 °C. Using cascade/weir aeration, is shown in Table II.

Table II. Height of Cascade Fall to Achieve Indicated D.O. Increase and Resultant Unit Energy Consumption

<u>Change in D.O. (mg/L)</u>	<u>Required height -ft</u>	<u>kw-hr/ton of D.O. added</u>
2 to 3	1.0	903
3 to 4	1.1	1070
4 to 5	1.4	1320
5 to 6	2.0	1890
6 to 7	4.0	3780
2 to 4	1.6	740
3 to 5	2.1	990
4 to 6	3.3	1560
5 to 7	8.1	3830
4 to 7	13.6	4290

Under the conditions described in Table III, superoxygenation becomes more cost effective than conventional aeration technology at 25 oC:

Table III Cost Effectiveness Criteria for Aeration and Oxygenation

Target D.O. mg/L	>5	>3	>1.2
Cost of electricity	\$0.05	\$0.08	\$0.11

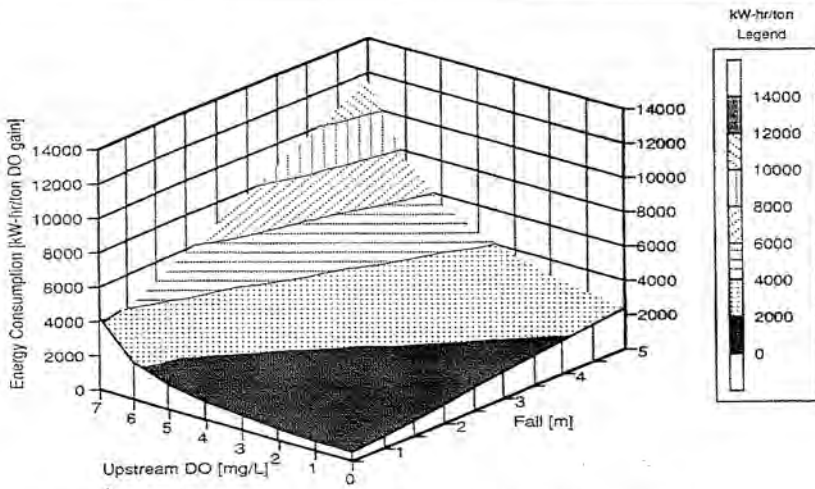
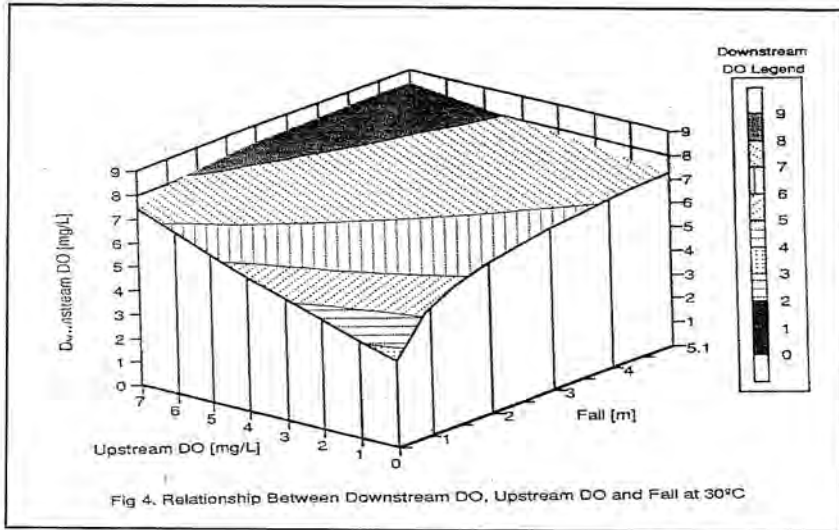
An example of the impact of higher D.O. standards and increased energy costs would be the beautiful Chicago Canal Cascade Aeration System (see photo) which already consumes unusually large amounts of electricity (3000 kwhr/ton D.O.) to meet the present low standard of only 3 to 4 mg/L. If higher dissolved oxygen standards are mandated, this system will have to be completely replaced with a more cost effective oxygenation system.



The following Figures... depict the performance characteristics of cascade/weir aerators. The upstream D. O. is related to downstream D. O as a function of fall height. The energy consumed by the pumps used in the process is shown for the various combinations of D. O. and fall height.

Weir aeration can be expressed as:

$$\text{Log } D_o = (0.815 \text{ Log } D_i - 0.385 \text{ Log height of fall}) ((1.024)^{T-20} + 0.062)$$



III. Dissolved Nitrogen Problems Associated with Deep Water Air Injection

A. Reaeration Coefficient (k_2) Factors

It is often prematurely assumed that supersaturated gases will be stripped back down to saturation levels in a short distance as the water flows freely downstream. Gas transferred into or out of a river is generally characterized by a parameter called the reaeration coefficient (k_2) in units of per day. The reaeration coefficient is a function of the depth of the river and the energy dissipation rate. Energy dissipation, in turn, is a function of velocity and the slope or fall of the river. Therefore in a shallow river with a steep slope such as a mountain stream, the reaeration coefficient is high, perhaps in excess of 10 per day, and D.O. and DN tend to approach saturation in relatively short distances.

However, hydropower discharges frequently feed deeper slow moving downstream reaches, which often have reaeration coefficients of less than 0.1 per day. For instance the Columbia River is pooled between dams for navigation purposes, and thus has minimal energy dissipation which is compounded by its considerable depth. Consequently in the Columbia River, D. N. values of 130% have been measured with very little decrease over distances of 50 to 80 miles downstream. One cause for this slowness of reaching equilibrium is the gradual warming of the water which increases supersaturation by approximately 2.5% per degree C. increase.

Therefore it is significant that stripping of supersaturated dissolved gases will be intolerably slow in deep harbors and thus cannot be considered as a mitigating factor to achieve compliance with water quality standards for D. O. and DN and /or for total gas pressure (TGP).

B. TGP and D.O./D.N. Ratios in Preventing Fish Mortality

When supersaturation was first recognized on the Columbia River, 110% dissolved nitrogen was adopted by several U. S. northwestern states and the National Academy of Sciences and Oregon adopted 105%, as the maximum standard. However it was later determined that gas bubble disease is related to TGP so at present the U.S. Environmental Protection Agency has established 110% TGP as the water quality criteria. This TGP standard replaces standards based on only dissolved nitrogen (U.S. EPA 1976).

Several studies show that a high dissolved oxygen pressure can reduce the potential of a given TGP to produce gas bubble disease (Rucker 1976; Nebeker, Bouck and Stevens 1976; Nebeker, Hauck and Baker 1979). Even though gas bubble disease is related to TGP rather than just dissolved nitrogen, the D. O./D. N. ratio is important in determining the severity of symptoms and rate of mortality (Nebeker and Brett 1976). According to their study there was a significant decrease in mortality when the ratio of D. O./D.N. was increased while holding TGP constant.

C. Need for a New EPA TGP Standard for Superoxygenation

Nebeker and Brett's finding raises a question as to the validity of the present day EPA water quality criteria of 110% TGP being applicable to both spillway discharges and hydropower discharges. It is crucial to differentiate the impacts of air entrainment in spillways and hydropower releases from oxygenation using pure oxygen. The former increases D.N. – the major component in gas bubble disease – while oxygenation with pure oxygen does not increase D.N. at all. These two types of configuration have characteristically different DO/DN ratios, which are a definite factor in fish response in mortality. Bouck previously stated that "a single numerical criterion is a simplistic approach, which can be defended only as a first step in a sequence, culminating in field verification."

As a case in point, two fish kills occurred below the Mactaquac hydroelectric station in New Brunswick, Canada in the summer of 1968. Gas bubbles were observed on the dead and dying Atlantic salmon and eels. Due to the opening of the automatic vacuum breakers at low discharge rates, the DO and DN were elevated to 80% oxygen and 120% nitrogen. Even though this total gas pressure of 112% was only slightly above the present EPA water quality criteria of 110%, it resulted in killing 10% of the 1968 up river run of Atlantic salmon (Mac Donald and Hyatt 1973). This author believes that a revaluation of the present EPA standard of 110% TGP should be undertaken to reflect more accurately N₂ or O₂ supersaturation as the actual cause of fish stress/mortality. The EPA TGP standard was developed in the context of hydropower and spillway discharges and was developed based on air aspiration at dams and spillways on the Columbia River. However it has been noted that spring water fed to fish hatcheries with diurnal heating that 103% TGP gave 100% kill over long seasons.

D. Gas Bubble Disease: Result of Several Causes

Lethality occurs only at high total gas pressures and is not the sole factor to be considered. Fish under stress can be in a weakened state, making them susceptible to bacterial infections and parasites (McLaughlin and Busch 1981). Elevated D.N. levels are always dangerous to the resident fishery.

Physical symptoms of gas bubble diseases in fish have been reported to be:

- emphysema
- lesions
- gil congestion
- popeye
- cardiac blockage by embolism

(Fickeisen and Montgomery 1978, Bouck 1980, Weitkamp and Katz 1980).

E. Dissolved Nitrogen Problems Associated with Air Injection

When air is introduced into a water column, both oxygen and nitrogen gas are dissolved. Fig. shows the projected D.N. increase when air was injected into a water supply reservoir in Germany. These are rather high D.N. concentrations. This figure indicates that the dissolved nitrogen in the plume of an airlift aeration device is increased from a background saturated level of about 16 mg per liter by an additional 9 mg per liter in the airlift plume, resulting in 150% dissolved nitrogen supersaturation in the discharge.

Injection of air with its 79% N₂ content into a harbor would result in both O₂ and N₂ dissolution in the water column. Natural waters are always 100% saturated with dissolved nitrogen (D.N.) in equilibrium with 0.79 atmospheres partial pressure of N₂, corresponding to about 16 mg/L at 20 °C and sea level. Aquatic life is not adversely affected by D.N. as long as it remains below ambient air saturation. However injection of air into the water column results in raising the D.N. above this level and can result in gas bubble disease.

The State of Michigan has also reported high mortality rates in fish hatcheries which incorporate deep aeration basins used for the purpose of D.O. enhancement. Therefore caution should be exercised to prevent such an occurrence when using air aspiration into turbine vents of hydropower dams. As mentioned previously oxygenation with pure O₂ does not result in an increase in D.N.

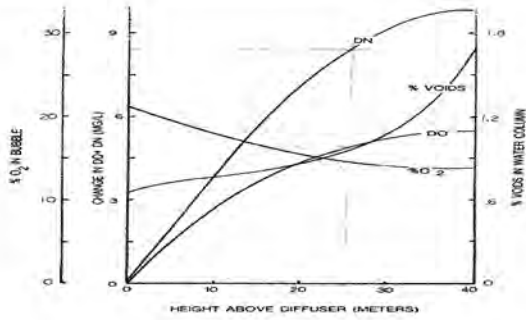


FIG. 1 GAS TRANSFER CHARACTERISTICS OF WAHNBACH SYSTEM

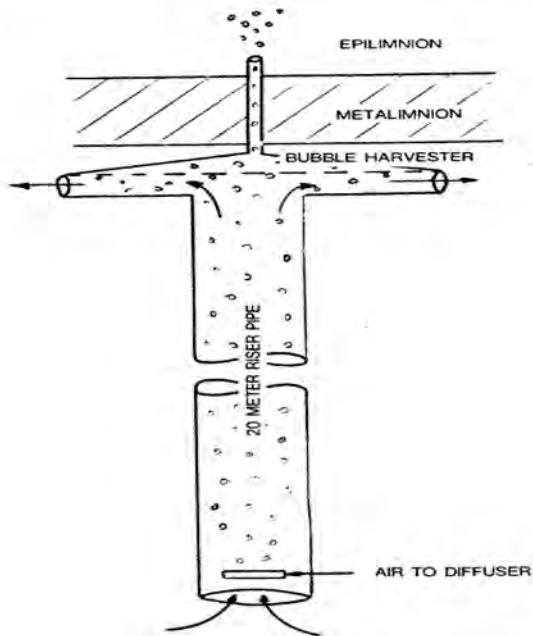


FIG. 2 PROPOSED HYPOLIMNION AERATION MODIFICATION

IV. Aeration System Evaluations

A. Chicago Canal Aeration System

The following section is quoted from a report on evaluation of the cascade aeration system used on the Chicago Canals.

Review of Chicago SEPA Stations Performance by Dr. Russ Brown

The most well known waterfall facility for aeration of a river is the Metropolitan Water Reclamation District's side-stream elevated pool aeration (SEPA) stations along the Calumet Waterway Cal-Sag channel. This 17-mile long navigation channel (connecting the Des Plaines River with Lake Michigan is 225 feet wide, 9 feet deep, and is extremely slow moving. The low-flow condition in the channel is estimated to be about 1,200 cfs. The DO objective established by the Illinois Pollution Control Board is 3 mg/l. Each of the five SEPA stations are designed to lift about 400 cfs with 2-5 rotary or screw pumps about 12 to 15 feet and discharge over a series of 3-4 waterfalls (i.e., cascade). The number of pumps operated can be adjusted to match the ambient DO conditions to minimize electrical costs. The design assumption was that the waterfalls would increase DO to 95% of saturation. The SEPA stations were completed in 1993 at a cost of about \$40 million.

The Illinois State Water Survey (ISWS) conducted a 2-year measurement program following the construction and operation of the SEPA stations to determine the actual performance of the five stations for a range of ambient DO conditions and temperatures.

They report (Butts *et al* 1998) that the cascades (3-4 waterfalls of 3-5 feet each) produced water that was more than 90% saturated with DO. A majority of the aeration occurred in the large screw pumps. A cascade of 3 waterfalls with a combined drop of 10 feet will likely provide a reaeration efficiency of 90%.

The effects of the waterfall stations on the river DO were more difficult to detect (Butts *et al* 2000). Mixing of the waterfall water back into the channel occurred near the surface and the downstream channel measurements could not easily determine an increase compared with the upstream river measurements. Algae and macrophyte (i.e., aquatic plants) productivity and natural aeration caused the surface DO concentrations to fluctuate and made it more difficult to isolate the effects of the waterfall aeration. More attention should be given to mixing the aerated waterfall effluent back into the river.

B. San Joaquin Ship Channel Aeration Performance Evaluation

The San Joaquin River flows from Stockton, California toward the San Francisco Bay and is used for shipping. The current is slow moving, causing the reaeration rate to be quite low, resulting in D.O. deficiency. Note the low oxygen efficiency of the aeration equipment.

The following is quoted from a report by Dr. Russ Brown on the performance of this system.

The manufacturer design documents suggested that these two sets of bubble-jets would each transfer 1,250 lb/day of oxygen. The depth of 25 feet suggested a maximum transfer efficiency of 20% for the oxygen dissolved from the bubbles into the water. The actual performance on September 26, 2001 was about 75% of the design value for the south jet (i.e., $925/1250 = 75\%$ of design). This seems quite good considering that the DO deficit was only about 2 mg/l. The oxygen absorption would be greater at a higher deficit. The north bubble-jet was operating at less than 20% of the design value (i.e., $225/1250 = 18\%$ of design). It is likely that the performance can be increased considerably by simply turning up the air flow rate to increase the bubble column upwelling and flow-away current. How much of this potential DO increment is transferred to the DSWC depends on the surface DO of the DSWC during the day.



Bubble Jet Aerators

If the average DO increment measured at the railroad bridge is reliable, the overall efficiency of the Corps aeration device was about 30% of the design value (i.e., $740/2500 = 30\%$ of design). However, because the air bubbles do not appear to be spread across the river channel, and a considerable amount of the compressed air is allowed to vent to the atmosphere, some design changes should be considered. It appears that a single 20 hp air blower (260 scfm) could produce an equivalent air bubble column from traditional diffuser heads (i.e. ceramic head or holes in pipe). The water jets with the two 15 HP jet pumps could be eliminated, and an equivalent amount of oxygen transfer from the upwelling currents could be achieved for less than 30% of the energy (i.e., 20 hp compared to 70 hp for current device).

A preliminary estimate of upwelling flow that could be generated from an equivalent air delivery rate to a single line diffuser can be derived from the equations presented above (Brown et al. 1989). Assuming the 260 scfm is distributed through a 10-m long diffuser, an upwelling flow of about 675 cfs of oxygenated water could be produced. Even with conservative assumptions that the oxygen transfer efficiency is the same between the line diffuser and jet-type aerator, this would represent a slightly greater amount of oxygenated water being distributed into the channel. The upwelling equations suggest that similar entrainment of water could be generated without the need for a supplemental water jet pump and its associated power consumption costs.

Another possible design change would replace the air compressor with pressurized (i.e., liquid) oxygen gas, to increase the amount of oxygen dissolved by these relatively shallow bubble columns. The compressor power costs would be saved but the oxygen costs to satisfy the design (i.e., 2,500 lb/day) would be about \$250/day. This aeration facility, if converted to an oxygen supply, might allow more than the current increment of 2,500 lb/day of oxygen to be added to the DWSC. The ability to remove the diffusers from the water during the winter and spring remains a very nice design feature of the Corps device. Its location along the side of the SJR channel is another very important design feature.

No measurements of supersaturation levels of D.N. caused by air injection 25 ft below the water surface were made.

V. Conclusions

With low target D.O. levels and inexpensive electricity rates, aeration equipment can suffice in some locations to bring water quality into compliance. However D.O. target levels above 4 mg/L and rising energy costs will preclude many aeration technology applications in the future and mandate replacement of some existing installations now in use.

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Section 4. Oxygenation Technology

4. Oxygenation Technology

I. Background

The unit energy consumption of a successful oxygenation system is relatively insensitive to the discharge D.O. up to about 70 mg/L, as shown in Fig. 2 (Speece, Khandan and Tchobanoglous). But recent developments in superoxygenation technology make possible highly elevated discharge D.O. concentrations economically achieved which solve many water quality issues.

Successful oxygenation of a surface water body is predicated on efficient dissolving of gaseous oxygen into water. The specific design constraints for superoxygenation technology which must be achieved are:

- high oxygen absorption efficiency
- low unit energy consumption (kwhr/ton D.O.)
- side stream superoxygenation (50 to 100 mg/L) at reasonable capital cost
- retention of superoxygenated D.O. in solution

II. Comparison of commercial oxygen vs air as the oxygen source

A. Disadvantages of air as the oxygen source

It may appear counterintuitive to utilize commercial oxygen in raising D.O. concentrations when air is available free. There are several mitigating factors, however, which make the use of commercial oxygen more economical than air in most cases. For instance dissolving oxygen from air into the water involves considerable capital and operating costs. There are also some adverse effects associated with the use of air which are negated using commercial oxygen.

The use of air in contact with water under more than ambient pressure results in supersaturation of the water column with dissolved nitrogen gas with its potential adverse impact on fish. Air as the oxygen source also restricts the maximum dissolved oxygen concentration achievable in a sidestream, and therefore increases the required sidestream flow to achieve a given daily oxygen supplementation mass rate.

In addition the use of air necessitates almost an order of magnitude greater energy expenditure per ton of dissolved oxygen increase when compared to commercial oxygen use. Conventional aeration devices consume 1000 to 2000 kWh per ton of oxygen dissolved, requiring energy expenses of \$0.05/kwhr or \$50-\$100 per ton of oxygen dissolved, with amortization of the capital adding still more cost. Commercial oxygen costs \$40 to \$200 per ton in bulk, depending on site-specific conditions. Commercial oxygen can be dissolved even in stratified water columns and generally becomes more economically competitive when the target dissolved oxygen goal exceeds 4 to 5 mg/L.

B. Advantages of pure oxygen as the oxygen source

Equipment is now available for superoxygenation (using pure oxygen) to achieve discharge D.O. concentrations of 50 to 100 mg/L. Contrary to a popular misconception, these high D.O. concentrations of less than 100 mg/L do not spontaneously effervesce, but are kept in solution. It is now possible to pull a small sidestream from a river, superoxygenate it, and dilute it back into the main river to satisfy D.O. deficiencies *without treating the entire river*.

To minimize the fraction of river flow thus moved through the oxygenation system, the D.O. concentration achieved must be maximized. This necessitates the use of commercial oxygen, either liquid oxygen (LOX) trucked in or high purity oxygen (HPO) produced on site. Commercial oxygen can be dissolved at elevated pressures without the adverse effects of nitrogen gas supersaturation, which occur when using air under pressure. Use of commercial oxygen allows exceptionally high D.O. concentrations to be produced in the oxygenation system effluent.

Advantages of superoxygenation treatment, when compared to aeration, pollutant reduction, or low flow augmentation in raising the D.O. levels include:

- no measurable negative impact on water quality and the receiving water
- no dissolved nitrogen (DN) supersaturation problems
- a smaller footprint for the oxygenation installation
- less energy consumption
- higher sidestream D.O. levels of 50 to 100 mg/L achieved and kept in solution
- wider spacing of oxygen supplementation stations
- more practicality than tertiary removal of BOD
- less cost than aeration if the dissolved oxygen target exceeds 5 mg/L and electrical costs exceed \$ 0.05 per kilowatt-hour

Highly supersaturated D.O. concentrations are possible if special provision is made to prevent effervescent loss before dilution with the bulk harbor water. This makes it possible to supplement the desired oxygen tonnage into a relatively small side stream, minimizing the size of the oxygenation system and associated pumping requirements, and thus increasing the required spacing between oxygenation stations.

A good system for transferring oxygen from air will probably be a poor system for transferring pure oxygen into water. Air dissolution systems are designed to minimize the unit energy consumption and have low O₂ absorption efficiencies, because the air is available free. Conversely, a good oxygen absorption system must achieve high O₂ absorption efficiency, because the cost of oxygen is the dominant Life Cycle Cost component and the cost of energy consumption per ton is minor (i.e. 200 to 500 kWhr/ton D.O.), being only about 10 % of the oxygen cost.

Even pure oxygen is sparingly soluble in water. In order to assure efficient absorption of pure oxygen in water two requirements must be met:

- 1) the oxygen gas must be maintained in contact with the water for a prolonged period of time to achieve efficient oxygen absorption
- 2) dissolved oxygen stripping from the water into the oxygen bubble must be minimized

Since the water is initially saturated with dissolved N₂ from being in contact with air, this dissolved N₂ will partition back into the pure oxygen bubble. Consequently the partial pressure of O₂ in the bubble will be reduced progressively below its initial 100% purity. This in turn will lower the D.O. saturation concentration as well as the D.O. deficit. Higher pressures inside the oxygenation system reduce the stripping potential of nitrogen gas dissolved in the water into the gas phase and therefore tend to reduce dilution of the pure oxygen feed by stripped nitrogen gas.

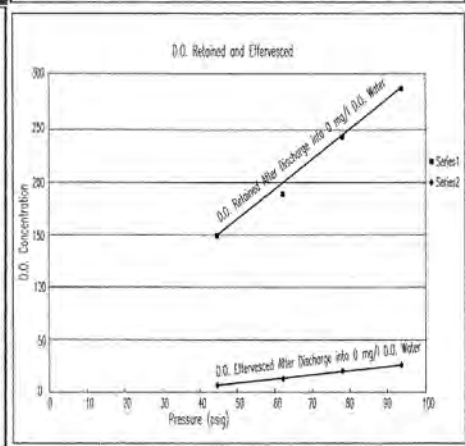
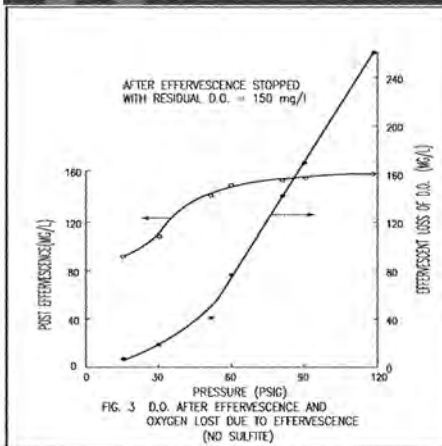
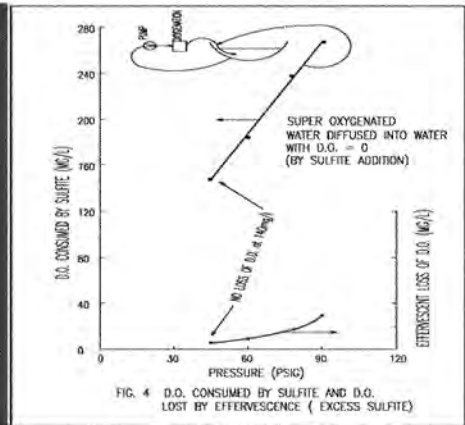
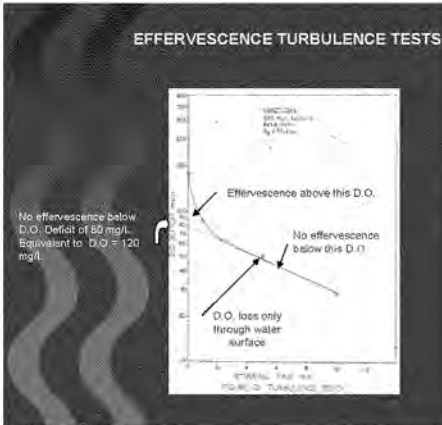
C. Effervescence

At steady state the concentration of D.O. in water will eventually reach that concentration which corresponds to saturation in contact with the gas phase. However the time to reach steady state can be quite prolonged. For instance the Columbia River flows for 80 miles at 130% supersaturation of dissolved gas and loses very little in transit. Of course the rate at which D.O. in undersaturated water reaches equilibrium is the same as the rate at which supersaturated D.O. reaches equilibrium. This is directly a function of the reaeration rate, k_2 , of the river. Slow moving, deep rivers have very low rates of reaeration while fast moving, shallow rivers have high rates of reaeration. The very low rate of gas exchange at the surface of Savannah Harbor is perhaps the reason for its chronic low D.O. concentrations. Conversely if a gas transfer device were used in the harbor which could raise the D.O. to 10 to 20 mg/L in a restricted region where it was produced, there would be negligible loss to the atmosphere.

In laboratory tests, it has been shown that the D.O. in water can be raised to 120 mg/L (D.O. deficit of 80 mg/L) using pure O₂ under pressure and no spontaneous effervescent loss of this high concentration of D.O. will result upon depressurization of the system. This is shown in the accompanying Fig. _____. Furthermore the D.O. can be raised to as high as 250 mg/L using pure O₂ under pressure and 90% of this can be retained in solution if it is diluted rapidly with water having a D.O. of less than 10 mg/L. In a third experiment in which water was highly superoxygenated to over 250 mg/L D.O. with pure O₂ under pressure, if no care was taken to dilute it rapidly and spontaneous effervescence was allowed to occur, the residual D.O. after all effervescence had ceased was approximately 150 mg/L (380% saturation for pure O₂).

These observations are corroborated by results from dissolved air flotation systems. DAF units operate the gas saturation vessel at about 60 psig which is 5 atmospheres absolute or about 400 to 500% saturation in the discharge. If the gas saturation reactor is not operated this high, then relatively little gas effervesces when it passes through the exit throttling valve.

The 45 - 50 ft depth of Savannah Harbor can be utilized advantageously for depressurization of pressurized superoxygenated side streams. The theoretical dissolved oxygen saturation concentration for pure oxygen at a 45 foot depth is 90 mg per liter. Since spontaneous effervescence does not occur below about 250 % of dissolved oxygen saturation when using pure oxygen it would thus be possible to raise the dissolved oxygen to about 2 1/2 times the 90 mg per liter of saturation i.e. 225 mg/L D.O. without the problem of effervescent loss of dissolved oxygen when it leaves a pressurized oxygen transfer vessel.



D. Types of Oxygen Absorption Technology

Pure oxygen absorption systems are generally grouped into the following categories:

- Jet/Venturi Aspirators
- Soaker Hose
- Contained Atmosphere Surface Splashing
- Side Stream Pressurization
- U-Tube
- Speece Cone

E. Pure oxygen source advances

Appropriate technology for supplementation of pure oxygen is determined by the following three factors:

- the present worth of the equipment – (purchase or rental)
- the present worth of total oxygen required (therefore oxygen absorption efficiency becomes important)
- the energy consumption per ton D.O. supplemented.

There is generally a trade-off between equipment cost and oxygen absorption efficiency. At low oxygen absorption efficiency the cost of equipment may be insignificant but the present worth of 'Oxygen Not Dissolved' may be large. An example of a low capital cost system with low O₂ absorption efficiency would be injection of gaseous O₂ through diffusers in waters with depths of less than 60 to 80 ft. Another example is a Venturi system which shears the bubbles to small diameters but depends on their rise up through the water column for most of the absorption. Thus shallow depths result in lower oxygen absorption efficiency for such a system.

Optimal high oxygen efficiency and minimal energy expenditure must be incorporated into the design of the oxygenation system adopted. Pressurized systems are desirable for producing superoxygenated D.O. concentrations in the discharge, but it is considerably more energy-efficient to achieve pressurization by hydrostatic head than by pumped head. Generally the unit energy consumption is < 400 kwhr/ton D.O. having a concentration of D.O. of >50 mg/L if the natural hydrostatic head is the means of pressurization vs the case where the pressurization is achieved by pumping against a throttling valve in the discharge line.

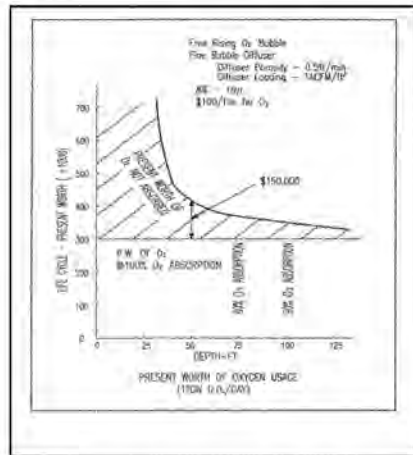


Fig. Present Worth of Oxygen

A superoxygenation device used in a harbor must be capable of highly superoxygenating a sidestream so that the amount of water to be treated is proportionately smaller. But this system must be located where the oxygen is needed. The Praxair ISO has a small zone of influence. This means that the modules have to be placed within the shipping channel involving many individual units with their electrical power lines strung across the surface area of the shipping channel.

Recent developments in molecular sieves and pulsed swing adsorption (PSA) technology for producing gaseous high purity oxygen (HPO) allow a practical and economical scale-down to capacities of < 1000 lb. O₂/day. PSA oxygen generators are much less complicated than cryogenic oxygen units because they require only a conventional air compressor, an air preparation package to remove water vapor and

hydrocarbons from the feed air and molecular sieve beds. In addition there is no on-site storage of oxygen as is the case when using liquid oxygen (LOX).

Vacuum PSA (VPSA) units are as energy efficient as cryogenic oxygen consuming <500 kwhr/ton O₂ for delivery pressure of 0 to 2 psig. The capital costs also are competitive at about \$70,000 per 1 ton O₂/day using the PSA system. This capital cost is generally flat over the O₂ production capacity of 1 to 40 ton/day. Oxygen purity is 90 to 95%. VPSA systems are operationally more attractive than PSA. For smaller oxygen users, however, the LOX tank rental cost can be almost as much as the cost of the LOX itself.

III. Evaluation of Types of Oxygenation Systems

In evaluating D.O. supplementation technology, the following considerations must be critically addressed:

- D.O. concentration in side stream discharge
- O₂ absorption efficiency
- depth of water column
- location in water column where D.O. is needed
- target D.O. in harbor
- mixing requirements
- unit energy consumption per ton of D.O. added
- capital cost of oxygenation system
- required spacing of D.O. supplementation stations
- placement outside the shipping channel

Praxair ISO

Praxair Company markets an oxygen transfer system which consists of a floating device which has a down pumper. There is also a large diameter shroud at the top which captures fugitive bubbles from the system. The down pumping device moves water downward and entrains gas from the headspace into the down flowing water. In this manner the oxygen enriched bubbles are moved down through the water in the downward plume and then the bubbles rise back to the surface as they migrate outside the downflow plume. As the oxygen bubbles rise they are captured as they exit the water by the shroud at the top. This mechanism satisfies the contact time requirement for efficient absorption of high purity oxygen because the bubbles are kept in contact with the water for over a hundred seconds. The pump works under very little head, requiring very little power to move the water in a downward direction.

This device achieves high oxygen absorption efficiency with a capacity of over 90% oxygen absorption efficiency. It also entails low unit energy consumption per ton of oxygen dissolved. However it is not able to raise the dissolved oxygen in a sidestream to more than about 10 mg/L of dissolved oxygen because the Praxair device operates under ambient pressure.

The downward pumping of the water drags bubbles down approximately 10 feet from which they then rise back to the surface. Thus the bubbles are under a maximum of about 1.3 atm absolute of pressure which corresponds to only about 10 foot below the surface in a harbor.



Fig. Aire Liquide Surface Oxygenator

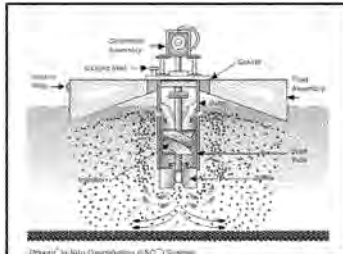


Fig. Praxair ISO Schematic



Fig. Praxair ISO Photo

The performance characteristics of the Praxair ISO system are:

- oxygen absorption efficiency is related to depth of water column
- unit energy consumption – 200 kwhr/ton D.O.
- cost of units - \$/ton D.O./day capacity (rental \$1500/month per unit)
- 5400 lb D.O./day per unit
- 25 Kw pump / unit

Venturi Systems

According to the Venturi principle of oxygen absorption, water is pumped at a high velocity through a Venturi throat section into which high purity O₂ is aspirated. Due to the high velocity there is a high degree of shear, which results in the production of very small bubbles forming a high gas/water interface to be generated by the production of very fine bubbles in the throat of the Venturi.

A major drawback is that since the residence time within the Venturi is very short, even though the bubbles are tiny and have a high gas/water interfacial area, the brief

contact time precludes efficient absorption. Since these microbubbles are not absorbed in the Venturi they remain in the discharge of the jet where some additional oxygen absorption takes place as the jet containing the microbubbles enters the bulk of the liquid for additional oxygen absorption. But this phenomenon causes the absorption efficiency of any Venturi device to be dependent upon the following factors:

- proper depth of the water column into which the oxygen is being absorbed
- appropriate energy input into the throat of the Venturi
- adequate relative rate of oxygen injection to water flow through the Venturi
- amount of velocity in the throat of the venturi
- correct rate of entrainment of the bulk liquid after the water bubble mixture leaves the throat of the Venturi
- efficiency of oxygen dissolution in the bulk liquid
- overall target dissolved oxygen level for the entire system

Oxygen absorption efficiency is increased by deepening the water column, lowering the O₂/water injection rates, and lowering D.O. in the water column.

Venturi systems produce oxygen absorption efficiency in the range of 60% and the unit energy consumption per ton of dissolved oxygen is in the range of approximately 1000 kWh per ton of dissolved oxygen. These systems are not able to transfer oxygen into water favorably, producing a discharge of only about 10 mg/L using high purity oxygen. Consequently the required spacing between the supplemental oxygenation units in the system is relatively short. However they could be located at the edge of the shipping channel and discharge their high velocity jet perpendicularly into the shipping channel.

In the evaluation of any Venturi type oxygen transfer system, the four key criteria for evaluation of performance which must be considered are:

- oxygen absorption efficiency
- unit energy consumption per ton of dissolved oxygen
- level of dissolved oxygen which can be achieved in the discharge
- relative spacing between the supplemental oxygenation units within the harbor.

O₂ absorption efficiency increases as the relative O₂/water ratio decreases, thus reducing the mass rate of D.O. addition per module. Likewise the unit energy consumption increases because the input HP remains constant.

Vendors which utilize the Venturi aspiration principle to achieve absorption of high purity oxygen include Air Products, Mazzei and Linde (similar technology - see photo).

Air Products: Oxy Dep

Venturi aspirators are utilized by these vendors as the oxygen dissolving systems. Water is pumped through a venturi at high velocity and oxygen gas is introduced at the throat. The venturi per se is not an oxygen absorber, but a high turbulence zone. Due to the high velocity/turbulence, the oxygen bubbles are sheared into very small diameters having high gas interfacial area. This enhances oxygen transfer primarily after the water enters the water column. Thus oxygen absorption efficiency is related to the depth below



Fig. Venturi Aspirator Throat

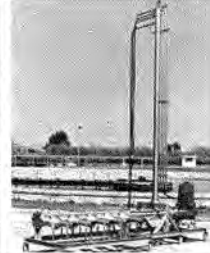


Fig. Air Products Oxy
Dep

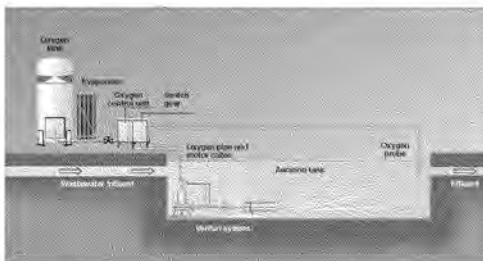


Fig. Venturi Oxygenator Schematic

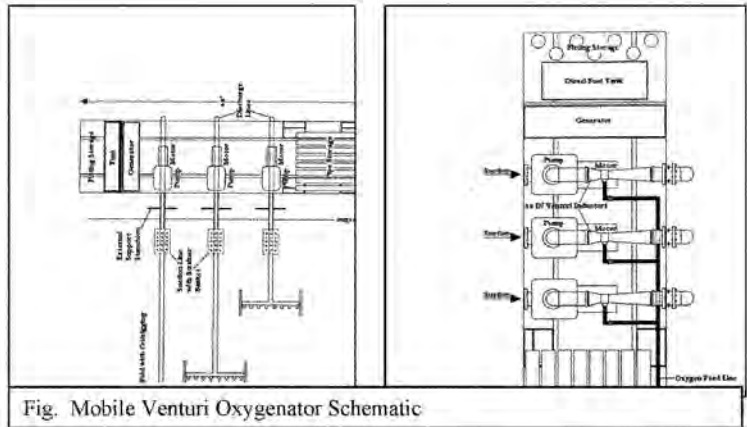


Fig. Linde Venturi Oxygenator

the surface at which the venturi discharges. The information needed to evaluate the performance of a venturi aspirator oxygenation system is:

- oxygen absorption efficiency for jet/Venturi aspirators injecting pure oxygen over a wide range of oxygen feed rates
- oxygen absorption efficiency as a function of depth of water column
- corresponding unit energy consumption – kwhr/ton D.O.

- cost of units - \$/ton D.O./day capacity



Oxygen Bubble Injection

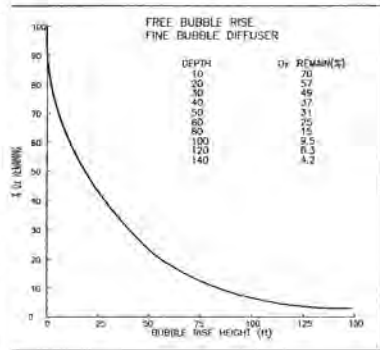
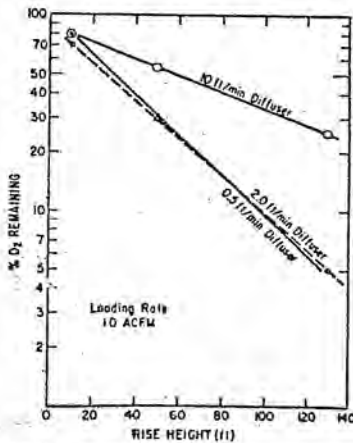
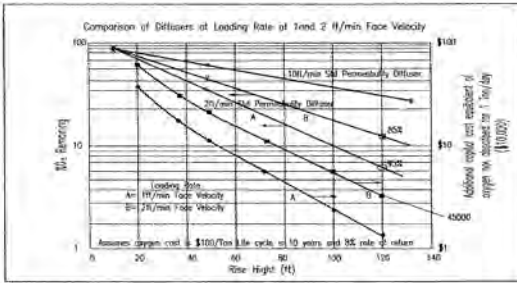
In the past high purity oxygen has been injected directly into various water bodies, but typically inefficiently. The issue is the difficulty encountered in absorbing oxygen into water efficiently at various depths. Table III shows oxygen absorption efficiencies for oxygen injection as fine bubbles associated with a range of depths are indicated. Fig. ___ shows % oxygen remaining vs bubble rise height.

Field evaluation of the O₂ absorption efficiency achieved by injection of fine bubbles ~2 mm diameter, into various depths of water columns was made in Clark Hill Reservoir in 1978 and the results are shown in Table III.

Table III Oxygen absorption efficiency from free rising oxygen bubbles in a 140 ft deep impoundment

<u>Depth-ft</u>	<u>Oxygen Absorption Efficiency-%</u>
10	20
20	45
40	62
60	78
80	85
100	90

Vertically induced flow from a bubble plume has a horizontal recycle cell zone of influence of about 4 times the bubble rise height within the hypolimnion. Thus for a hypolimnion depth of 100 ft, the oxygenated water would distribute itself within a cell of



at most only 400 ft diameter around the bubble source axis. On the other hand although vertical circulation is hindered by density gradients due to temperature, horizontal momentum of a cold-water inflow (which encounters negligible density differences) has been observed to travel the entire 45 miles length of a run-of-the-river impoundment at Clark's Hill Reservoir in the Savannah River.

Practically it may be of significant benefit in extending the zone of influence within the hypolimnion of the highly oxygenated sidestream to install low speed large diameter impellers directed in the line of flow from the discharge. This boost in momentum after a month of operation potentially could double the effective distance to 4-miles to which the oxygenated water is transported.

Figs. ___ and ___ demonstrate graphically the inability of free rising oxygen bubble plumes to oxygenate the zone at the sediment water interface. Due to the nature of the mixing in the free rising bubble plume, oxygen supplemented water always comes to equilibrium at some distance above the bubble diffuser. For instance in Lake Hallwilersee in Switzerland, using a fine bubble diffuser fed with pure O₂, there is a 4 kilometer zone of sediment water interface which is not supplemented with D.O.

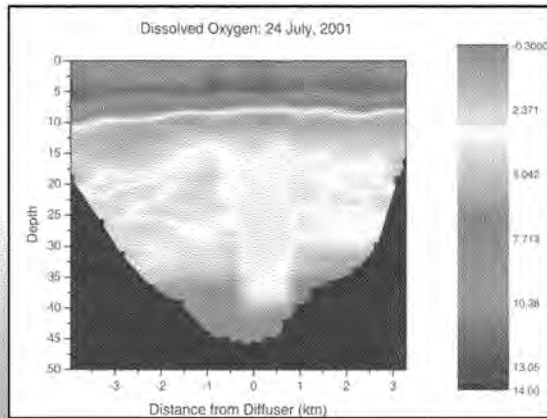
Soaker Hose

The so-called soaker hose oxygen transfer technology utilizes porous tubing similar to the tubing that is used in landscaping that allows water to escape slowly from the hose. The porous nature of the hose is utilized for absorption of high purity oxygen by placing the hose in the bottom of an impoundment and pressurizing it with pure oxygen. A series of feeder hoses and weights are incorporated to anchor the system to the bottom of the impoundment. Since the soaker hose system is a linear diffuser, its operational performance is dependent on the following principles.

- O₂ unit loading rate (0.015 to 0.12 scfm/ft – 1.8 to 14 lb O₂/ft/day)
- % O₂ absorption vs depth
- vertical circulation pattern (not horizontal)

All of the oxygen transfer takes place as the bubbles diffuse from the soaker hose and freely rise up through the water column. Therefore the oxygen absorption efficiency is very much related to the oxygen loading rate on the soaker hose or ft³ O₂ per min per foot of hose. At low oxygen loading rates relatively smaller bubbles are formed, whereas

Hallwilersee: Limited Oxygen Coverage



BROWN AND
CALDWELL

D.O. Distribution from Fine Bubble Diffusers in Swiss Lake – Note no D.O. at sediment interface below diffuser

when the oxygen loading rate increases, the relative diameter of the bubbles rising from

the soaker hose also increases. Thus at low oxygen loading rates fine bubbles are generated but at high oxygen loading rate relatively larger oxygen bubbles are generated. Since oxygen absorption efficiency in free rising bubbles is related to the size of the bubble, the oxygen absorption efficiency deteriorates as the oxygen loading rate increases.

Another mitigating factor is that the oxygen absorption efficiency is also very much related to the depth of the water column in which the soaker hose is placed. The oxygen absorption efficiency versus water column depth takes on a characteristic pattern, as shown in Fig. _____. Thus to achieve an oxygen absorption efficiency of over 80%, it is necessary that the soaker hose be placed in water columns that are in excess of about 100 feet. Since Savannah Harbor is approximately 50 ft deep, only relatively low oxygen absorption efficiency would result using soaker hose technology. O₂ loading rates might need to be reduced by a factor of 10 to achieve more efficient absorption but such a reduction would require 10 times the lineal feet of soaker hose to transfer a given tonnage of O₂ in more shallow water columns.

A second disadvantage of soaker hose technology for oxygen transfer in Savannah Harbor is that the soaker hose would have to be placed within the main channel and therefore be subject to the high turbulence of all of the propellers of the large ships traversing the channel.

The installed cost for soaker hose installation is reported to be about \$50/lineal foot. In some installations the cost estimate has been as high as \$75/ft. The O₂ loading rate is controlled by the depth of installation. In order to achieve 90% O₂ absorption in 50 ft of water, the O₂ loading rate would have to be reduced to <2lb O₂/ft/day. At \$50/ft installed cost, this would be \$50,000 capital cost per ton D.O./day.

No experimental mass balances are available to determine O₂ absorption efficiency as a function of depth and O₂ loading rate per lineal foot. Claims for O₂ absorption efficiency are based on a computer model that was calibrated by air, not O₂

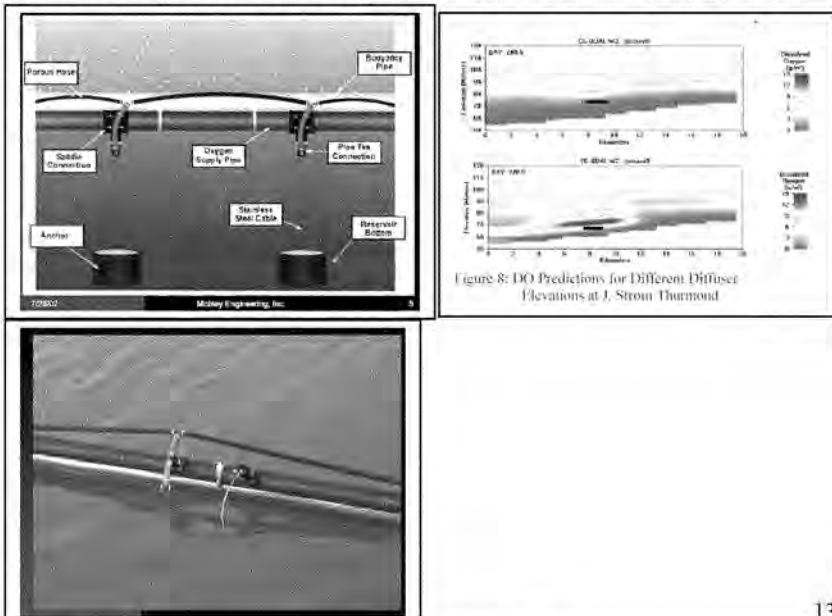


Fig. Soaker Hose Schematic, D.O. Placement and Photo

injection, in a 14 meter deep tank.

Speece Cone Oxygenator

The Speece Cone oxygenator incorporates efficient oxygen absorption with low unit energy consumption per ton of D.O. discharged and achieves highly superoxygenated discharge levels. Speece Cone technology can achieve O₂ absorption efficiencies in excess of 90% while producing D.O. concentrations of 50 mg/L at unit energy consumption rates of <300 kwhr/ton D.O. if placed on the bottom of a 50 ft deep impoundment or harbor.

An outstanding feature is that *the equipment can be located outside of the shipping channel* by directing its superoxygenated discharge perpendicularly across the ship channel (see Fig. _____). The cone discharges the highly superoxygenated sidestream back into the harbor in a horizontal direction through a diffuser with 2 inch diameter ports at port velocities of 10 to 20 ft/sec. This type of diffuser accomplishes two crucial functions:

- the dilution of the D.O. in the highly oxygenated sidestream
- the transport of this oxygenated water horizontally

Even though the cone discharge is highly oxygenated (50 mg/l) it is not above saturation level for its hydrostatic pressure and therefore has no effervescence potential. The D.O. is diluted down to below approximately 10 mg/l within a short distance of the discharge ports.

This device incorporates an inverted conical gas transfer vessel in which the water is introduced at the top of the cone, flowing in a downward direction. As the water flows downward its velocity decreases in proportion to the cross-section of the cone. Pure O₂ is also injected into the cone and the resulting hydraulic turbulence creates a bubble swarm which has an exceptionally high oxygen/water interfacial area, which greatly enhances oxygen transfer.

By sizing the cross sectional area of the cone so that the downward velocity of the water slows to a point where it is less than the buoyant velocity of the bubbles within the cone, it is possible to retain the oxygen bubbles within the cone for prolonged periods of time, far in excess of the 100 seconds required for efficient oxygen absorption.



The pressure differential across the cone is rather small, being primarily in proportion to the void volume of the bubble swarm within the cone. Thus the unit energy required to pump water through the bubble swarm is relatively small, and therefore the unit energy per ton of D. O. dissolved is also relatively small.

The concentration of D. O. that can be produced in the discharge is related to be depth of submergence or the hydrostatic

pressure within the cone. This feature also greatly enhances the oxygen transfer process. The deeper the cone is placed below the surface of the harbor, the higher the dissolved oxygen concentration produced in the discharge. Although the discharge D.O. increases in proportion to depth of submergence, the required pumping energy remains essentially constant, resulting in lower unit energy Kwhr/ton vs depth.

Oxygen transfer is enhanced by pressurizing the oxygen transfer reactor. This allows the achievement of higher dissolved oxygen concentrations in the discharge. Higher oxygen concentration in the discharge, however, has the disadvantage of also consuming more energy per ton of D.O. absorbed. Typically the unit energy consumption per ton of D.O. added is approximately 1000 kWh per ton of D.O. absorbed, if the oxygen transfer takes place under pumped pressurized conditions. However, if placed in an excavated caisson (see Fig. ___) the gas transfer vessel is statically pressurized by the hydrostatic head without the need for pumping against a back pressure throttling valve energy. The water simply flows down into the gas transfer reactor and back out, achieving natural hydrostatic pressurization.

If a deep caisson is unavailable and pressurization by pumping against a back pressure throttling valve is required, a proprietary system of oxygen transfer is available to recover the energy of the water leaving the pressurized vessel by use of a regenerative turbine or pump (Vendor: ECO2). For instance, if the efficiency of the pump pressurizing the feed to the gas transfer reactor is 80% efficient, and the energy recovery from the pressurized discharge is 80% efficient, then 64% of the energy can be recovered in this arrangement.

This pressurized arrangement allows pressurization with its associated high discharge D.O. concentrations, while consuming only approximately 500 kwhr/ton D.O. added and producing as much as 500 mg/L D.O. in the discharge.

It is possible to operate the cone at even higher pressures than in the water column by pumping through the system against a back pressure imposed by a throttling valve located on the discharge. Whenever water is pumped against an imposed back pressure the unit energy consumption will rise to about 1000 kwhr/ton D.O. This principle holds for pressures required to produce D.O. concentrations over the broad range of 100 to 500 mg/L. Thus if an increased unit energy consumption is acceptable, the tonnage of D.O. /day can be produced in a proportionately reduced size of oxygen transfer reactor. With proper design of the discharge diffuser it is possible to depressurize and dilute these very high D.O. concentrations without effervescent loss of D.O.

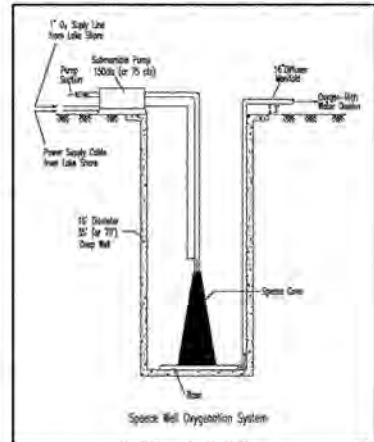


Table IV. Expected Results of a Speece Cone Installation at 50 ft Depth

A Speece Cone 12 feet in diameter and 15 ft tall placed 50 ft below the water surface will give the following results using a 45 HP pump:

- 60 mg/L discharge D.O.
- 34 cfs flow through cone
- 12,000 lb D.O. required per day
- >90% oxygen absorption
- 200 kwhr/ton D.O. consumed (if depth is 50 ft.)
- cost of units - \$500,000 per 12 ft diameter unit with pump

The excellent results of this system (>90% O₂ absorption efficiency) and low unit energy consumption (<200 kwhr/ton D.O. produced) occur in part because turbulence is confined to the inside of the cone with no bottom scouring. *These outstanding results are achieved without interfering with ship channel activity.*

Pressurized Energy Recovery Oxygen Transfer System

This type of exceptionally high superoxygenated discharge has the advantage of requiring fewer supplemental oxygenation stations positioned at greater intervals.

The dissolved oxygen produced in the discharge of the Pressurized Energy Recovery System is proportional to the pressure under which the system operates. If the operating pressure is doubled, the dissolved oxygen concentration in the discharge would also be doubled along with a doubled energy requirement. Consequently the higher the pressure under which the system operates, the higher the dissolved oxygen in the discharge and the higher the energy consumption.

Thus exceptionally high dissolved oxygen concentrations can be produced by a recent proprietary system in pressurized vessels for 1000 kWh per ton of D. O. even at D.O. concentrations of 500 mg/L. Therefore if the D. O. in the discharge is kept below the spontaneous effervescence level, exceptionally high concentrations of D. O. can be produced with a unit energy consumption of approximately 1000 kWh per ton of D.O.

The only practical limit to this concept is the spontaneous effervescence level but this problem can be kept under control by proper dilution. The spontaneous effervescence level for pure oxygen dissolved in water is approximately 250% or 100 mg/L.

Turbine Mixers Operating In Confined Headspace – Emscher River Installation

The Emscher River in Germany has historically served as an open sewer because no prior treatment is applied to the municipal and industrial wastewaters which are all discharged into it. Subsequently the entire river is diverted through primary clarifiers and is then redirected into the river channel where it is completely diverted through an activated sludge treatment facility about 10 miles downstream from the primary clarification location. Ultimately a supplemental oxygenation system was installed on the Emscher River to raise the D.O. to approximately 10 mg/L so that it would remain oxidic and thus odor free in this 10 mile stretch

The D.O. supplementation facility consists of a covered concrete tunnel through which the entire river flows. Submerged baffles at the beginning and end of this tunnel serve to provide a confined headspace above the water surface which is filled with an oxygen rich atmosphere into which the river water is splashed to accomplish oxygen transfer by means of surface aeration equipment suspended from the roof of the oxygenation tunnel. This system is similar to the principle of the old UNOX oxygen transfer process.

These systems can achieve high oxygen absorption efficiency with low unit energy consumption but are affected by dissolved nitrogen stripping. Target D.O. levels are limited to about 10 mg/L. Turbine mixers can scour basin bottoms if earthen. It should be noted, however, that these installations must be placed within the river channel to be effective.

Contained Atmosphere Surface Splashing

The original UNOX activated sludge process used pure oxygen and utilized a water sealed head space which was equipped with surface splashing turbines. One version utilized injection of the O₂ down a hollow shaft below a submerged mixer as well as surface splashing turbines. Thus the water was splashed in contact with enriched O₂ in the head space. The system operated at ambient pressure and was able to keep the O₂ in contact with the water for an extended time. It could only operate with a D.O. in the water of less than 10 mg/L to insure an increased D.O. deficit. With a D.O. of less than 10 mg/L the unit energy consumption is below 1000 kwhr/ton of D.O. transferred. The entire reactor surface area is required for oxygen transfer, but achieves > 90% absorption affectively.

Sidestream Pressurized Oxygenation

Sidestream pressurization is a gas transfer technology which withdraws a relatively small sidestream of water, injects pure oxygen into the pressure side of the pump, and pumps it at high pressure through a long pipe loop. The water velocity is maintained sufficiently high enough to assure two-phase flow so that the gas/water interfacial area is quite high to maximize the rate of gas transfer. The system is pressurized to as much as 100 psig by a throttling valve on the discharge end which results in a C_{sat} concentration for pure O₂ of 300 mg/L at 25 °C.

Depending on the diameter of the pipe loop, a velocity of at least 10 ft/sec is required to generate the turbulence required to maintain two phase flow. Since it requires nominally about 100 seconds of contact time between the O₂ bubbles and the water regardless of the water pressure to achieve > 90% O₂ absorption, the pipe loop must be about 1000 ft long. Since this is an excessively long pipe loop, it is common to make it shorter and thus sacrifice O₂ absorption efficiency.

Criteria used to evaluate performance of this system involves: the oxygen absorption efficiency attainable, the unit energy consumed per ton of dissolved oxygen added, the dissolved oxygen concentration in the discharge, and the capital cost.

Sidestream systems are able to achieve very efficient oxygen absorption efficiency if the length and retention time within the pipe loop are sufficiently long (at least a hundred seconds). Operated at very high pressures, these systems can produce a highly superoxygenated discharge.

An advantage of such a system in Savannah Harbor would be that the system could be located along the edge of the shipping channel and discharge a highly superoxygenated effluent perpendicular to the harbor axis into the main channel. Disadvantages of the system are the high unit consumption required plus the limited oxygen absorption efficiency that is usually obtained if the length of the pipe loop and the residence time is not long enough to achieve very high oxygen absorption efficiencies.

To raise the rate of gas transfer, the gas/water interfacial area should be maximized and the D.O. deficit should also be optimized. Gas/water interfacial area is enhanced by increasing the amount of gas injected per unit volume of water and minimizing the resulting bubble diameter. The D.O. deficit is maximized by pressurizing the gas transfer system. The gas transfer equation is as follows:

$$dc/dt = K_L (A/V)(C_{sat} - C_{act})$$

Under these conditions of 100 psig pressurization, it is possible to achieve over 200 mg/L D.O. in the discharge. By proper design, most of this superoxygenated water can be retained in solution. Discharge at 50 ft below the surface and rapid dilution just after the pressure drop at the throttling valve would need to be incorporated. Rapid dilution can be achieved by directing all of this energy in the high velocity discharge into a shroud discharge tunnel which entrains bulk water containing low D.O., similar to that used with Venturi/jet gas transfer systems.

A sidestream pressurization unit capable of dissolving 40,000 lb D.O. per day would have the following design parameters:

- discharge D.O. : 200 mg/L
- flow of side stream ; 37 cfs (if 200 mg/L D.O. in the discharge)
- diameter of pipe constituting contact loop ; 26 inches
- cost of 1000 ft of 26 "diameter 316 SS ; _____
- pump HP @ 70% efficiency ; 1380 HP (pumping against 100 psig)
- cost of pump ; _____
- unit energy consumption ; 1200 Kwhr/ton D.O.
- O₂ absorption efficiency ; >90% (if pipe loop 1000 ft long)
- operating cost per ton D.O. ; _____ (6 months/yr 6%, 15 yr)

Thus high levels of superoxygenation can be achieved, which proportionately reduce the fraction of a side stream required for a given tonnage of D.O. per day. As with all pressurized systems pumping against a throttling valve to achieve pressurization of the gas transfer reactor, the unit energy consumption rate is high, e.g. 1200 kwhr/ton D.O., which is a major drawback. Additionally the length/cost of the pipe loop are

comparatively high so that less than 100 seconds detention time frequently results from the short lengths utilized in most cases.

U-Tube Oxygenation Technology

The U-tube aeration concept first applied in the Netherlands in 1958 exhibits excellent potential for dissolution of insoluble gas into a liquid. This process involves passage of a gas water mixture vertically down a shaft underneath the baffle and back up to the surface, providing prolonged contact of the bubbles with the water and pressurization of the bubbles by the hydrostatic head. Water is pumped down the center of this shaft to the bottom and then flows back through an annular space to the surface. A vertical shaft of considerable depth is required for this type of oxygen transfer technology.

Several reactions occur by injecting high purity oxygen into the downward flow: the contact of gaseous oxygen with the water will be in proportion to the depth and velocity characteristics of the system and since the water is flowing vertically downward or vertically upward, there will be no problem in maintaining two-phase flow of the oxygen bubbles and water if the velocity is sufficiently high. Also the head loss across the system will be relatively small due to friction loss (most of the head loss is related to the void volume differential of gas in the down leg and the up leg).

The oxygen absorption efficiency characteristic of a U-Tube oxygen transfer system will be related to the O₂/water ratio that enters the system. Consequently at low O₂/water injection ratios, higher absorption efficiency will be achieved, but lower discharge D.O. concentrations result. Conversely when the O₂/water injection ratio is increased, the oxygen absorption efficiency will decrease but the discharge D.O. concentration will increase. It thus becomes obvious that higher oxygen absorption efficiency is realized at the expense of the D. O. concentration in the discharge.

Even though the depth of the U-tube is approximately 200 feet deep, oxygen absorption efficiency may not exceed 80 - 90% depending upon the water velocity through the system, the depth of the system, and the O₂/water injection ratio realized. See Fig. ___ for a schematic view of the system.

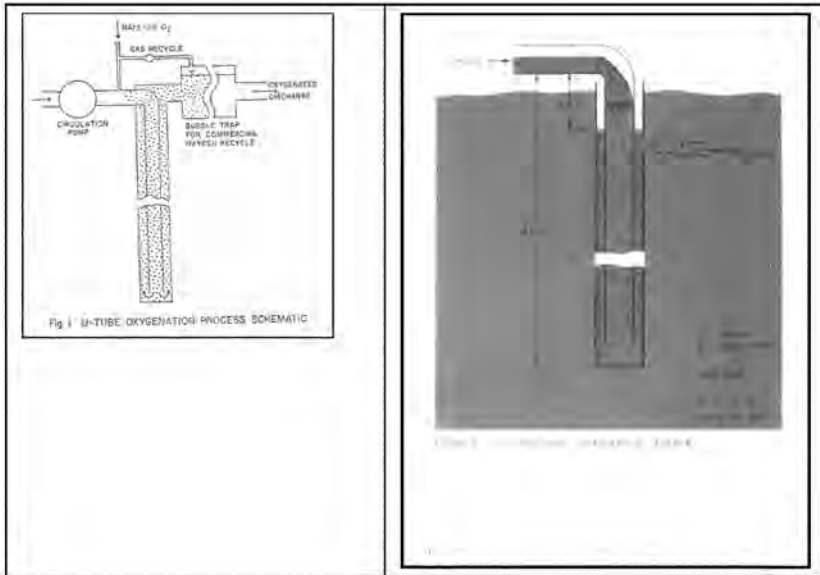
Advantages of U-Tube Technology

U-Tube oxygenation technology incorporates several desirable features when compared to other methods of raising D.O. levels. The major advantages of U-tube oxygenation are as follows:

- Oxygen transfer occurs in a pressurized reactor, which results in very high D.O. concentrations up to 50 mg/L at 28°C. A high rate of oxygen transfer per unit volume of reactor, up to 5400 mg/L per hour, may be achieved versus 100 mg/L per hour for conventional aeration tanks.
- Unit energy consumption per ton of D.O. is approximately only 400 kWh per ton, which is quite low because the head loss across the system is minimal, even though the oxygen transfer occurs at hydrostatic pressures of up to 175 feet.

- The oxygen bubble contact time is prolonged in transit through the U-Tube.
- Exceptionally high saturation concentrations are generated, enabling supersaturation of D.O. in the discharge.
- Oxygen gas bubble pressurization is accomplished hydrostatically, thus consuming low energy. Contrasted with the excessive energy consumption of pumped pressurization vessels which lose all of the input energy across the pressure throttling valve, no supersaturated D.O. may be lost by effervescence with pumped pressurization.
- No external pumping is necessary if the hydraulic head of the effluent is at least 5 feet above the harbor surface.
- Dissolved nitrogen stripping is minimized from the water as well as nitrogen gas dilution of the oxygen composition of the bubbles because gas transfer occurs in a pressurized vessel. Water saturated with nitrogen gas in air will strip if the nitrogen partial pressure in the gas phase is less than .79 atm. If the process is at atmospheric pressure, the nitrogen composition approaches 79%, but at 4 atmospheres the nitrogen composition approaches only 20%. This results in oxygen compositions of 21 % and 80% for 1 and 4 atm respectively.

The U-tube is comprised of a deep hole about 150 to 200 feet deep. The water flows down an open-ended pipe inside a casing and back up to the top through the annular space between the two pipes. See Fig____. The water velocity is approximately 6 to 10 fps, which greatly exceeds the 1 fps bubble rise velocity of the bubbles. Therefore when oxygen gas is introduced at the inlet, the bubbles are dragged along with the water flow down to the bottom and back to the top. Oxygen transfer is achieved by the hydrostatic pressurization, but also is enhanced by the turbulence and extended contact time. At 175 feet of hydrostatic head, the pressure is over 6 atm and with a 100% oxygen bubble, the saturation D.O. concentration is over 250 mg/L.



Hydroflo

HydroFlo technology withdraws a sidestream of water into which high purity oxygen is injected, then directed through equipment in which the oxygen absorption takes place, and sent back into the harbor. Similar criteria are used to evaluate the HydroFlo technology performance as have already been mentioned: the oxygen absorption efficiency achieved, the unit energy consumption per ton of dissolved oxygen, the level of super oxygenated water present in the discharge, and the relative required spacing of units throughout the harbor.

HydroFlo units could be located on the edge of the shipping channel and discharge their high velocity superoxygenated stream back into the ship channel. However proprietary data needed to determine oxygen absorption efficiency which can be achieved by the HydroFlo technology is not available at this time.

Mobile Oxygenation Barge

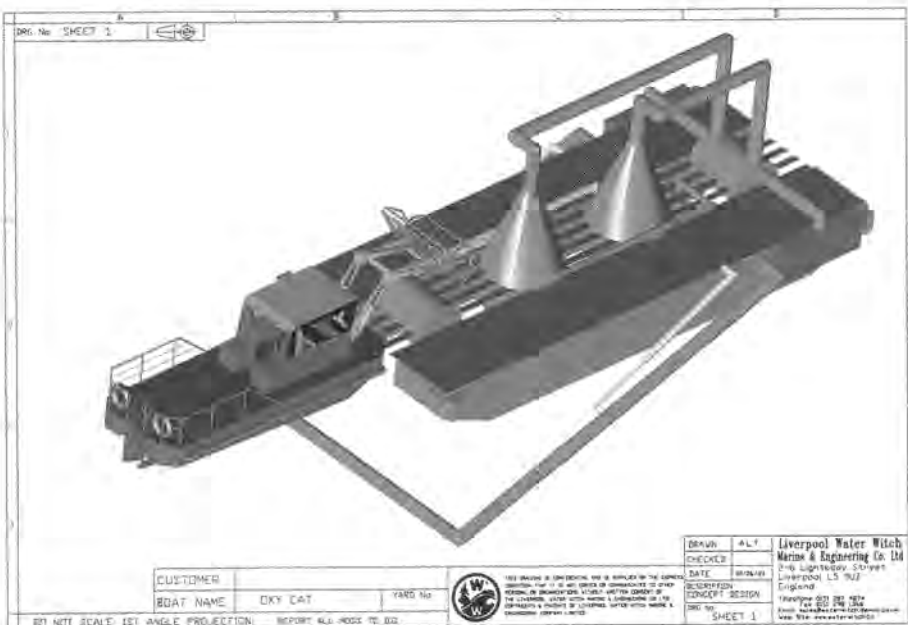
Mixing and transporting of the super oxygenated water within the harbor are key goals which must be achieved in a successful D.O. supplementation project. Oscillating tidal currents will be one of the main mechanisms which can be capitalized upon for movement of superoxygenated side streams away from the zone where they are generated. However a hydraulic model of water movement within the harbor would probably indicate some locations which will not have adequate transport of supplemented D.O. so as to meet compliance. Furthermore these D.O. deficient regions may change with flow and temperature conditions.

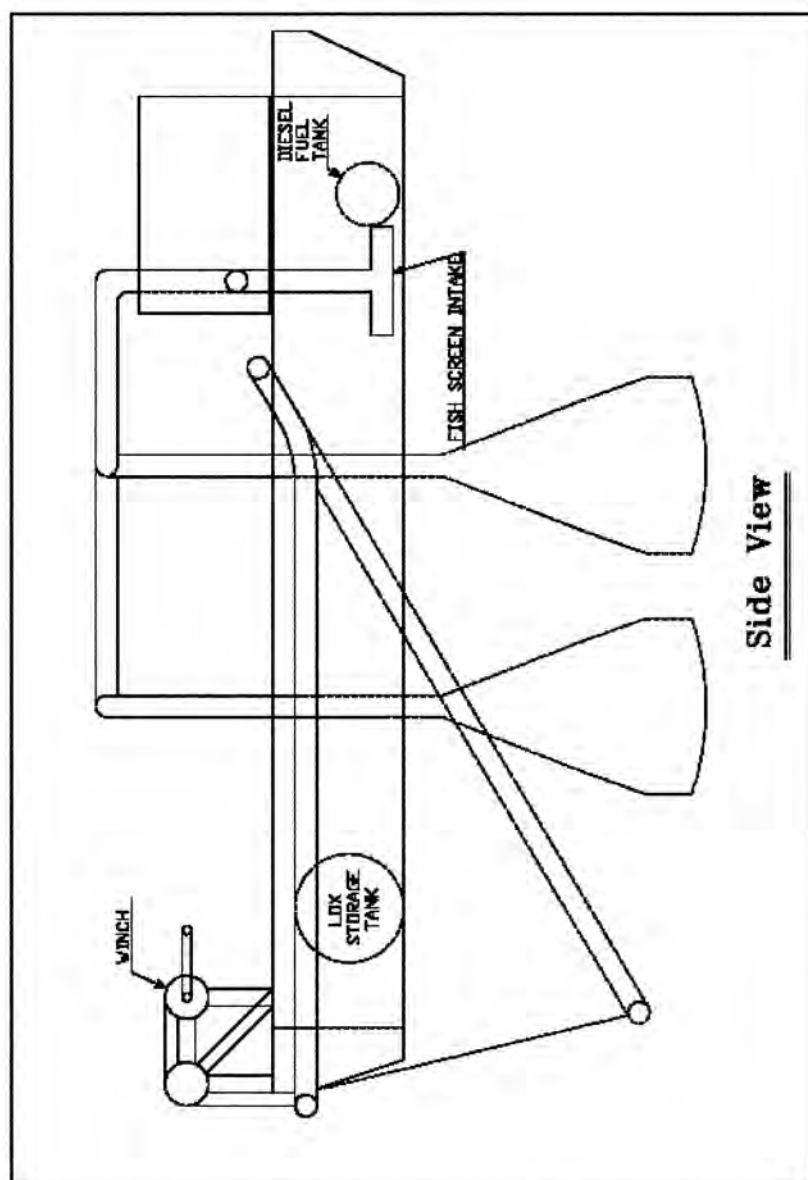
In such cases a logical solution would be to incorporate a means to deliver D.O. directly to the locations which are out of compliance. The concept of a self contained mobile oxygenation system could be used to address such deficiencies in tidal mixing effectiveness for effective transport of D.O. to all regions where needed.

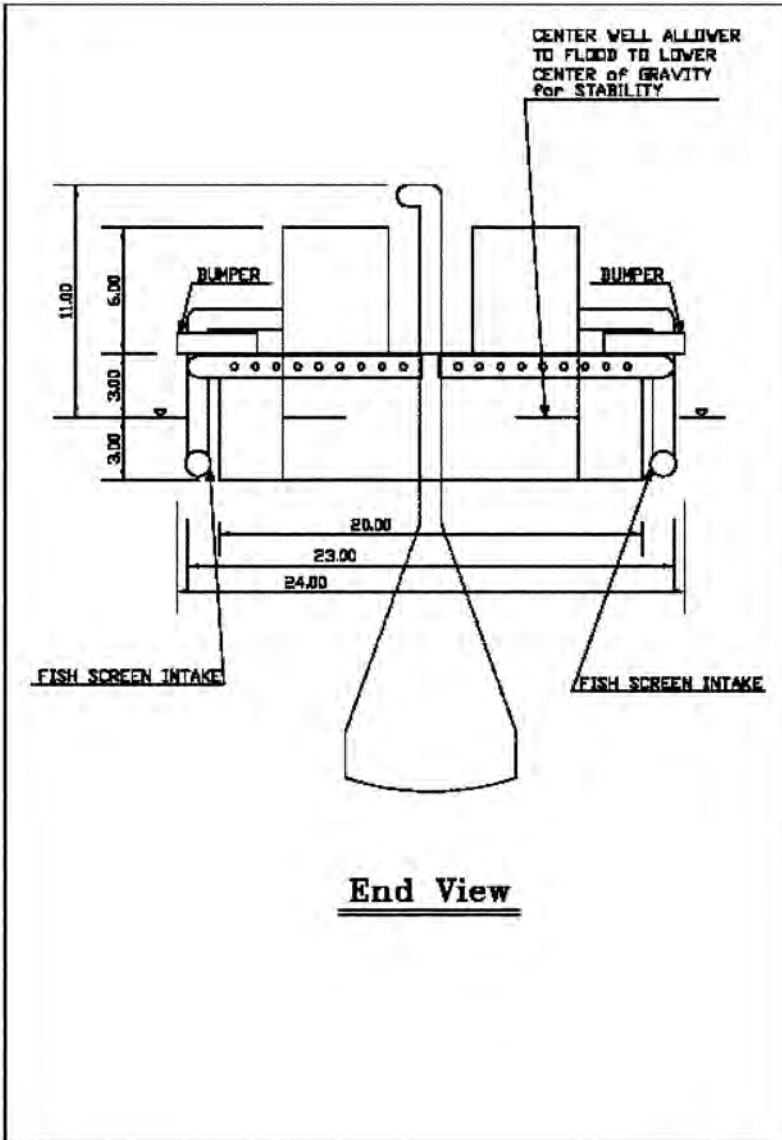
A self-contained mobile oxygenation system would include on-board oxygen generation by pulsed swing adsorption or vacuum swing adsorption. This feature would avoid the safety concern of needing to store oxygen. Diesel or propane driven engines could either directly drive the oxygen generation system and pumps to move water through the oxygen transfer system or could generate electricity on board to power such components.

It would be advantageous to capitalize on the hydrostatic depth of the harbor for enhancement of oxygen transfer by placing the oxygen transfer reactor as far below the surface as possible. Of course there may be regions outside the main deep ship channel where the depths are much less deep that may require the aid of a mobile oxygen supplementation system.

The following Figs. ___ show schematics of a mobile oxygenation system. It would be capable of withdrawing denser water from the bottom of the water column, superoxygenating it and discharging it horizontally back at the same depth by means of an adjustable discharge boom. Sound insulation for the diesel could mitigate the noise pollution arising therefrom.







IV. On-Site Performance Studies of Selected Superior Oxygenation Systems

A. Speece Cone Performance, Logan Martin Dam

This oxygenation system was designed to handle 21 ft.³ per second. The top diameter is 20 inches and the diameter at the bottom of the cone is 9 feet with a cone height of 15 feet and a bottom cylindrical skirt that was 5 feet high to contain the discharge piping. It was projected that the 21 ft.³ per second system could add 55 mg/L of D. O. if the inlet D. O. was 0 mg/L and the O₂/water ratio injection ratio was 5%.

This proposed system would satisfy about one third full-scale D. O. requirements of 18,000 pounds of oxygen per day for a leakage flow of 700 ft.³ per second to raise the D. O. to 4 milligram per liter in the discharge from a background D. O. concentration of 1 mg/L in the influent. Therefore if this 21 ft.³ per second system was found to be successful it was decided that it would be combined in the final design with an additional system capable of handling another 42 ft.³ per second. This system was installed to determine its operational performance so that scale up problems for a full-size system would be minimized.

Oxygen/Water Ratio

The data are presented graphically showing O₂/water ratio ratios of 3, 4, 5 and 6% respectively. The relevant points that can be drawn from the graphs are as follows.

Maximum oxygen absorption efficiency occurred at a water flow rate of 22 to 25 ft.³ per second through the system. A slight reduction in absorption efficiency occurred below this range and a more rapid decline occurred at higher velocities.

All oxygen absorption efficiency decreased with increasing O₂/water ratios. Likewise all oxygen absorption efficiencies declined with increasing water flow rate in excess of 22 to 25 ft.³ per second.

The greatest D. O. increase resulted at water flows of 22 to 25 ft.³ per second for all oxygen water ratios, as mentioned previously, because increased water flow resulted in bubbles being swept out of the system prematurely. Thus oxygen absorption efficiency was thereby reduced, as reflected in the lower D. O. concentration in the oxygenation system discharge.

The pressure losses across the system are plotted in Fig. _____. Pressure at the oxygenation discharge with no flow-through the system was 52 feet, reflecting the static head of water above the dam with respect to the location of the oxygenation cone. With no oxygen in the injection, the discharge pressure was 44 and 42 feet at water flows of 22 and 25 ft.³ per second, respectively and at an O₂/water injection rate of 4%. Discharge pressures were 38 and 37 foot. It is to be noted that the total head loss across the

oxygenation cone was nearly constant at 6.2 feet regardless of water flow through the system when oxygen was injected at 4% O₂/water ratio.

Results

The oxygenation cone has a volume of 320 ft.³. The five foot-high cylindrical section on the bottom of the cone that contains the discharge piping also had a volume of 320 ft.³, resulting in a total volume of 640 ft.³. At the design flow of 22 ft.³ per second and 4% O₂/water ratio, the system added 48 mg/L of D. O. to a background influent D. O. of 3.6 mg/L for a total of 5600 pounds of D. O. per day. This is equivalent to 9 pounds of D. O. per cubic foot per day or 100 mg/L per minute of D. O. at 90% oxygen absorption efficiency. The average pressure in the cone was approximately 29 feet at the centerline of the cone and the water temperature was 86°F. At this pressure and temperature the saturation D. O. would be 66 mg/L, if the gas phase was 100% oxygen. The discharge D. O. was 51 mg/L and the oxygen content of the bubbles within the oxygenation cone was approximately 83%, as measured with a 4% O₂/water injection rate, indicating the oxygenation system was able to achieve 94% of theoretical saturation under these conditions. This is indicative of a very good oxygen transfer system since the hydraulic retention time is only about 30 seconds.

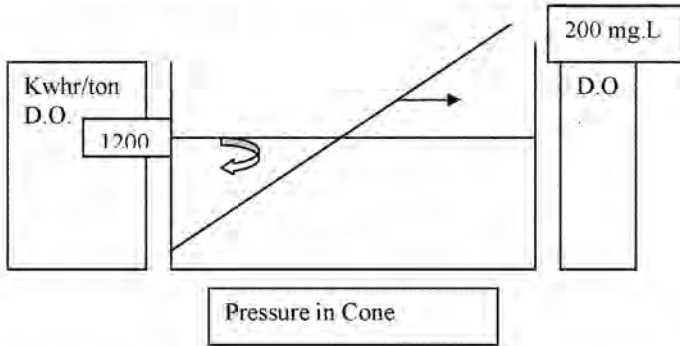
In the flow range of 22 to 25 ft.³ per second with an O₂/water injection ratio of 3%, the discharge D. O. was 42 mg/L for a net increase of 38 mg/L over background. Under these conditions the absorption efficiency was 95%. When the O₂/water injection ratio was increased to 4% under the same water flow conditions, the discharge D. O. was 51 mg/L over the background concentration of 4 mg/L, resulting in an oxygen absorption efficiency of 87%.

Pressurized oxygen transfer

The nature of pressurized oxygen transfer is demonstrated by the fact that when pressurization was incorporated it increased the unit energy consumption rate to about 1200 kWh per ton of D.O. In cases where no pressurization was utilized, such as placing the oxygen transfer device on the bottom of the ship channel 50 foot below the surface, a discharge from a Speece Cone would be about 60 mg per liter of dissolved oxygen. A 12 foot diameter cone can handle 35 ft.³ per second of water flow. The head loss across the cone is approximately 10 feet, which would thus require a 55 hp pump, if it were operating at 70% efficiency. Thus each cone could deliver approximate by 11,000 pounds of dissolved oxygen per day and the unit energy consumption would be approximately 200 kWh per ton of dissolved oxygen added.

If the Speece Cone were operated at a pressure of 215 feet of head it would produce a discharge dissolved oxygen level of 200 mg per liter and a 12 foot diameter cone would be able to deliver 38,000 pounds of dissolved oxygen per day. To pump 35 ft.³ per second against a head of 215 foot of head plus 8 foot of head loss would require a

1300 hp pump. The unit energy consumption would be approximately 1200 kWh per ton of dissolved oxygen.



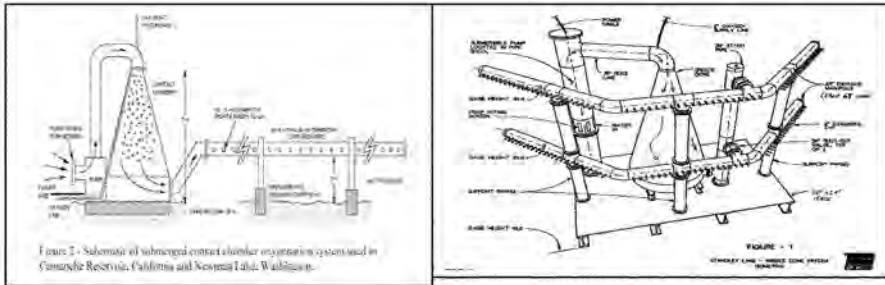
These data suggest that a Speece Cone operating under ambient pressure at the bottom of the Savannah Harbor Ship Channel would produce 60 mg/L in the discharge and be able to deliver 11,000 pounds of dissolved oxygen per day with a unit energy consumption of less than 200 kWh per ton of D.O. If the cone was operating at 215 ft of pressure it would produce 200 mg/L D.O. in the discharge and deliver 38,000 pounds of oxygen per day, with a unit energy consumption of 1200 kWh per ton of dissolved oxygen.

Life cycle costs of non-pressurized, pressurized, and energy recovery oxygen transfer

Since the above systems achieve greater than 90% oxygen absorption efficiency, whether operated under ambient or pressurized conditions, the key comparison is life cycle cost of energy consumption and additional oxygen transfer volume. The non-pressurized system would require approximately 3 1/2 times as many Speece Cones as would the pressurized system. Therefore the reduction in energy costs must be compared with the increase in capital cost for additional cones.

Assuming 50% utilization of the system throughout the year, the following life cycle costs result for transfer of 38,000 lb D.O. per day.

Assume equivalent power costs for diesel engines to be \$0.12/kwhr. Power for non-pressurized system would consume $19 \text{ T/d} \times 200 \text{ kwhr/T} = 3800 \text{ kwhr/day} \times \$0.12/\text{kwh} \times 180 \text{ d/y} \times \text{PWF of } 9.7 (6\% @ 15 \text{ yr}) = \$800,000$ for the present worth. The equivalent cost for the pressurized system would be 6 times this or \$4,800,000. This is considerably more than the cost for an additional 2.5 Speece Cones of 12 ft diameter needed to transfer 38,000 lb D.O./day. Thus it appears that the non-pressurized mode of supplementing D.O. is economically more favorable than the pressurized mode.



B. U-Tube Pilot Study

Deep U-Tubes offer excellent potential as energy and cost efficient oxygen transfer systems. The depths of 25 to 60 m appear to be most useful for optimal oxygen absorption.

U-Tubes have been used for aeration of:

- fish hatchery water
- sewer mains
- free-flowing rivers
- activated sludge treatment

Mixed liquor oxygen transfer energy has proved to be comparable or superior to that produced by conventional surface aerators, and produces dissolved oxygen concentrations in the discharge which exceed saturation under ambient conditions. Even D.O. levels in excess of 200% can be produced with an oxygen transfer energy efficiency of 4 kg of oxygen per kwhr.

The ICI deep shaft process is operational at a number of waste water treatment locations in Europe and Canada but there is only operational information available for one depth and velocity at each location. Design criteria were not yet available to estimate rationally sizing costs and to predict the operational characteristics of deep U-Tubes for any of the above potential applications.

In order to include U-tube aeration as an alternative design the design engineer needs to ascertain the following data:

- depth required
- throughput velocity
- appropriate gas/water injection rate
- discharge D.O. target
- head loss across U-tube to determine energy consumption.
- oxygen transfer economy and kilograms of O_2 per kwhr
- oxygen cost per ton, which includes the amortized capital plus the electricity to operate the system.

The pressure loss across a U-Tube system due to oxygen injection is shown in Figure _____ as a crosshatched bar. The pressure loss across the 1/10 meter diameter U-Tube due to frictional losses alone is shown as the open bar on top of the crosshatched bar. The calculated frictional loss of a 1 m² U-Tube is noted on the graph by the solid bar since this larger pipe size would be the best prototype system.

The oxygen transfer per kwhr is calculated for a prototype U-Tube with 1 m² of cross-section in both the up and down legs. This energy consumption data is shown in

Figure _____. It is seen that a U-tube depth of 30 m and 25% O₂/water injection ratio yields 12 kg of oxygen per kwhr as the energy consumption ratio. It should be noted that recycle of the gas would change the oxygen composition from 100% to approximately 70%, due to stripping of dissolved nitrogen from the influent water. This would tend to reduce the kilograms of oxygen per kwhr accordingly. There is essentially little practical incentive to attempt to improve oxygen transfer energy consumption beyond 200 kwhr/ton D. O. because such savings in energy per metric ton of oxygen dissolved are negligible. Therefore the high rate of oxygen transfer at 30 m depth and 4% O₂/water ratio, which is 25 kg of O₂ per kwhr, is not worth exploiting.

Pilot Study Evaluation Criteria

The following parameters were evaluated:

- velocity: 0.9, 1.4, and 1.8 m per second.
- depth: 12, 30, 61 and 103 m deep.
- oxygen injection ratio: 7.5% to 25% oxygen/water ratio.

U-Tube Pilot Study Preparations

A pilot U-tube facility was constructed with 0.1 meter diameter pipe in a 0.3 m diameter hole that was 120 m deep. The U-tube depth was adjusted as desired to evaluate the following parameters:

- depth at 12, 30, 60 and 103 m respectively
- velocity at 0.9, 1.4 and 1.8 m per second respectively
- injected air and pure oxygen
- pure oxygen gas injection ratio 7 1/2 and 25%
- tap water and simulated wastewater with 5 mg/L of anionic detergent and 100 mg/L bentonite.

The experimental data were collected for each set of conditions according to the inlet D.O., discharge DO, pressure loss across the U-Tube and water temperature. Due to the fact that D.O. concentrations in excess of 100 mg/L were encountered, special procedures were developed to ensure accurate D.O. measurements at these unusually high concentrations.

Throughput velocity was based on the nominal velocity of the water alone without gas injection. Thus the actual velocity in the gas/water mixture would vary somewhat throughout the U-Tube because of the hydrostatic compression of the gas phase. Nominal velocities of 0.9, 1.4 and 1.8 m per second were investigated and are shown in Fig. _____. There is a practical lower limit of nominal velocity below which the U-tube will not function in a stable manner.

It is noted from Fig. _____ that there is no consistent effect of nominal velocity on the increase in D.O. across the system. In some cases nominal velocity (1.4 m per second) gave slightly higher or lower increase in dissolved oxygen. Lower velocity increased the bubble contact time within the U-Tube as well as lowered the Reynolds number, but apparently these two effects nullified each other.

The pressure at the inlet and discharge was recorded for each set of experimental conditions. The pressure loss across the system was composed of losses due to hydraulic friction, bubble drag and differential void volume in the down and up legs. Hydraulic frictional losses are a function of the pipe diameter. The bubble drag and differential void volumes in the two legs were observed to be independent of pipe diameter.

For each set of experimental conditions pressure readings were taken before any gas was injected into the U-Tube and after the desired gas water injection ratio was established. In this manner, the two components of pressure loss across the U-Tube could be identified.

Oxygen absorption efficiency can be achieved by either of two approaches when using U-Tube technology. The O₂/water ratio and the U-tube depth and velocity can be matched to result in 90% oxygen absorption efficiency in one pass through the U-tube. Or with a second approach a high O₂/water ratio may be injected into a more shallow depth U-Tube shaft but must provide for capture of the bubbles in the discharge to re-inject these fugitive bubbles back into the inlet.

Low, intermediate and high O₂/water ratios were investigated, namely 4, 7.5 and 25%. These results are shown in Figure 13. The dotted line in Figure 13 indicates the 90% oxygen absorption range. It can be noted from this graph that even at 103 m depth less than 90% oxygen absorption occurs with 1% O₂/water ratio resulting in a change in D.O. of only 9 mg/L. In this case the increase in D.O. level and U-tube depth are impractical. Consequently the second approach is the best alternative, namely high O₂/water injection ratios incorporating gas capture and recycle.

The study revealed that the optimum design of a U-tube oxygenation system operating at minimal cost incorporates a depth of 25 to 60 m, a velocity of 1.8 to 3.0 m per second, and an O₂/water injection ratio of 25%.

This portion of the pilot study revealed that a substantial increase in dissolved oxygen resulted at 61 m depth in comparison to 30 m depth. However at 103 m there was little increase in D.O. across the system in comparison to the 61 m depth (see Fig. 13).

Results

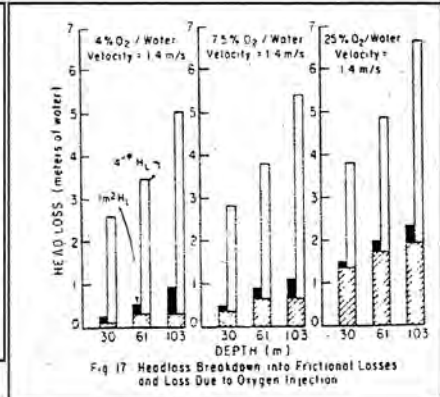
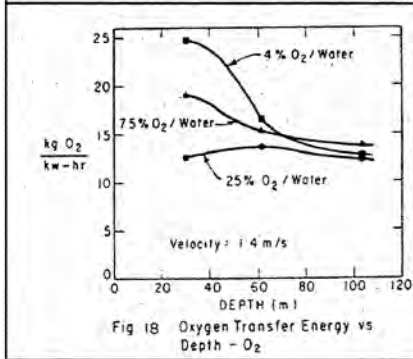
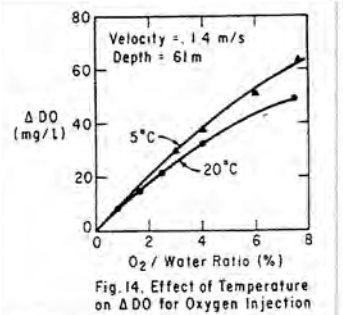
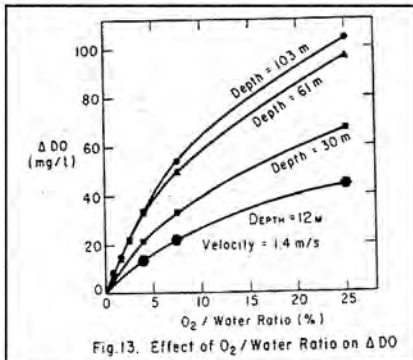
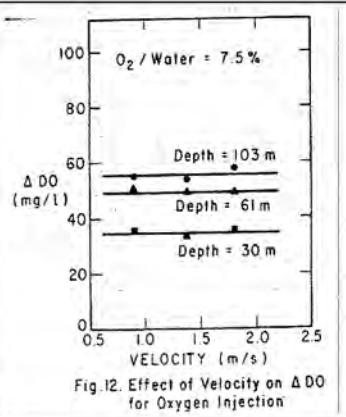
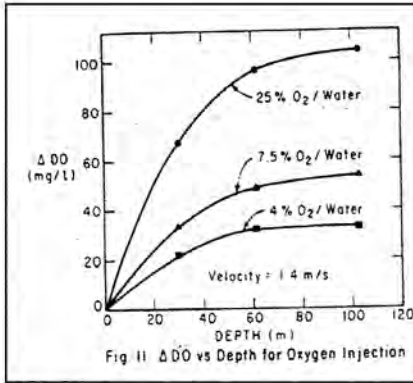
Fig. 13 indicates that only minor variations in change in dissolved oxygen were observed over the velocity range tested. This is fortunate because the maximum nominal velocity was thus limited only by frictional head loss considerations, and therefore permitted very high tonnage of oxygen dissolved per cubic meter of U-tube. Such a high rate of dissolved oxygen offsets to a large degree the capital expenditure for the deep shaft hole.

It was not possible to achieve 90% oxygen absorption in a 103 m deep U-tube even though the injection gas ratio was less than 1%. At such low gas water ratios there would not be any effervescent loss of dissolved gas. Even lower oxygen absorption efficiencies would be observed in water containing surfactants. This observation contradicts the claim of Hemming *et al.*, that all of the gas phase is dissolved in deep U-Tubes, and that some subsequently comes back out of solution in the upper region of the up leg.

Very encouraging results were noted with a particular O₂/water ratio combined with the 61 m depth shaft: 96 mg/L D.O. concentrations were found in the discharge using a 25 % O₂/water ratio. The estimated unit energy transfer and total costs amounted to 12 kg of D.O. per kwhr and \$6.50 per ton of D.O. added. But there was little advantage found in operating as U-Tube in excess of 61 m depth.

According to the pilot study when pure oxygen was injected at 25% O₂/water ratio at 30 m depth, the dissolved oxygen increased from 68 mg/L to 95 mg/L at 61 m U-Tube depth. Negligible improvement in dissolved oxygen concentrations were observed after 103 m depth.

Over the velocity range investigated of 0.9 to 1.8 m per second, there was no significant effect on increase in D.O. The maximum absorption efficiency for pure oxygen at 7.5 % O₂/water injection ratio was observed to be 52% in the 103 m deep U-tube, demonstrating that the U-tube requires capture and recycle of the off gases if it is to be used in an efficient manner as the absorption system for an oxygen supplementation station.



An Existing U-Tube Application on the Tombigbee River, Alabama

U-Tube Oxygenation was selected for the two oxygen supplementation locations on the Tombigbee River. The U-Tube with oxygen injection produced an effluent D.O. 50 mg/L at 28° C. within oxygen absorption efficiency of 80 to 90% for a unit energy consumption of 94 kWh per ton of D.O.. The oxygenation capacity was 5400 mg/L of D.O. per U-Tube volume per hour, and the head loss across the 175 foot deep U-Tube was 5 feet. A bubble harvester is desirable to harvest any undissolved bubbles and recycle them back to the influent of the U-Tube. By discharging a highly elevated D.O. sidestream into the river through a diffuser in the bottom, advantage was taken of the hydrostatic head to prevent effervescent loss of D.O. and a high D.O. discharge was mixed throughout the river cross-section within a short distance downstream.

A schematic diagram is shown of both the gravity fed to U-Tube which puts in 12,000 pounds of D. O. per day, as well as a schematic of the U-Tube where 125 MGD of water is pumped from the river through the U-Tube and then discharged back into the river with 50 mg/L of supersaturated D. O. concentration, resulting in 40,000 lb/day supplementation.

Field testing at James River of the U-Tube, which oxygenated the treated effluent from a James River mill, yielded the following observational operational results:

- discharge D. O. of up to 50 mg/L at 25°C in the water
- head differential across the U-Tube was 5.3 ft and
- oxygen transfer capacity of up to 18,000 pounds of D. O. per day and
- oxygen absorption efficiencies of 80 to 90% were realized.

Advantages of the U-Tube Technology

Table V. The major advantages of U-Tube oxygenation, which led to its selection for remediating the Tombigbee River D.O. depletion problems, were as follows:

1. efficient oxygen absorption of 75 to 90%
2. high rate of oxygen transfer per unit volume of reactor, up to 5400 mg/L per hour, versus 100 mg/L per hour for conventional aeration tanks and
3. unit energy consumption per ton of D. O. add was approximately 100 kWh per ton of D. O., which is low because head loss across the system is low even though oxygen transfer occurs at hydrostatic pressures up to 175 feet
4. high D. O. concentrations of up to 50 mg/L at 28°C
5. exceptionally high D. O. saturation concentrations generated enabling supersaturation of D. O. in its discharge.
6. oxygen bubble contact time prolonged
7. pressurization of the oxygen gas bubbles provided by hydrostatic pressurization
8. negligible energy consumed in contrast to the excessive energy consumption of pumped pressurized vessels which lose all of the input energy across the pressure throttling valve (thus also potentially losing supersaturated D. O. concentrations by effervescence)

9. no external pumping required if the water being discharged was at 30 foot above river level
10. stripping of dissolved nitrogen gas from the water minimized with consequent nitrogen gas dilution of the oxygen composition of the bubbles because gas transfer is occurring in a pressurized vessel (water saturated with nitrogen in air will strip if the nitrogen partial pressure in the gas phase is less than 0.79 atm.) If the process is at atmospheric pressure the nitrogen compensation approaches a theoretical value of 79%, but at four atmospheres the nitrogen composition approaches a theoretical value of only 20%.

Section 5. Mixing and Transport in Harbors

5. Mixing and Transport of D.O. within Savannah Harbor

I. Requirements for Meeting D.O. Standards for Savannah Harbor

A. Essential Requirements for Harbor Mixing and Transport

The following essential components must be successfully incorporated into an oxygenation system to meet D.O. standards throughout Savannah Harbor:

- dissolving requisite D.O. (lb D.O./day)
- transporting D.O. evenly throughout the harbor
- strategically locating oxygen supplementation stations so that tides, propellers or horizontal flow diffusers can transport superoxygenated discharges effectively
- utilizing large diameter propeller pumps or horizontal flow diffusers to transport the oxygen away from the location where it superoxygenated water is generated

B. Diffuser Design Considerations

Once the sidestream is highly oxygenated it must be reintroduced into the hypolimnion and transported throughout the entire impoundment. Such success requires special considerations in the diffuser design as follows:

- jet velocity in diffuser ports
- number of diffuser ports required
- spacing of diffuser ports
- height of diffuser above sediments
- direction of diffuser ports
- velocity of horizontal jet less than the re-suspension velocity of the sediments when reaching the bottom of the impoundment
- velocity of horizontal jet sufficiently low enough to prevent erosion of the underside of the thermocline when reaching the top of the hypolimnion

C. Horizontal Flow Design Possibilities

Velocity of horizontal jets must be sufficiently low to prevent erosion of the overlying fresh water. Such design considerations are especially critical in shallower impoundments such as Savannah Harbor. In one installation where Prof. Lawrence of the University of British Columbia provided the design of the diffuser, the impoundment was less than 30 feet deep, and the hypolimnion was only about 15 feet deep. After one season of operation, stratification was maintained, bottom sediments were not re-

suspended and D.O. was transported to regions of the hypolimnion that were approximately two miles away from the oxygenator diffuser.

A key consideration in supplemental oxygenation of Savannah Harbor is to induce a superoxygenated sidestream to flow horizontally across the bottom layer of more dense water where D.O. is more needed than in the upper surface of the water column.

At Camanche Reservoir a diffuser was located at the toe of the dam. It dissolves 18,000 lbs of oxygen per day in a sidestream of 35 ft³/sec withdrawn from the hypolimnion and discharged through a 100 ft long diffuser. It is located near the dam in the vicinity of the bottom penstock. When the water is 100 ft deep, the sidestream that is oxygenated has a D.O. of about 100 mg/l. The diffuser discharges toward the head end of the reservoir and a D.O. increase of 4 mg/l was observed in the hypolimnion 10,000 feet from the diffuser about two weeks after operation commenced. Oxygen supplementation of the hypolimnion allowed power to be generated, prevented hydrogen sulfide production, and met the D.O. criteria for the river and fish hatchery. This system is hidden from public view at the bottom of the reservoir, another strong recommendation.

II. Spacing of Oxygenation Stations for Maximum Mixing and Transport within the Harbor

A. Limitations on Zones of D.O. Supplementation Influence

There is an economy of scale associated with oxygen supplementation stations which favors the utilization of fewer and larger stations. This likewise is reflected in greater distances between oxygenation stations. Since a key consideration in any supplemental oxygenation system is that the superoxygenated water must be transferred away from the location where it is being superoxygenated, this places certain limitations on the spacing of the supplemental oxygenation systems. Transport of the superoxygenated water away from the superoxygenation station can be accomplished by:

- tidal action
- discharge jets
- large diameter slow-moving propellers

Thus, there are certain limitations on the zone of influence for oxygen supplementation from a given fixed location. If there is negligible tidal action and if there is not the availability of large diameter, slow-moving propeller pumps to move the water away from the fixed location, then there will be a limitation on the distance between supplemental oxygenation stations. Also there may be certain regions within the harbor that have very little tidal action mixing or are shielded by peninsulas of land or other such obstructions which prevent the movement of superoxygenated water into that area.

Such isolated zones will require special attention to the incorporation of large diameter propellers or location of oxygenation stations in that particular zone. This may be accomplished by mobile systems as described below.

B. Effective Circulation of Oxygenated Discharges Throughout the Harbor

In addition to the mixing/transport accomplished by tidal action, it may be necessary to incorporate additional mixing/transport mechanisms to move the superoxygenated water away from the location of the oxygenation station. Unless the superoxygenated water is moved away, eventually a 'hot spot' of highly oxygenated water will short circuit back through the oxygenation station reducing the efficiency of O₂ absorption.

There are various means which can insure that the requisite transport/mixing is accomplished. The large diameter slow moving propellers are very efficient in moving large quantities of water with little energy required. Following are pictures of two types of these devices. In both cases, a screen enclosure is required to preclude harm to swimmers. The results of hydrodynamic modeling of the plumes indicates that the momentum imparted by the propellers can move the water over two miles away from the source. The graphs of such models are shown below.

Properly designed diffusers can also insure that the oxygenated water moves out of the zone where it was produced. Following is also a schematic view of a diffuser designed to insure that the oxygenated water is added at various depths throughout the water column if needed. If it is desirable to place the superoxygenated water in the bottom layer, then only the lowest diffuser would be employed.

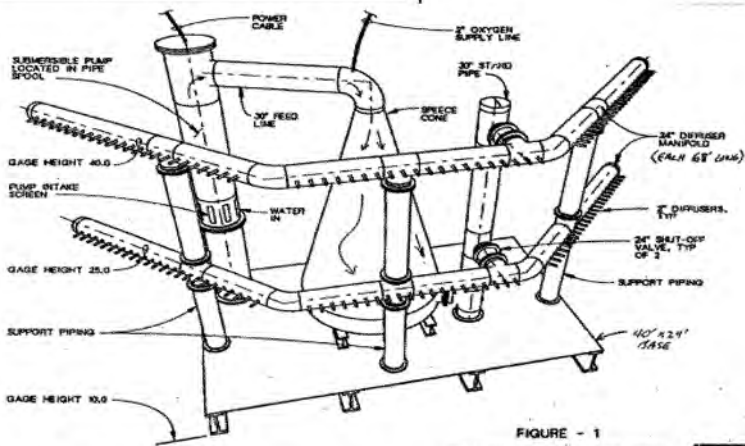
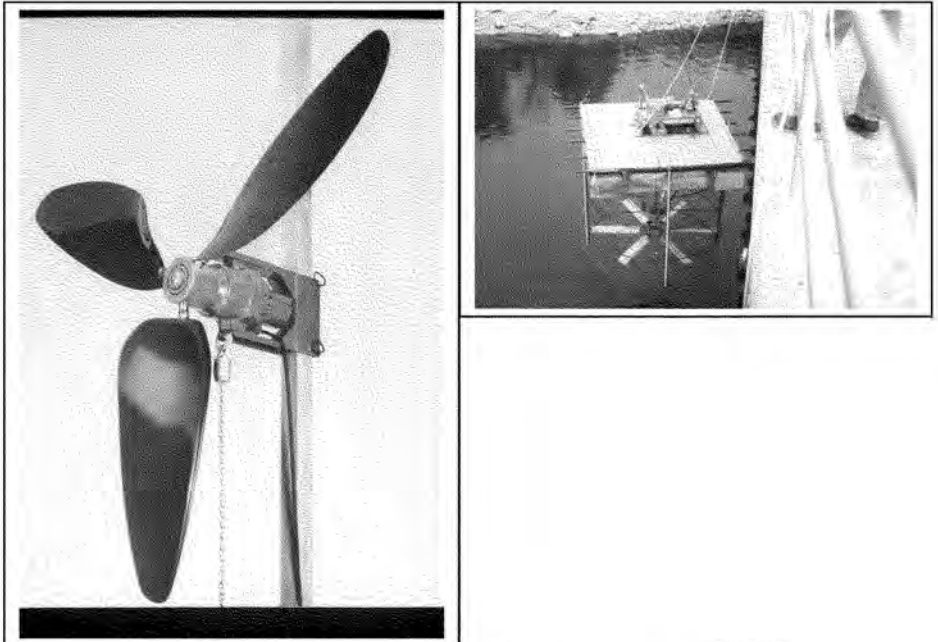


FIGURE - 1
STANLEY LAKE - SPEECE CONE SYSTEM
ISOMETRIC



Figure 1. Cross-reservoir velocity profiles

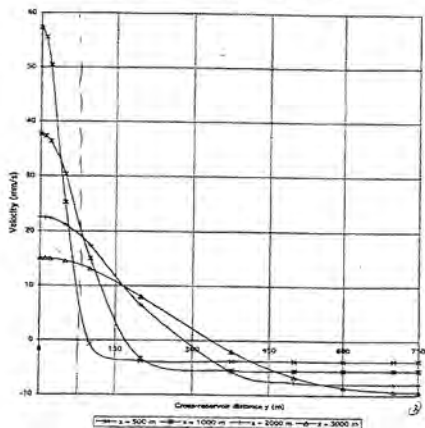
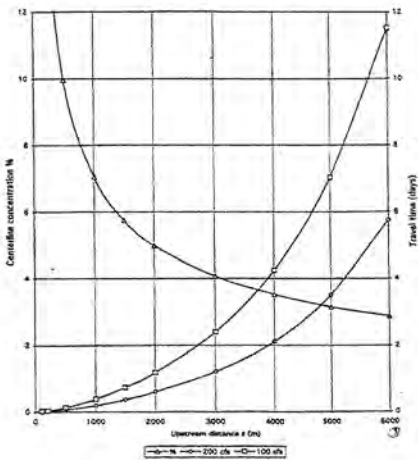
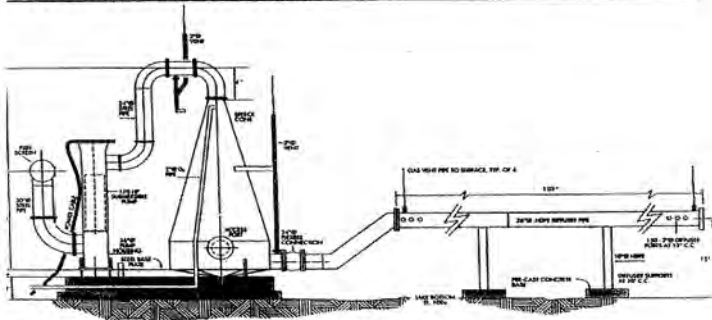


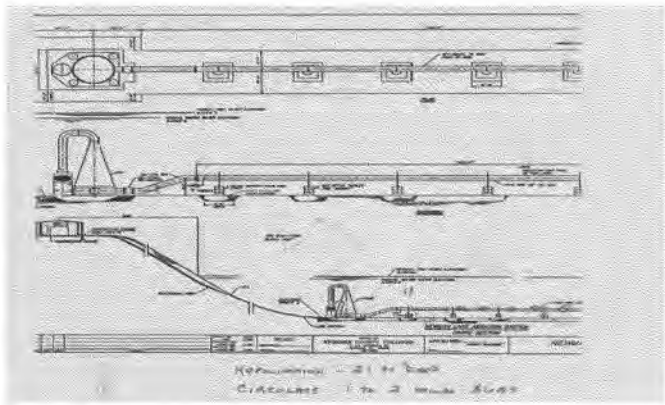
Figure 2. Travel times and dilutions



CAMANACHE HYPOLIMNETIC OXYGENATION DEMONSTRATION PROJECT
SPEEC CONE AND DIFFUSER PIPE DETAIL



DETAIL
(not to scale)



III. Mobile Barge Oxygenation Advances

A. Advantages of Self-Contained Mobile Oxygenation Barges

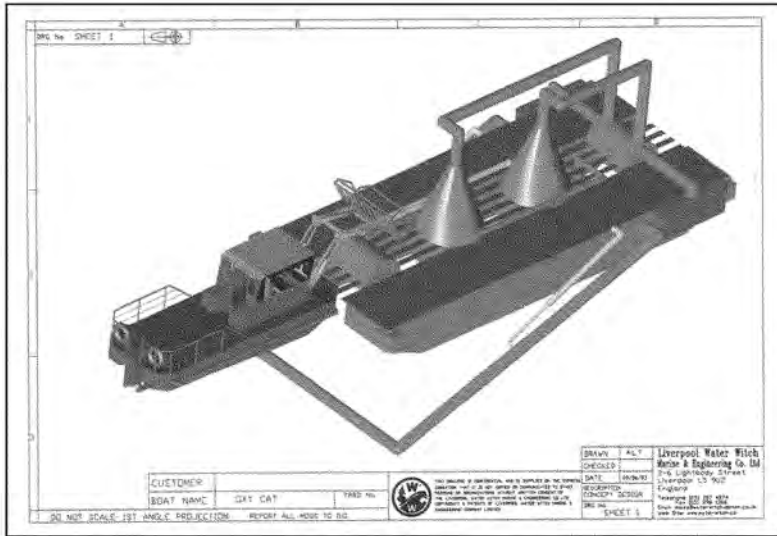
A key consideration in supplementing oxygen to the harbor will be the availability of land at key locations dictated by D.O. deficiency conditions within the harbor, upon which the oxygenation system could be placed. The availability of electricity is another consideration. Generally it is quite expensive to bring in electricity and the demand charge component of the cost can be considerable. So these two facets, the availability of the real estate in the vicinity of the place where the oxygen is needed and the availability of electricity brought to that location will be significant economic factors.

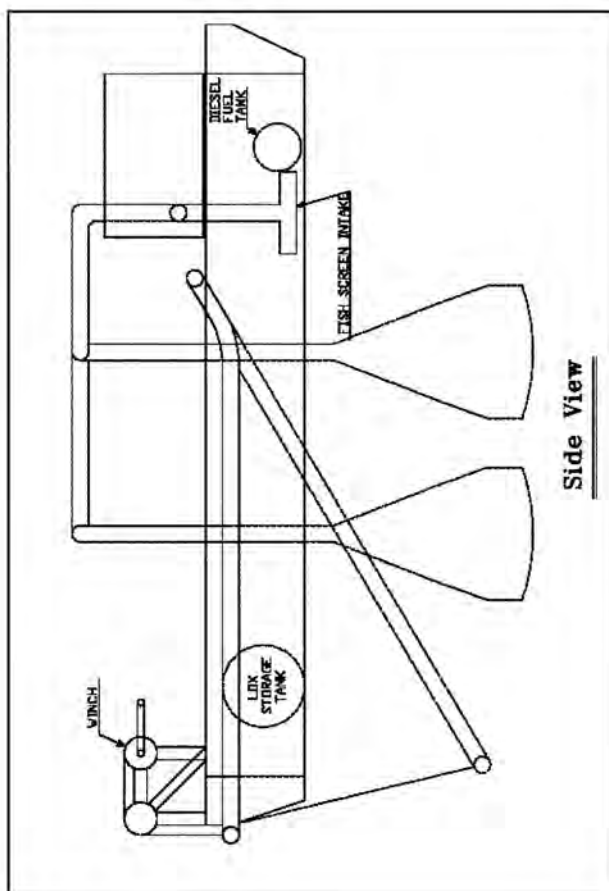
Mobile oxygenation barge systems such as are used in the Thames River, Shanghai Harbor and Cardiff Bay would be a practical choice for use in Savannah Harbor since a barge mounted unit would supplement the oxygen directly into the harbor. Such barge units hold a unique advantage in that they can either be tied up permanently at a given location or moved to various oxygen depleted locations within the harbor, without requiring land use.

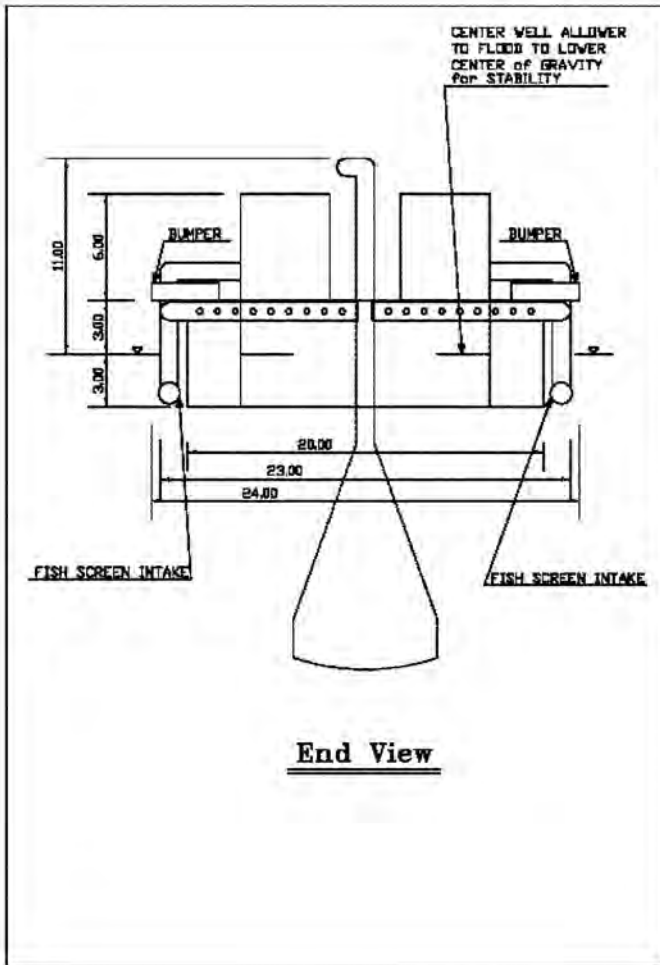
This type of unit can be self-contained with its own PSA oxygen generation source, which could be driven by an internal combustion engine that requires no electrical power being brought in. The pumps required to move water through the oxygen transfer vessel can also be powered by combustion engine driven pumps. Another alternative is to utilize an engine driven electrical generator to power the PSA generation system as well as the pumps supplying the oxygen absorption reactors. Thus the barge units would only need to be supplied with diesel fuel. In some cases, propane driven pumps have been used to anticipate the possibility of a spill in the harbor. Propane with its volatile nature would not present a pollution problem if spilled into the harbor such as diesel fuel would.

Thus in the overall strategy for meeting the dissolved oxygen standard for Savannah Harbor, it may be appropriate to consider the provision of one or more mobile oxygenation units which are self contained except for the need of periodic fuel delivery. These mobile oxygenation units would be moved to areas which were not readily impacted by fixed location supplemental oxygenation stations.

The mobile oxygenation system would operate with the oxygen absorption reactors lowered to the bottom of the harbor to take advantage of the hydrostatic head enhancement of oxygen transfer and would be raised during transport. Schematics of a proposed mobile oxygenation station are shown below.







B. Thames River Oxygenation Barges

One large world class ship channel area which employs a mobile oxygenation system is the busy Thames River in London with its "Thames Bubbler" and "Thames Vitalizer" self-contained barges.

Historically the Thames River has had occasional oxygen deficiencies. These dissolved oxygen deficiencies have been related to combined sewer overflows resulting from storm events. They are further exacerbated by residual organic loads in the treated effluents being discharged into the river. In an attempt to comply with the dissolved oxygen standard in the Thames River, a mobile oxygenation system that has been dubbed the "Thames Bubbler" was constructed. This system is a motorized barge that contains a 40 ton per day, PSA oxygen generation unit. Thus the oxygen is generated on site and the oxygen transfer system incorporates a series of Venturi jets extending from the barge unit itself. Whenever a section of the Thames River has dissolved oxygen concentrations below the targeted standard, the mobile oxygenation unit is transported to that stretch of the river, where it supplements the oxygen until it meets the targeted D.O. Water is withdrawn from the river and pumped at high pressure and velocity through the venturi jets which aspirate high purity oxygen into the throat of the venturi. The same performance characteristics would apply to these venturi oxygen transfer units, as are described above for evaluation:

- the unit energy consumption per ton of dissolved oxygen
- the relative oxygen absorption efficiency
- the level of super oxygenation, which can be achieved in the discharge

C. Example of Bay Mobile Oxygenation: Cardiff Bay, England

A dam has been constructed across the mouth of Cardiff Bay in England to segregate tidal action from the Bay, thereby eliminating the exposed mud flats at low tide within the Bay which cause malodorous conditions during low tide. In order to comply with D. O. standards within the estuary inside the impounded area, a series of air diffusers was placed on the bottom of the bay. Air was injected into these diffusers in order to mix the water column, as well as provide some oxygen transfer.

Because D.O. deficient conditions occur within the impoundment in the bottom waters in some areas, it was decided to provide a mobile oxygenation system unit, which could be transported to those areas and inject super oxygenated water into the prescribed vertical elevation a wedge of water. An oxygen transfer device was constructed and placed upon a barge, which is moved to any area within the Bay to satisfy the D.O. deficit in a particular layer of water in any region of the bay.

IV. Horizontal Placement of Superoxygenated Discharge in the Water Column

A. Advantages of Horizontal Placement of Superoxygenated Side Stream

Because the anaerobic sediment /water interface is the key location for bottom dwelling organisms and adverse water quality transformations, it follows that any remedial D.O. supplementation scheme should focus on maintaining this interface as oxic as possible to prevent the above mentioned water quality degradation

Superoxygenation of the harbor sediment interface using properly designed equipment is reported to be more beneficial than simply oxygenating the water column near the surface. Such an oxygenation alternative has emerged only recently. This important type of superoxygenation system successfully incorporates the following features:

- the salinity stratification is maintained intact and in place
- highly efficient oxygen absorption must be attained
- oxygen transfer turbulence is contained within the oxygen transfer reactor and is thus minimized to p
- revert destratification
- effective placement is achieved
- benign environmental impact is sustained

The relatively high concentration of microorganisms at the sediment/water interface, compared to their concentration in the water column, results in this zone dominating water quality transformations such as iron and manganese reduction and hydrogen sulfide production.

B. Difficulties of Free Rise Bubble Plume Systems in Sediment Oxygenation of the Water Column

A classic mode of D.O. supplementation is to inject air or oxygen into a diffuser located near the bottom. The buoyant nature of the bubble causes it to rise vertically and thus to impart a vertical movement of the water in the vicinity of the bubbles column. Eventually near the thermocline, the rising bubbles uncouple from the rising water column when the circulation pattern is weak and unable to overcome the water density differential.

If the vertical rise velocity of the water entrained in the bubble plume is sufficiently high, both the bubbles and water rise all the way to the water surface, at which point the water velocity turns horizontally and eventually downward to replace the water moving vertically within the bubble plume.

As shown in Fig. ___ the net result of cooler water mixing with warmer water higher in the bubble plume is that the cold water initially entrained in the bubble plume does not return all the way down to the sediment interface from which it originated, but comes to equilibrium at an elevation some distance above the sediment/water interface. Unfortunately free rising air or oxygen bubble injection within the hypolimnion does not affect the sediment water interface because the internal circulation "cells" within the lake

caused by vertically induced currents are confined to the higher elevations above the sediments. This problem is pictured schematically in Fig. ____.

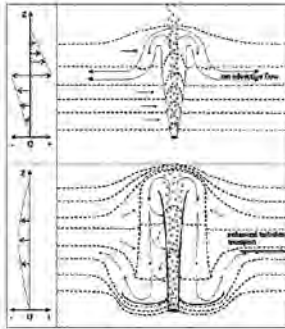
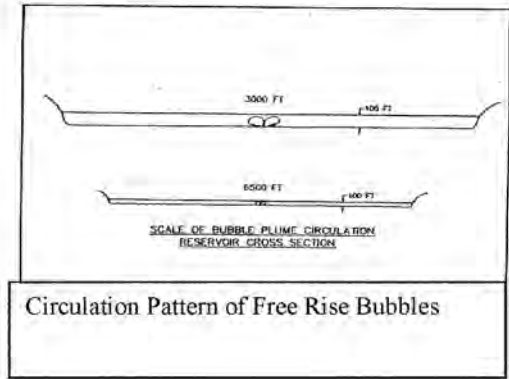


Figure 11. (top) Traditional plume model approach and (bottom) new model concept of plume behavior and short-circuiting in deep lakes (not to scale). Dashed line indicates constant temperature isopleths demonstrating near-field alteration. Left axis shows approximate far-field vertical compensation flow rate distribution (see Figure 12).



Circulation Pattern of Free Rise Bubbles

C. Salt Wedge Flow Oxygenation

If the salt wedge flows into Savannah Harbor are of significant importance then supplementation of D.O. at the mouth of the harbor would transport some of the D.O. into the harbor within the salt wedge tidal action. A superoxygenation station being fed salt water at the mouth of the harbor would exploit this type of circulation possibility

V. Conclusions

The unique configuration characteristics and use requirements of a moderately deep harbor require sufficient oxygenation circulation to reach locally depleted areas as well as sediment layers without disturbing the sediments with their large oxygen demand or impeding ship channel traffic to maintain adequate D.O. levels throughout.

Innovative new technology which makes possible horizontal flow circulation for significant distances away from the superoxygenated discharge thus enlarging the zones of influence considerably, is an advance with much promise for meeting Savannah Harbor's mixing and transport requirements.

In addition mobile barge self-contained oxygenation units, already installed successfully in Shanghai Harbor, Cardiff Bay and on the Thames River make possible timely intervention not hindered by stationary placement in the ship channel.

Section 6. Recommendations for Savannah Harbor Supplemental Oxygenation.

Criteria for Choice of Oxygenators

In evaluating D.O. supplementation technology, the following considerations must be critically addressed:

- O₂ absorption efficiency
- unit energy consumption per ton of D.O. added
- D.O. concentration in side stream discharge
- capital cost of oxygenation system
- depth of water column
- location in water column where D.O. is needed
- target D.O. in harbor
- mixing requirements
- required spacing of D.O. supplementation stations
- placement outside the shipping channel
- availability of real estate
- availability of electricity

Life Cycle Cost Components

Appropriate technology for supplementation of pure oxygen is determined by the following three life cycle factors:

- present worth of the equipment – (purchase or rental)
- present worth of total oxygen required (therefore oxygen absorption efficiency becomes important)
- present worth of energy consumption per ton D.O. supplemented.

Life Cycle Cost of Speece Cone - \$8,500,000

The Speece Cone oxygenation reactor and pump are estimated to be \$85,000 per ton D.O. per day of capacity or **\$8,500,000** for a 100 ton D.O./day system.

Calculation of Life Cycle of O₂

Assume that:

- 100 tons/day of D.O. must be supplemented to the Harbor.
- oxygen is generated on-site by PSA units which cost \$65,000 per each ton/day capacity and require 600 kwhr/ton of oxygen produced
- 50% utilization of the system per year
- \$0.12/kwhr (diesel generated)
- 6% and 15 year life of the project.

Life Cycle Cost of On-Site Generation of Oxygen - \$19,000,000

Since the oxygen cost is commonly the major economic component in the life cycle cost for supplemental oxygenation of rivers and harbors, this requires special consideration to select oxygen transfer devices which achieve high oxygen absorption efficiencies. A second aspect is that if the oxygen supplementation system is a mobile system with its own PSA oxygen generator, reduced oxygen absorption efficiencies are reflected in the need for greater oxygen generation capacity to account for the oxygen not absorbed. The Venturi aspirator oxygen absorption system incorporated on the Thames Bubbler is estimated to be about 65% efficient in its absorption of oxygen. Thus the required PSA oxygen generation unit must be 50% larger requiring 50% more power than if the system was 100% efficient in its oxygen absorption system.

The capital cost would be \$6,500,000 for 100 ton/day PSA oxygen generation capacity. The energy consumption would be 60,000 kwhr/day for an equivalent cost of \$7,200/day. Yearly amortization would be $\$6,500,000 \times 0.1 = \$650,000/\text{y}$. Yearly energy cost would be $600 \text{ kwhr/ton} \times 100 \text{ ton/day} \times \$0.12/\text{kwhr} \times 180 \text{ day/y} = \$1,300,000/\text{year}$. So the total yearly cost for generation of oxygen would be \$1,950,000/year for 18,000 tons oxygen per year or \$110/ton of oxygen produced.

The life cycle present worth of \$1,950,000/year for O₂ at 6% and 15 years (9.7) = **\$19,000,000** for 100 ton D.O./day.

Implications of O₂ Absorption Efficiency on Life Cycle Costs

The implications of oxygen absorption efficiency on life cycle costs are as follows for a 100 ton/day usage for 180 days per year for \$110/ton O₂ for 6% @ 15 yrs:

O ₂ Absorp. %	Ton O ₂ /day Needed	Ton O ₂ /day wasted	O ₂ wasted ton/yr	Present Worth \$ of O ₂ <u>not</u> absorbed
100	100	0	0	0
90	110	10	1,800	1,900,000
80	125	25	4,500	4,800,000
70	145	45	8,100	8,600,000
60	165	65	11,700	12,500,000
50	200	100	18,000	19,200,000

This table indicates that O₂ absorption efficiency has a considerable impact on life cycle costs of this project. Therefore selection of the oxygen transfer process is heavily weighted by its inherent absorption efficiency. Low O₂ absorption processes will probably be cheaper than efficient ones on a capital cost basis, but will incur proportionately greater life cycle costs as the above table indicates.

Life Cycle Cost of Energy - \$4,200,000

For a 100 ton D.O./day system that had a unit energy consumption of 200 kwhr/ton D.O. the daily energy consumption would be 20,000 kwhr/day for 180 days per year and 6% for 15 years (9.7). If the cost of diesel generated electricity is \$0.12/kwhr then the daily cost would be \$2400/day for 180 days/year = \$430,000 /year multiplied by 9.7 SPWF = **\$4,200,000.**

Off Channel Oxygenation Systems

The following generic oxygen transfer systems qualify for off channel use to supplement D.O. to Savannah Harbor:

- Venturi
- Pressurized Side Stream
- U-Tube
- Speece Cone

Comparison of U-Tube and Speece Cone

Of the four systems above, only the U-Tube and Speece Cone meet the economic criteria. Both the U-Tube and Speece Cone have comparable:

- O₂ absorption efficiency - >80 to 90%
- Unit energy consumption per ton D.O. – 200 to 300 kwhr/ton D.O.
- Level of superoxygenation in discharge – 50 to 60 mg/L

Capital cost per ton D.O./day will be a deciding factor.

ADVANTAGES OF THE U TUBE TECHNOLOGY

The advantages of U-Tube oxygenation, which led to its selection for the Tombigbee River, were as follows:

- oxygen transfer occurs in a pressurized vessel
- high D. O. concentrations of up to 50 mg/L at 28°C
- high rate of oxygen transfer per unit volume of reactor, up to 5400 mg/L per hour, versus 100 mg/L per hour for conventional aeration tanks and
- efficient oxygen absorption of 80 to 90%
- unit energy consumption per ton of D. O. add was approximately 200 kWh per ton of D. O., which is low because head loss across the system is low even though oxygen transfer occurs at hydrostatic pressures up to 175 feet
- U-Tube prolongs the oxygen bubble contact time
- generates exceptionally high D. O. saturation concentrations, enabling supersaturation of D. O. in its discharge.



- provides pressurization of the oxygen gas bubbles by hydrostatic pressurization
- consumes negligible energy in contrast with the excessive energy consumption of pumped pressurized vessels which lose all of the input energy across the pressure throttling valve thus also potentially losing supersaturated D. O. concentrations by effervescence.
- requires no external pumping where the water being discharged is at 30 foot above river level
- minimizes stripping of dissolved nitrogen gas from the water with consequent nitrogen gas dilution of the oxygen composition of the bubbles because gas transfer is occurring in a pressurized vessel.

The U-Tube requires a caisson which is 175 ft deep and requires a bubble harvester to capture undissolved bubbles in the discharge for recycle back into the down leg. This is required to achieve the required O₂ absorption efficiency.

The Tombigbee River U-Tubes cost \$10,000,000 for the entire project which included a 35 MGD gravity flow unit and a 125 MGD pumped flow unit. These two units transferred a combined total of 56,000 lb D.O./day. They were placed in a concrete caisson whose top exceeded the 100 year flood level and a diffuser was placed in the bottom of the river to disperse the superoxygenated discharge. I do not have accurate information on the cost of just installing the U-Tubes and their associated bubble harvesters. If it was half of the \$10,000,000 total that would be \$5,000,000 for 28 ton D.O. per day or \$180,000 per ton D.O. per day of capacity. Unfortunately this specific cost information is not available.

For the pumped unit having 125 MGD flow a 10 ft diameter casing was excavated to a depth of 100 ft. and the lower 75 ft had an 8 ft diameter casing. Inside this casing a 7 ft diameter pipe served as the outer wall of the U-Tube and a 5.5 ft diameter pipe inside the 7 ft diameter wall served as the downcomer pipe. A 350 HP pump pulled water from the river and moved it through the U-Tube. The 35 MGD U-Tube was proportionately smaller.

A schematic diagram is shown of both the gravity fed to U-Tube which puts in 12,000 pounds of D. O. per day, as well as a schematic of the U-Tube where 125 MGD of water is pumped from the river through the U-Tube and then discharged back into the river with 50 mg/L of supersaturated D. O. concentration, resulting in 40,000 lb/day supplementation.

Field testing at James River of the U-Tube, which oxygenated the treated effluent from a James River mill, yielded the following observational operational results:

- discharge D. O. of up to 50 mg/L at 25°C in the water
- head differential across the U-Tube was 5.3 ft and
- oxygen transfer capacity of up to 16,000 pounds of D. O. per day and
- oxygen absorption efficiencies of 80 to 90% were realized.

energy consumption rates of <200 kwhr/ton D.O. if placed on the bottom of a 50 ft deep impoundment or harbor.

This device incorporates an inverted conical gas transfer vessel in which the water is introduced at the top of the cone, flowing in a downward direction. As the water flows downward its velocity decreases in proportion to the cross-section of the cone. Pure O_2 is also injected into the cone and the resulting hydraulic turbulence creates a bubble swarm which has an exceptionally high oxygen/water interfacial area, which greatly enhances oxygen transfer.

By sizing the cross sectional area of the cone so that the downward velocity of the water slows to a point where it is less than the buoyant velocity of the bubbles within the cone, it is possible to retain the oxygen bubbles within the cone for prolonged periods of time, far in excess of the 100 seconds required for efficient oxygen absorption.

The pressure differential across the cone is rather small being primarily in proportion to the void volume of the bubble swarm within the cone. Thus the unit energy required to pump water through the bubble swarm is relatively small, and therefore the unit energy per ton of D. O. dissolved is also relatively small.

The concentration of D. O. that can be produced in the discharge is related to be depth of submergence or the hydrostatic pressure within the cone. Pressure enhances the oxygen transfer process. The deeper the cone is placed below the surface of the harbor, the higher the dissolved oxygen concentration produced in the discharge. Although the discharge D.O. increases in proportion to depth of submergence, the required pumping energy remains essentially constant, resulting in lower unit energy Kw/hr/ton vs depth.

The cone discharges the highly superoxygenated sidestream back into the harbor in a horizontal direction through a diffuser with 2 inch diameter ports at port velocities of 10 to 20 ft/sec. An outstanding feature is that the equipment can be located outside of the shipping channel by directing its superoxygenated discharge perpendicularly across the ship channel.

In summary, a 12 feet diameter Speece Cone 15 ft tall placed 50 ft below the water surface will give the following results

- 60 mg/L discharge D.O.
- 34 cfs cone flow
- 12,000 lb D.O. per day dissolved
- 45 HP pump utilized
- $>90\%$ oxygen absorption achieved
- <200 kwhr/ton D.O. consumed depending on depth
- cost of units - \$85,000/ton D.O./day (\$500,000 per 12 ft diameter unit with pump)

The excellent results of this system ($>90\%$ O_2 absorption efficiency) and low unit energy consumption (<200 kwhr/ton D.O. produced) occur in part because turbulence is confined to the inside of the cone with no bottom scouring. These



outstanding results are achieved without interfering with ship channel activity.

Self-Contained Mobile or Stationary Oxygenation Barge.

It is recommended that all municipal and industrial effluents be equipped with superoxygenation systems capable of adding D.O. concentrations equivalent to their effluent BOD_L concentration so that no D.O. resources from the harbor are consumed.

For supplying the oxygen demand of decaying vegetation, self contained barge mounted systems capable of supplementing 48,000 lb D.O./day to the harbor are recommended. Each unit would be comprised of 4 – 12 ft diameter Speece Cones each driven by a 45 HP pump. These oxygen transfer reactors would be suspended as far below the barge as possible to capitalize on the increased hydrostatic head. The D.O. in the discharge will be about 60 mg/L. This superoxygenated discharge can be placed near the bottom of the water column where it is needed most. The option is there to place it at any elevation in the water column. This will be rapidly diluted in the discharge diffusers which will be designed so that the discharge velocity and elevation above the sediments do not unduly disturb them resulting in exacerbation of the D.O. demand.

However with the intense turbulence generated by the propeller wake of numerous ships traversing the harbor, it would appear that the sediment/water interface is already continuously perturbed making the relatively minor turbulence caused by the oxygenated side stream a moot point by comparison. These oxygen supplementation systems could be permanently anchored any place within the harbor or be moved to any location within the harbor as needed. The most likely scenario is that some would be permanently anchored at a pier along the harbor where tidal action would be primarily used to move the oxygenated water away.

A key consideration in supplementing oxygen to the harbor will be the availability of land at key locations defined by D.O. deficiency conditions within the harbor, upon which the oxygenation system could be placed. The availability of electricity is another consideration. Generally it is quite expensive to bring in electricity. So these two facets, the availability of the real estate in the vicinity of the place where the oxygen is needed and the availability of electricity brought to that location will be significant economic factors.

As has been done on the Thames River and the Shanghai Harbor mobile oxygenation systems, one possibility for Savannah Harbor would be construction of a barge mounted unit that would be able to supplement oxygen directly to the harbor. The advantage of a barge mounted unit, is that it does not require any real estate along the harbor. Another advantage is that it can either be tied up permanently at some location along the ship channel or it could be moved to various points as needed in the harbor where oxygen is deficient. This unit can be self-contained, with its own PSA oxygen generation source, which could be driven by an internal combustion engine that requires no electrical power be brought in. Furthermore, the pumps required to move water through the oxygen transfer vessel can be powered by combustion engine driven pumps. Thus, the barge units would only need to be supplied with diesel fuel. In some cases, propane driven pumps have been used to anticipate the possibility of a spill in the harbor. Propane with its volatile nature would not present a pollution problem if spilled into the harbor such as diesel fuel would.

Mobile Oxygenation Barge

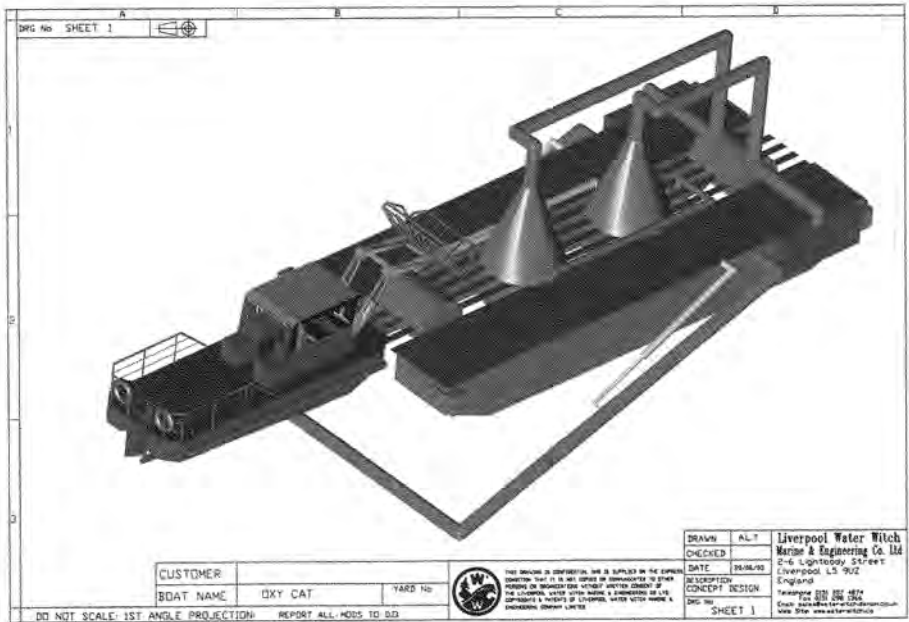
Mixing and transporting of the super oxygenated water within the harbor are key goals which must be achieved in a successful D.O. supplementation project. Oscillating tidal currents will be one of the main mechanisms which can be capitalized upon for movement of superoxygenated side streams away from the zone where they are generated. However a hydraulic model of water movement within the harbor would probably indicate some locations which will not have adequate transport of supplemented D.O. so as to meet compliance. Furthermore these D.O. deficient regions may change with flow and temperature conditions.

In such cases a logical solution would be to incorporate a means to deliver D.O. directly to the locations which are out of compliance. The concept of a self contained mobile oxygenation system could be used to address such deficiencies in tidal mixing effectiveness for effective transport of D.O. to all regions where needed.

A self-contained mobile oxygenation system would include on-board oxygen generation by pulsed swing adsorption or vacuum swing adsorption. This feature would avoid the safety concern of needing to store oxygen. Diesel or propane driven engines could either directly drive the oxygen generation system and pumps to move water through the oxygen transfer system or could generate electricity on board to power such components.

It would be advantageous to capitalize on the hydrostatic depth of the harbor for enhancement of oxygen transfer by placing the oxygen transfer reactor as far below the surface as possible. Of course there may be regions outside the main deep ship channel where the depths are much less deep that may require the aid of a mobile oxygen supplementation system.

The following Figures show schematics of a mobile oxygenation system. It would be capable of withdrawing denser water from the bottom of the water column, superoxygenating it and discharging it horizontally back at the same depth by means of an adjustable discharge boom. Sound insulation for the diesel could mitigate the noise pollution arising there from.



Placement of oxygen within the water column by a variable depth discharge diffuser system.

Recommendation

Speece Cone superoxygenation technology is recommended for remediation of the D.O. resources in Savannah Harbor based on cost, superoxygenation level, flexibility and mobility.

*Identification and Screening Level Evaluation of Measures to Improve
Dissolved Oxygen in the Savannah River Estuary
USACE Savannah District
Savannah, Georgia*

*FINAL
June 7, 2005
MACTEC Project 6301-03-0001
Contract No. W91278-04-D-0009, Delivery Order CYP1*

APPENDIX E

TECHNOLOGY CONFIGURATIONS

QUOTATION

Date: April 6, 2005
 To: Tanya Kinnard
 Company: Mactec Engineering & Associates
 Project: 10 Mile Pipeline – 80,000 lbs/day BOD Loading

Thank you for your interest in Mazzei® Injectors. The following items are quoted per your request. Quoted prices are valid for ninety (90) days. If you have not ordered from us before, or if your shipping address has changed, please provide a complete ship to address, including a local contact and phone number.

Item	List Price	Quantity	Total
Model 12050 Stainless Steel Injector	\$13,744.00	22	\$ 302,368.00
Model N100 Stainless Steel Nozzle*	\$2,250.00	44	\$ 99,000.00
TOTAL			\$ 401,368.00

* Due to changing fabrication and material costs, final price may vary from quoted price.

Mazzei Injector Corporation Mass Transfer Multiplier (MTM) Nozzle Sizing			
Prepared For:	MacTec		
Project:	Pipeline Aeration		
Purpose For Aeration:	BOD Reduction		
Date:	3/15/2005		
Injector Specification			
	Units	Value	Comments
Mazzei Injector Model	Model #	12050	
Injector Inlet Pressure	PSI	15	
Injector Flow Rate	GPM	2525	
Operating Conditions			
Gas Injection Rate	SCFM	33	
Design Back Pressure	PSI	1	
Pipeline Pressure, ft H2O	Feet	5	Assuming Pipeline is not pressurized
Mass Transfer Multiplier (MTM) Nozzle Specification			
MTM Nozzle Model	Model #	100	Special Fabricated Nozzle
Number of MTM Nozzles	#	2	
Calculated Nozzle Operating Conditions			
Calculated Exit Velocity	ft/s	18.8	
Calculated Back Pressure	PSI	2.2	
Estimated Piping Head Loss	PSI	2.0	
Total Injector Outlet Pressure	PSI	6.4	
Thrust Per Nozzle	Pounds	102.4	
Copyright Mazzei Injector Corporation, 500 Rooster Dr. Bakersfield CA USA			

						
Dissolved Gas Equilibrium Concentration						
Prepared For:			MacTec			
Project:			Pipeline Aeration			
Purpose For Aeration:			BOD Reduction			
Date:			3/15/2005			
Operating Parameters						
Inlet PSI	15	Pressure	Temperature	Gas Volume	Equilibrium	Gas Phase
Injector GPM	2525	PSIG	Centigrade	SCFM	Volume, GPM	H2O Vol %
Pump Efficiency, %	70					
Equilibrium Ratio	16.5	1	20	33	41662.5	2.35
		Starting		Equilibrium		
Subject Gas	Henry's Constant	Dissolved Conc. mg/l	Gas Phase Vol %	Percent Water Phase	Dissolved Conc. mg/l	Percent Gas Phase
Oxygen	38000	2	99	94.0	9.34	6.0
Nitrogen	84506	15	1	87.6	13.2	12.4
CO2	1360	81	0	99.8	80.82	0.2
Argon	38000	0.5	0	94.0	0.5	6.0
			100			
Oxygen Transferred Into Solution, Pounds/hour					153.06	
Oxygen Transferred Into Solution, Percent					91.59	
Power Consumption, Water Horsepower, WHP					22.09	
Transfer Efficiency, #'s O2/WHPHr					6.93	
Power Consumption, Brake Horsepower, BHP					31.56	
Transfer Efficiency, #'s O2/BHPHr					4.85	
Copyright Mazzei Injector Corporation						

USACE SHEP/SHERS
Chatham County, Georgia

MACTEC Project Number: 6301-05-0001
Contract Number: W912798-04-D-0009:CV01
April 4, 2005
Revised: June 2, 2005

**Preliminary Screening Level Opinion of Construction Costs
General Summary**

ITEM	WORK DESCRIPTION	TOTAL
Option I-A	Option I-A, All Three Facilities, 12 Hr. HRT, Gravity Discharge to River	\$42,400,000
Option I-B	Option I-B, All Three Facilities, 30 Day HRT, Gravity Discharge to River	\$51,700,000
Option I-C	Option I-C, All Three Facilities, 60 Day HRT, Gravity Discharge to River	\$59,100,000
Option II-A-1	Option II-A-1, International Paper Only, 12 Hr. HRT, Pumped to Discharge Point #1 (River Mile 5.5 +/-)	\$43,200,000
Option II-A-2	Option II-A-2, International Paper Only, 12 Hr. HRT, Pumped to Discharge Point #2 (River Mile 0.0 +/-)	\$66,000,000
Option II-B-1	Option II-B-1, International Paper Only, 30 Day HRT, Pumped to Discharge Point #1 (River Mile 5.5 +/-)	\$49,000,000
Option II-B-2	Option II-B-2, International Paper Only, 30 Day HRT, Pumped to Discharge Point #2 (River Mile 0.0 +/-)	\$71,400,000
Option II-C-1	Option II-C-1, International Paper Only, 60 Day HRT, Pumped to Discharge Point #1 (River Mile 5.5 +/-)	\$58,000,000
Option II-C-2	Option II-C-2, International Paper Only, 60 Day HRT, Pumped to Discharge Point #2 (River Mile 0.0 +/-)	\$81,200,000

Notes:

1) Reference used to generate this Opinion of Cost: Heavy Construction Cost Data, 2004 - 18th Annual Edition by RSMeans and actual costs from recently completed projects

2) All values rounded.

Prepared By:


Roger O. Blackwell

Date:

6-6-05

Checked By:


Stephen A. Lind

Date:

6/6/05

USACE SHEP/SHERS
Chatham County, Georgia

MACTEC Project Number: 6301-05-0001
Contract Number: W912798-04-D-0009:CV01
April 4, 2005
Revised: June 2, 2005

Table 5.1

Preliminary Screening Level Opinion of Construction Costs, Summary
Identification and Screening Level Evaluation
Savannah Harbor Expansion Project & Savannah Harbor Ecosystem Restoration Project
Chatham County, Georgia

ITEM	WORK DESCRIPTION	ITEM TOTAL	OPTION TOTAL
Option I-A	Option I-A, All Three Facilities, 12 Hr. HRT, Gravity Discharge to River Weyerhaeuser Pump Station and Piping to Pond (20 MGD, 36" DIP) International Paper Pump Station and Piping to Pond (30 MGD, 36" DIP) President Street WWTP Pump Station and Piping to Pond (10 MGD, 24" DIP) Pond Construction. HRT 12 Hrs, 10.5 AC x 9' Deep Contingency	\$15,500,000 \$8,400,000 \$7,300,000 \$1,400,000 \$9,800,000	\$42,400,000
Option I-B	Option I-B, All Three Facilities, 30 Day HRT, Gravity Discharge to River Weyerhaeuser Pump Station and Piping to Pond (20 MGD, 36" DIP) International Paper Pump Station and Piping to Pond (30 MGD, 36" DIP) President Street WWTP Pump Station and Piping to Pond (10 MGD, 20" DIP) Pond Construction. HRT 30 Days, 614 AC x 9' Deep Contingency	\$15,500,000 \$8,400,000 \$6,300,000 \$9,600,000 \$11,900,000	\$51,700,000
Option I-C	Option I-C, All Three Facilities, 60 Day HRT, Gravity Discharge to River Weyerhaeuser Pump Station and Piping to Pond (20 MGD, 36" DIP) International Paper Pump Station and Piping to Pond (30 MGD, 36" DIP) President Street WWTP Pump Station and Piping to Pond (10 MGD, 20" DIP) Pond Construction. HRT 60 Days, 1228 AC x 9' Deep Contingency	\$15,500,000 \$8,400,000 \$6,300,000 \$15,300,000 \$13,600,000	\$59,100,000
Option II-A-1	Option II-A-1, International Paper Only, 12 Hr. HRT, Pumped to Discharge Point #1 (River Mile 5.5 +/-) International Paper Pump Station and Piping to Pond (30 MGD, 36" DIP) Pond Construction. HRT 12 Hrs, 5.1 AC x 9' Deep Pond Outfall Pump Station and Piping (69 CFS, 48" DIP) Contingency	\$8,400,000 \$1,100,000 \$23,800,000 \$9,900,000	\$43,200,000
Option II-A-2	Option II-A-2, International Paper Only, 12 Hr. HRT, Pumped to Discharge Point #2 (River Mile 0.0 +/-) International Paper Pump Station and Piping to Pond (30 MGD, 36" DIP) Pond Construction. HRT 12 Hrs, 5.1 AC x 9' Deep Pond Outfall Pump Station and Piping (69 CFS, 54" DIP) Contingency	\$8,400,000 \$1,100,000 \$41,300,000 \$15,200,000	\$66,000,000
Option II-B-1	Option II-B-1, International Paper Only, 30 Day HRT, Pumped to Discharge Point #1 (River Mile 5.5 +/-) International Paper Pump Station and Piping to Pond (30 MGD, 36" DIP) Pond Construction. HRT 30 Days, 307 AC x 9' Deep Pond Outfall Pump Station and Piping (69 CFS, 48" DIP) Contingency	\$8,400,000 \$6,700,000 \$22,600,000 \$11,300,000	\$49,000,000

ITEM	WORK DESCRIPTION	ITEM TOTAL	OPTION TOTAL
Option II-B-2	Option II-B-2, International Paper Only, 30 Day HRT, Pumped to Discharge Point #2 (River Mile 0.0 +/-)		\$71,400,000
	International Paper Pump Station and Piping to Pond (30 MGD, 36" DIP)	\$8,400,000	
	Pond Construction, HRT 30 Days, 307 AC x 9' Deep	\$6,700,000	
	Pond Outfall Pump Station and Piping (69 CFS, 54" DIP)	\$39,800,000	
	Contingency	\$16,500,000	
Option II-C-1	Option II-C-1, International Paper Only, 60 Day HRT, Pumped to Discharge Point #1 (River Mile 5.5 +/-)		\$56,000,000
	International Paper Pump Station and Piping to Pond (30 MGD, 36" DIP)	\$8,400,000	
	Pond Construction, HRT 60 Days, 614 AC x 9' Deep	\$9,500,000	
	Pond Outfall Pump Station and Piping (92 CFS, 54" DIP)	\$25,200,000	
	Contingency	\$12,900,000	
Option II-C-2	Option II-C-2, International Paper Only, 60 Day HRT, Pumped to Discharge Point #2 (River Mile 0.0 +/-)		\$81,200,000
	International Paper Pump Station and Piping to Pond (30 MGD, 36" DIP)	\$8,400,000	
	Pond Construction, HRT 60 Days, 614 AC x 9' Deep	\$9,500,000	
	Pond Outfall Pump Station and Piping (92 CFS, 60" DIP)	\$44,600,000	
	Contingency	\$18,700,000	

Notes:

1) Reference used to generate this Opinion of Cost: Heavy Construction Cost Data, 2004 - 18th Annual Edition by RSMeans and actual costs from recently completed projects

2) All values rounded

3) HRT = Hydraulic Retention Time

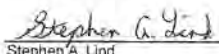
Prepared By


 Roger O. Blackwell

Date

6-6-05

Checked By


 Stephen A. Lind

Date

6/6/05

Preliminary Screening Level Opinion of Construction Cost

Prepared by: Roger O. Blackwell
Checked by: Stephen A. Lind
6/6/05

Option I, Reroute All Three Facilities.

ITEM	WORK DESCRIPTION	UNIT	UNIT PRICE	EST QTY	LINE TOTAL	COST SOURCE ¹	ITEM TOTAL
1.0	Option I-A, 12 Hr. HRT, Gravity Discharge from Pond to River						
1.1	Weyerhaeuser Pump Station and Piping to Pond (20 MGD, 36" DIP) Mobilization & Demobilization Temporary Facilities and Controls Clearing (assume minor clearing 20' wide x length of trench) Silt Fence, Type C (assume double row along length of trench) Trench Excavation (assume 4' bottom, 1:1 side slopes & 4' cover over pipes) 36" DIP, Class 150 Installed in Trench 36" DIP Fittings (assume 5% of pipe cost) Trench Backfill Jacking/Receiving Pits (excludes dewatering) Microtunneling, 48" Diameter (includes casing) 36" DIP, Class 150 Installed in Casing 8" Air Release Valve	LS LS AC LF CY LF LS CY EA LF LF EA	\$200,000 \$200,000 \$262 \$3,00 \$2.54 \$159 \$290,175 \$2,44 \$19,300 \$950 \$159 \$4,500	1 1 17 73,000 104,000 36,500 1 94,500 4 6,500 8,500 4	\$200,000 \$200,000 \$4,454 \$219,000 \$264,160 \$5,803,500 \$290,175 \$230,580 \$77,200 \$6,240,000 \$1,033,500 \$18,000	02230-200-0600 Recent experience 02315-610-0610 02510-730-3000 and American Pipe 02315-610-3020, 02315-310-5040 02445-300-1101 02441-400-0110 (adverse conditions) 02510-730-3000 and American Pipe Doug Andrews at Apco Valves, 50% Added for Installation	\$15,493,249
	6' Dia Precast MH, 7' Deep Energy Dissipation Structure, 3:1 CY/EA Pumps w/Controls, Instrumentation and Backup Generator (3 (+2) Each Flygt CP3356/810 Impeller/505mm/135 HP Each). Assume housed in existing facility with power from existing facility.	EA EA LS	\$2,300 \$1,180 \$870,000	4 1 1	\$9,200 \$1,180 \$870,000	02630-400-1200&1210 03310-240-4200, GDOT STD 1125 Table I Dana Reid and John Rodriguez of ITT Flygt Corporation, (Emails Dated 3/18/05, 2:48 PM and 3:03 PM). Added 50% for Installation, \$100,000 for Generator and \$20,000 for Instrumentation. 02920-320-0200	
1.2	Grassing (assume 20' wide x length of trench)	AC	\$1,900	17	\$32,300		
	International Paper Pump Station and Piping to Pond (30 MGD, 36" DIP) Mobilization & Demobilization Temporary Facilities and Controls Clearing (assume minor clearing 20' wide x length of trench) Silt Fence, Type C (assume double row along length of trench)	LS LS AC LF	\$200,000 \$200,000 \$262 \$3,00	1 1 4 15,000	\$200,000 \$200,000 \$1,048 \$45,000	02230-200-0600 Recent experience	\$8,326,343

ITEM	WORK DESCRIPTION	UNIT	UNIT PRICE	EST QTY	LINE TOTAL	COST SOURCE¹	ITEM TOTAL
	Trench Excavation (assume 4' bottom, 1:1 side slopes & 4' cover over pipe)	CY	\$2.54	21,500	\$54,810	02315-610-0610	
	36" DIP, Class 150 installed in Trench	LF	\$159	7,500	\$1,192,500	02510-730-3000 and American Pipe	
	36" DIP Fittings (assume 5% of pipe cost)	LS	\$59,625	1	\$59,625		
	Trench Backfill	CY	\$2.44	19,500	\$47,580	02315-610-3020, 02315-310-5040	
	Jacking/Receiving Pits (excludes dewatering)	EA	\$193,300	2	\$38,660	02445-300-1101	
	Microtunneling, 48" Diameter (includes casing)	LF	\$980	5,000	\$4,800,000	02441-400-0110 (adverse conditions)	
	36" DIP, Class 150 installed in Casing	LF	\$159	5,000	\$795,000	02510-730-3000 and American Pipe	
	8" Air Release Valve	EA	\$4,500	2	\$9,000	Doug Andrews at Apco Valves, 50% Added for Installation	
	6' Dia Precast MH, 7' Deep	EA	\$2,300	2	\$4,600	02630-400-1200&1210	
	Energy Dissipation Structure, 3.1 CY/EA	EA	\$1,180	1	\$1,180	03310-240-4200, GDOT STD 1125 Table I	
	Pumps w/Controls, Instrumentation and Backup Generator (3 (+2) Each Flygt CP3356/810 Impeller/480mm/135HP Each). Assume housed in existing facility with power from existing facility	LS	\$870,000	1	\$870,000	Dana Reid and John Rodriguez of ITT Flygt Corporation, (Emails Dated 3/18/05, 2:46 PM and 3:03 PM). Added 50% for Installation, \$100,000 for Generator and \$20,000 for Instrumentation.	
	Grassing (assume 20' wide x length of trench)	AC	\$1,900	4	\$7,600	02920-320-0200	
1.3	President Street WWTP Pump Station and Piping to Pond (10 MGD, 24" DIP)						\$7,265,050
	Mobilization & Demobilization	LS	\$200,000	1	\$200,000		
	Temporary Facilities and Controls	LS	\$200,000	1	\$200,000		
	Clearing (assume minor clearing 20' wide x length of trench)	AC	\$262	5	\$1,310	02230-200-0600	
	Silt Fence, Type C (assume double row along length of trench)	LF	\$3.00	21,800	\$64,800	Recent experience	
	Trench Excavation (assume 4' bottom, 1:1 side slopes & 4' cover over pipe)	CY	\$2.54	24,000	\$60,960	02315-610-0610	
	24" DIP, Class 150 installed in trench	LF	\$83	10,800	\$898,400	02510-730-3180	
	24" DIP Fittings (assume 5% of pipe cost)	LS	\$44,820	1	\$44,820		
	Trench Backfill	CY	\$2.44	22,750	\$55,510	02315-610-3020, 02315-310-5040	
	Jacking/Receiving Pits (excludes dewatering)	EA	\$193,300	4	\$77,200	02445-300-1101	
	Microtunneling, 36" Diameter (includes casing)	LF	\$980	5,000	\$4,800,000	02441-400-0110 (adverse conditions)	
	24" DIP, Class 150 installed in casing	LF	\$83	5,000	\$415,000	02510-730-3180	
	4" Air Release Valve	EA	\$3,000	4	\$12,000	Doug Andrews at Apco Valves, 50% Added for Installation	
	6' Dia Precast MH, 6' Deep	EA	\$1,975	4	\$7,900	02630-400-1200	
	Energy Dissipation Structure, 1.7 CY/EA	EA	\$650	1	\$650	03310-240-4200, GDOT STD 1125 Table I	
	Pumps w/Controls, Instrumentation and Backup Generator (2 (+1) Each Flygt NP3301/635 Impeller/353mm/70HP Each). Assume housed in existing facility with power from existing facility)	LS	\$420,000	1	\$420,000	Dana Reid and John Rodriguez of ITT Flygt Corporation, (Emails Dated 3/18/05, 2:46 PM and 3:03 PM). Added 50% for Installation, \$100,000 for Generator and \$20,000 for Instrumentation.	
	Grassing (assume 20' wide x length of trench)	AC	\$1,900	5	\$9,500	02920-320-0200	

ITEM	WORK DESCRIPTION	UNIT	UNIT PRICE	EST QTY	LINE TOTAL	COST SOURCE ¹	ITEM TOTAL
1.4	Pond Construction, HRT 12 Hrs, 10.5 AC x 9' Deep Mobilization & Demobilization Temporary Facilities and Controls Clearing (assume minor clearing) Silt Fence, Type C (assume double row around perimeter of work area) Undercut (assume 2' under footprint of berm disposed of onsite) Stabilization Fabric (Synthetic Industries Geotex 4x4 or equal) Stabilization Stone Berm (Assume use of onsite dredge material) Fine grade bottom of pond Conc. Channel Through Pond Grassing Outfall Trench Excavation (assume 4' bottom, 1:1 side slopes) Inlet Headwall, 4.6 C/YEA 48" DIP Installed in Trench 48" Gate Valve Energy Dissipation Structure, 4.8 C/YEA	LS LS AC LF CY CY TN CY AC CY AC CY EA LF EA EA	\$200,000 \$200,000 \$252 \$3,00 \$3.09 \$2.75 \$17 \$3.45 \$2,904 \$127.00 \$1,900 \$2.54 \$1,750 \$372 \$10,170 \$1,825	1 1 17 7,000 18,500 30,500 27,500 92,000 12 105 17 200 1 100 1 1	\$200,000 \$200,000 \$4,454 \$21,000 \$57,165 \$93,875 \$474,375 \$213,900 \$34,848 \$13,335 \$32,300 \$508 \$1,750 \$37,200 \$10,170 \$1,825	02230-200-0600 Recent experience 02315-452-0300 Local Contractor 02370-450-0100 02315-520-0190, 02315-310-5040 02310-100-0100 03300-240-4840 02920-320-0200 02315-610-0610 03310-240-4200, GDOT STD 1125 Table I 02510-730-3000 and American Pipe 02080-500-3832 Extrapolated to 48" 03310-240-4200, GDOT STD 1125 Table I	\$1,386,705
	SUBTOTAL: Contingency TOTAL:					30% 30%	\$32,472,347 \$9,741,704 \$42,214,051

1) Source of unit costs (unless otherwise noted): "Heavy Construction Cost Data 2004", by RS Means Company, Inc.

Preliminary Screening Level Opinion of Construction Cost

Prepared by Roger O. Blackwell
Checked by Stephen A. Lind
6/6/05

Option 1. Reroute All Three Facilities

ITEM	WORK DESCRIPTION	UNIT	UNIT PRICE	EST QTY	LINE TOTAL	COST SOURCE ¹	ITEM TOTAL
1.0	Option 1-B, 30 Day HRT, Gravity Discharge from Pond to River						
1.1	Weyerhaeuser Pump Station and Piping to Pond (20 MGD, 36" DIP) Mobilization & Demobilization Temporary Facilities and Controls Clearing (assume minor clearing 20' wide x length of trench) Silt Fence, Type C (assume double row along length of trench) Trench Excavation (assume 4' bottom, 1:1 side slopes & 4' cover over pipe) 36" DIP, Class 150 installed in Trench 36" DIP Fittings (assume 5% of pipe cost) Trench Backfill Jacking/Receiving Pits (excludes dewatering) Microtunneling, 48" Diameter (includes casing) 36" DIP, Class 150 installed in Casing 8" Air Release Valve 6' Dia Precast MH, 7' Deep Energy Dissipation Structure, 3.1 C/YEA Pumps w/Controls, Instrumentation and Backup Generator (3 (+2) Each Flygt CP3356/810 Impeller/505mm/135 HP Each). Assume housed in existing facility with power from existing facility. Grassing (assume 20' wide x length of trench)	LS LS AC LF CY LF LS CY EA LF LF EA EA EA EA EA EA LS AC	\$200,000 \$200,000 \$262 \$3.00 \$2.54 \$159 \$230,175 \$2.44 \$19,300 \$960 \$159 \$4,500 \$2,300 \$1,180 \$870,000 \$1,900	1 1 17 73,000 104,000 36,500 1 94,500 4 6,500 6,500 4 4 1 1 1 17	\$200,000 \$200,000 \$4,454 \$219,000 \$264,160 \$5,803,500 \$290,175 \$230,590 \$77,200 \$6,240,000 \$1,033,500 \$18,000 \$5,200 \$1,180 \$870,000 \$32,300	02230-200-0600 Recent experience 02315-610-0610 02510-730-3000 and American Pipe 02315-610-3020, 02315-310-5040 02445-300-1101 02441-400-0110 (adverse conditions) 02510-730-3000 and American Pipe Doug Andrews at Apco Valves, 50% Added for Installation 02630-400-1200&1210 02310-240-4200, GDOT STD 1125 Table I Dana Reid and John Rodriguez of ITT Flygt Corporation, (Emails Dated 3/18/05, 2-46 PM and 3:03 PM). Added 50% for Installation, \$100,000 for Generator and \$20,000 for Instrumentation. 02920-320-0200	\$15,493,249
1.2	International Paper Pump Station and Piping to Pond (30 MGD, 36" DIP) Mobilization & Demobilization Temporary Facilities and Controls Clearing (assume minor clearing 20' wide x length of trench) Silt Fence, Type C (assume double row along length of trench)	LS LS AC LF	\$200,000 \$200,000 \$262 \$3.00	1 1 4 15,000	\$200,000 \$200,000 \$1,048 \$45,000	02230-200-0600 Recent experience	\$8,326,343

ITEM	WORK DESCRIPTION	UNIT	UNIT PRICE	EST QTY	LINE TOTAL	COST SOURCE ¹	ITEM TOTAL
	Trench Excavation (assume 4' bottom, 1:1 side slopes & 4' cover over pipe)	CY	\$2.54	21,500	\$54,610	02315-610-0610	
	36" DIP, Class 150 installed in Trench	LF	\$159	7,500	\$1,192,500	02510-730-3000 and American Pipe	
	Trench Backfill	LS	\$59,825	1	\$59,825		
	Jacking/Receiving Pits (excludes dewatering)	CY	\$2.44	19,500	\$47,580	02315-610-3020, 02315-310-5040	
	Microtunneling, 48" Diameter (includes casing)	EA	\$19,300	2	\$38,600	02445-300-1101	
	36" DIP, Class 150 installed in Casing	LF	\$960	5,000	\$4,800,000	02441-400-0110 (adverse conditions)	
	8" Air Release Valve	LF	\$159	5,000	\$795,000	02510-730-3000 and American Pipe	
	6' Dia Precast MH, 7' Deep	EA	\$4,500	2	\$9,000	Doug Andrews at Apco Valves. 50% Added for Installation	
	Energy Dissipation Structure, 3.1 CY/EA	EA	\$2,300	2	\$4,600	02630-400-1200&1210	
	Pumps w/Controls, Instrumentation and Backup Generator (3 (+2) Each Flygt CP3356/810 Impeller/480mm/135HP Each). Assume housed in existing facility with power from existing facility.	EA	\$1,180	1	\$1,180	03310-240-4200, GDOT STD 1125 Table I	
	Grassing (assume 20' wide x length of trench)	LS	\$870,000	1	\$870,000	Dana Reid and John Rodriguez of ITT Flygt Corporation, (Emails Dated 3/18/05, 2:46 PM and 3:03 PM), Added 50% for Installation, \$100,000 for Generator and \$20,000 for Instrumentation.	
		AC	\$1,900	4	\$7,600	02920-320-0200	
1.3	President Street WWTP Pump Station and Piping to Pond (10 MGD, 20" DIP)						\$6,216,236
	Mobilization & Demobilization	LS	\$200,000	1	\$200,000		
	Temporary Facilities and Controls	LS	\$200,000	1	\$200,000		
	Clearing (assume minor clearing 20' wide x length of trench)	AC	\$262	1	\$262	02230-200-0600	
	Silt Fence, Type C (assume double row along length of trench)	LF	\$3,000	3,700	\$11,100	Recent experience	
	Trench Excavation (assume 4' bottom, 1:1 side slopes & 4' cover over pipe)	CY	\$2.54	4,100	\$10,414	02315-610-0610	
	20" DIP, Class 150 installed in trench	LF	\$67	1,850	\$123,950	02510-730-3180	
	20" DIP Fittings (assume 5% of pipe cost)	LS	\$6,198	1	\$6,198		
	Trench Backfill	CY	\$2.44	3,960	\$9,662	02315-610-3020, 02315-310-5040	
	Jacking/Receiving Pits (excludes dewatering)	EA	\$19,300	4	\$77,200	02445-300-1101	
	Microtunneling, 36" Diameter (includes casing)	LF	\$960	5,000	\$4,800,000	02441-400-0110 (adverse conditions)	
	20" DIP, Class 150 installed in casing	LF	\$67	5,000	\$335,000	02510-730-3180	
	4" Air Release Valve	EA	\$3,000	4	\$12,000	Doug Andrews at Apco Valves. 50% Added for Installation	
	6' Dia Precast MH, 6' Deep	EA	\$1,975	4	\$7,900	02630-400-1200	
	Energy Dissipation Structure, 1.7 CY/EA	EA	\$650	1	\$650	03310-240-4200, GDOT STD 1125 Table I	
	Pumps w/Controls, instrumentation and Backup Generator (2 (+1) Each Flygt NP3301/636 Impeller/363mm/70HP Each). Assume housed in existing facility with power from existing facility)	LS	\$420,000	1	\$420,000	Dana Reid and John Rodriguez of ITT Flygt Corporation, (Emails Dated 3/18/05, 2:46 PM and 3:03 PM), Added 50% for Installation, \$100,000 for Generator and \$20,000 for Instrumentation.	
	Grassing (assume 20' wide x length of trench)	AC	\$1,900	1	\$1,900	02920-320-0200	

ITEM	WORK DESCRIPTION	UNIT	UNIT PRICE	EST QTY	LINE TOTAL	COST SOURCE ¹	ITEM TOTAL
1.4	Pond Construction. HRT 30 Days. 614 AC x 9' Deep	LS	\$200,000	1	\$200,000		\$9,520,443
	Mobilization & Demobilization	LS	\$200,000	1	\$200,000		
	Temporary Facilities and Controls	AC	\$262	650	\$170,300	02230-200-0800	
	Clearing (assume minor clearing)	LF	\$3.00	43,000	\$129,000	Recent experience	
	Silt Fence, Type C (assume double row around perimeter of work area)	CY	\$3.09	128,000	\$395,520	02315-452-0300	
	Undercut (assume 2' under footprint of berm disposed of onsite)	SY	\$2.75	210,500	\$578,875	Local Contractor	
	Stabilization Fabric (Synthetic Industries Geotex 4x4 or equal)	TN	\$17	190,000	\$3,277,500	02370-450-0100	
	Stabilization Stone	CY	\$3.45	430,000	\$1,483,500	02315-520-0180, 02315-310-5040	
	Berm (Assume use of onsite dredge material)	AC	\$2,904	615	\$1,785,960	02310-100-0100	
	Fine grade bottom of pond	CY	\$127.00	105	\$13,335	03300-240-4840	
	Conc. Channel Through Pond	AC	\$1,900	650	\$1,235,000	02920-320-0200	
	Grassing	CY	\$2.54	200	\$508	02315-610-0610	
	Outfall Trench Excavation (assume 4' bottom, 1:1 side slopes)	EA	\$1,750	1	\$1,750	03310-240-4200, GDOT STD 1125 Table I	
	Inlet Headwall, 4.6 CY/EA	LF	\$372	100	\$37,200	02510-730-3000 and American Pipe	
	48" DIP installed in Trench	EA	\$10,170	1	\$10,170	02080-500-3832 Extrapolated to 48"	
	48" Gate Valve	EA	\$1,825	1	\$1,825	03310-240-4200, GDOT STD 1125 Table I	
	Energy Dissipation Structure, 4.8 CY/EA	EA					
	SUBTOTAL:						\$39,556,271
	Contingency					30%	\$11,866,881
	TOTAL:						\$51,423,152

1) Source of unit costs (unless otherwise noted): "Heavy Construction Cost Data 2004", by RS Means Company, Inc.

Preliminary Screening Level Opinion of Construction Cost

Prepared by: Roger O. Blackwell
Checked by: Stephen A. Lind
6/6/05

Option 1, Reroute All Three Facilities

ITEM	WORK DESCRIPTION	UNIT	UNIT PRICE	EST QTY	LINE TOTAL	COST SOURCE ¹	ITEM TOTAL
1.0	Option 1-C, 60 Day HRT, Gravity Discharge from Pond to River						
1.1	Weyerhaeuser Pump Station and Piping to Pond (20 MGD, 36" DIP) Mobilization & Demobilization Temporary Facilities and Controls Clearing (assume minor clearing 20' wide x length of trench) Silt Fence, Type C (assume double row along length of trench) Trench Excavation (assume 4' bottom, 1:1 side slopes & 4' cover over pipe) 36" DIP, Class 150 Installed in Trench 36" DIP Fittings (assume 5% of pipe cost) Trench Backfill Jacking/Receiving Pits (excludes dewatering) Microtunneling, 48" Diameter (includes casing) 36" DIP, Class 150 Installed in Casing 8" Air Release Valve	LS LS AC LF CY LF LS CY EA LF LF EA	\$200,000 \$200,000 \$262 \$3,00 \$2,54 \$159 \$290,175 \$2,44 \$19,300 \$980 \$159 \$4,500	1 1 17 73,000 104,000 30,500 1 34,500 4 6,500 6,500 4	\$200,000 \$200,000 \$4,454 \$219,000 \$264,160 \$3,803,500 \$290,175 \$77,200 \$6,240,000 \$1,033,500 \$18,000	02230-200-0600 Recent experience 02315-610-0810 02510-730-3000 and American Pipe 02315-610-3020, 02315-310-5040 02445-300-1101 02441-400-0110 (adverse conditions) 02510-730-3000 and American Pipe Doug Andrews at Apoo Valves 50% Added for installation	\$15,493,249
	6" Dia Precast MH, 7' Deep Energy Dissipation Structure, 3.1 CY/EA Pumps w/Controls, Instrumentation and Backup Generator (3 (+2) Each Flgnt CP-356/810 Impeller/505mm/135 HP Each). Assume housed in existing facility with power from existing facility. Grassing (assume 20' wide x length of trench)	EA EA LS AC	\$2,300 \$1,180 \$870,000 \$1,900	4 1 1 17	\$9,200 \$1,180 \$870,000 \$32,300	02630-400-1200&1210 03310-240-4200, GDOT STD 1125 Table I Dana Reid and John Rodriguez of ITT Flgnt Corporation, (Emails Dated 3/18/05, 2:48 PM and 3:03 PM). Added 50% for installation, \$100,000 for Generator and \$20,000 for instrumentation. 02920-320-0200	\$5,326,343
1.2	International Paper Pump Station and Piping to Pond (30 MGD, 36" DIP) Mobilization & Demobilization Temporary Facilities and Controls Clearing (assume minor clearing 20' wide x length of trench) Silt Fence, Type C (assume double row along length of trench)	LS LS AC LF	\$200,000 \$200,000 \$262 \$3,00	1 1 4 15,000	\$200,000 \$200,000 \$1,048 \$45,000	02230-200-0600 Recent experience	

ITEM	WORK DESCRIPTION	UNIT	UNIT PRICE	EST QTY	LINE TOTAL	COST SOURCE ¹	ITEM TOTAL
1.3	Trench Excavation (assume 4' bottom, 1:1 side slopes & 4' cover over pipe)	CY	\$2.54	21,500	\$54,610	02315-610-0610	\$5,216,238
	36" DIP Class 150 installed in trench	LF	\$159	7,500	\$1,192,500	02510-730-3000 and American Pipe	
	36" DIP Fittings (assume 5% of pipe cost)	LS	\$59,625	1	\$59,625		
	Trench Backfill	CY	\$2.44	19,500	\$47,580	02315-610-3020, 02315-310-5040	
	Jacking/Receiving Pits (excludes dewatering)	EA	\$19,300	2	\$38,600	02445-300-1101	
	Microtunneling, 48" Diameter (includes casing)	LF	\$960	5,000	\$4,800,000	02441-400-0110 (adverse conditions)	
	36" DIP Class 150 installed in Casing	LF	\$159	5,000	\$795,000	02510-730-3000 and American Pipe	
	8" Air Release Valve	EA	\$4,500	2	\$9,000	Doug Andrews at Apco Valves, 50% Added for Installation	
	8' Dia Precast MH, 7' Deep	EA	\$2,300	2	\$4,600	02630-400-1200&1210	
	Energy Dissipation Structure, 3.1 CY/EA	EA	\$1,180	1	\$1,180	03310-240-4200, GDOT STD 1125 Table I	
	Pumps w/Controls, Instrumentation and Backup Generator (3 (+2) Each Flygt CP3356/610 Impeller/480mm/135HP Each). Assume housed in existing facility with power from existing facility.	LS	\$870,000	1	\$870,000	Dana Reid and John Rodriguez of ITT Flygt Corporation, (Emails Dated 3/18/05, 2:45 PM and 3:03 PM). Added 50% for Installation, \$100,000 for Generator and \$20,000 for Instrumentation.	
	Grassing (assume 20' wide x length of trench)	AC	\$1,900	4	\$7,600	02920-320-0200	
	President Street WWTP Pump Station and Piping to Pond (10 MGD, 20" DIP)						
	Mobilization & Demobilization	LS	\$200,000	1	\$200,000		\$5,216,238
	Temporary Facilities and Controls	AC	\$200,000	1	\$200,000		
	Clearing (assume minor clearing 20' wide x length of trench)	LF	\$262	1	\$262	02230-200-0600	
	Silt Fence, Type C (assume double row along length of trench)	LF	\$3,000	3,700	\$11,100	Recent experience	
	Trench Excavation (assume 4' bottom, 1:1 side slopes & 4' cover over pipe)	CY	\$2.54	4,100	\$10,414	02315-610-0610	
	20" DIP Class 150 installed in trench	LF	\$67	1,860	\$123,960	02510-730-3180	
	20" DIP Fittings (assume 5% of pipe cost)	LS	\$6,198	1	\$6,198		
	Trench Backfill	CY	\$2.44	3,960	\$9,662	02315-610-3020, 02315-310-5040	
	Jacking/Receiving Pits (excludes dewatering)	EA	\$19,300	4	\$77,200	02445-300-1101	
	Microtunneling, 36" Diameter (includes casing)	LF	\$960	5,000	\$4,800,000	02441-400-0110 (adverse conditions)	
	20" DIP Class 150 installed in casing	LF	\$67	5,000	\$335,000	02510-730-3180	
	4" Air Release Valve	EA	\$3,000	4	\$12,000	Doug Andrews at Apco Valves, 50% Added for Installation	
	8' Dia Precast MH, 6' Deep	EA	\$1,975	4	\$7,900	02630-400-1200	
	Energy Dissipation Structure, 1.7 CY/EA	EA	\$860	1	\$860	03310-240-4200, GDOT STD 1125 Table I	\$5,216,238
	Pumps w/Controls, Instrumentation and Backup Generator (2 (+1) Each Flygt CP3301/636 Impeller/384mm/70 HP Each). Assume housed in existing facility with power from existing facility)	LS	\$420,000	1	\$420,000	Dana Reid and John Rodriguez of ITT Flygt Corporation, (Emails Dated 3/18/05, 2:45 PM and 3:03 PM). Added 50% for Installation, \$100,000 for Generator and \$20,000 for Instrumentation.	
	Grassing (assume 20' wide x length of trench)	AC	\$1,900	1	\$1,900	02920-320-0200	

ITEM	WORK DESCRIPTION	UNIT	UNIT PRICE	EST QTY	LINE TOTAL	COST SOURCE¹	ITEM TOTAL
1.4	Pond Construction, HRT 60 Days, 1228 AC x 9' Deep Mobilization & Demobilization Temporary Facilities and Controls Clearing (assume minor clearing) Silt Fence, Type C (assume double row around perimeter of work area) Undercut (assume 2' under footprint of berm disposed of onsite) Stabilization Fabric (Synthetic Industries Geotex 4x4 or equal) Stabilization Stone Berm (Assume use of onsite dredge material) Fine grade bottom of pond Conc. Channel Through Pond Grassing Outfall Trench Excavation (assume 4' bottom, 1:1 side slopes) Inlet Headwall, 4.6 CY/EA 48" DIP Installed in Trench 48" Gate Valve Energy Dissipation Structure, 4.8 CY/EA	LS LS AC LF CY CY SY TN CY AC CY AC CY EA LF EA EA	\$200,000 \$200,000 \$262 \$3.00 \$3.09 \$2.75 \$17 \$3.45 \$2,904 \$127.00 \$1,800 \$2.54 \$1,750 \$372 \$10,170 \$1,825	1 1 1,280 61,500 184,500 304,000 274,000 621,000 1,230 105 1,280 200 1 100 1 1	\$200,000 \$200,000 \$335,360 \$184,500 \$570,105 \$636,000 \$4,726,500 \$2,142,450 \$3,571,920 \$13,335 \$2,432,000 \$508 \$37,200 \$10,170 \$1,825	02230-200-0600 Recent experience 02315-452-0300 Local Contractor 02315-5040 02315-520-0190 02310-100-0100 02315-310-5040 02920-320-0200 02315-610-0610 03310-240-4200, GDOT STD 1125 Table I 02510-730-3000 and American Pipe 02080-500-3832 Extrapolated to 48" 03310-240-4200, GDOT STD 1125 Table I	\$15,263,623
	SUBTOTAL: Contingency TOTAL:					30%	\$45,299,451 \$13,589,835 \$58,889,286

1) Source of unit costs (unless otherwise noted): "Heavy Construction Cost Data 2004", by RS Means Company, Inc.

Preliminary Screening Level Opinion of Construction Cost

Prepared by: Roger O. Blackwell
Checked by: Stephen A. Lind 6/6/05

Option II, Reroute Only International Paper & Pump from Pond

ITEM	WORK DESCRIPTION	UNIT	UNIT PRICE	EST QTY	LINE TOTAL	COST SOURCE ¹	ITEM TOTAL
1.0	Option II-A-1, 12 Hr, HRT, Pumped to Discharge Point #1						
1.2	International Paper Pump Station and Piping to Pond (30 MGD, 36" DIP) Mobilization & Demobilization Temporary Facilities and Controls Cleaning (assume minor cleaning 20' wide x length of trench) Silt Fence, Type C (assume double row along length of trench) Trench Excavation (assume 4' bottom, 1:1 side slopes & 4' cover over pipe) 36" DIP, Class 150 Installed in Trench 36" DIP Fittings (assume 5% of pipe cost) Trench Backfill Jacking/Receiving Pits (excludes dewatering) Microtunneling, 48" Diameter (includes casing) 36" DIP, Class 150 Installed in Casing 8" Air Release Valve	LS LS AC CY CY LF LS CY EA LF LF EA	\$200,000 \$200,000 \$262 \$3,00 \$2,54 \$159 \$59,625 \$2,44 \$19,300 \$960 \$159 \$4,500	1 1 4 15,000 21,500 7,500 1 19,500 2 5,000 5,000 2	\$200,000 \$200,000 \$1,048 \$45,000 \$54,610 \$1,192,500 \$59,625 \$47,580 \$38,600 \$4,800,000 \$795,000 \$9,000	02230-200-0600 Recent experience 02315-810-0810 02510-730-3000 and American Pipe 02315-810-3020, 02315-310-5040 02445-300-1101 02441-400-0110 (adverse conditions) 02510-730-3000 and American Pipe Doug Andrews at Apco Valves. 50% Added for installation	\$8,326,343
	6" Dia Precast MH, 7' Deep Energy Dissipation Structure, 3.1 CY/EA Pumps w/Controls, Instrumentation and Backup Generator (3 (+2) Each Flygt CP3356/810 Impeller/480mm/135HP Each). Assume housed in existing facility with power from existing facility.	EA EA LS	\$2,300 \$1,180 \$970,000	2 1 1	\$4,600 \$1,180 \$970,000	02630-400-1200&1210 03310-240-4200, GDOT STD 1125 Table I Dana Reid and John Rodriguez of ITT Flygt Corporation, (Emails Dated 3/18/05 2:46 PM and 3:03 PM). Added 50% for installation, and \$100,000 for Generator and \$20,000 for instrumentation.	
	Grassing (assume 20' wide x length of trench)	AC	\$1,900	4	\$7,600	02520-320-0200	
1.4	Pond Construction, HRT 12 Hrs, 5.1 AC x 9' Deep Mobilization & Demobilization Temporary Facilities and Controls Cleaning (assume minor cleaning) Silt Fence, Type C (assume double row around perimeter of work area)	LS LS AC LF	\$200,000 \$200,000 \$262 \$3.00	1 1 9 5,000	\$200,000 \$200,000 \$2,358 \$15,000	02230-200-0600 Recent experience	\$1,034,414

ITEM	WORK DESCRIPTION	UNIT	UNIT PRICE	EST QTY	LINE TOTAL	COST SOURCE ¹	ITEM TOTAL
	Undercut (assume 2' under footprint of berm disposed of onsite) Stabilization Fabric (Synthetic Industries Geotex 4x4 or equal) Stabilization Stone Berm (Assume use of onsite dredge material) Fine grade bottom of pond Grassing	CY SY TN CY AC AC	\$3.09 \$2.75 \$17 \$3.45 \$2.904 \$1,900	12,900 21,500 19,500 43,500 5 9	\$39,861 \$59,125 \$336,375 \$150,075 \$14,520 \$17,100	02315-452-0300 Local Contractor 02370-450-0100 02315-310-5040 02310-100-0100 02920-320-0200	
1.5	Pond Outfall Pump Station and Piping (69 CFS, 48" DIP) ² Mobilization & Demobilization Temporary Facilities and Controls Clearing (assume minor clearing 20' wide x length of pipe) Silt Fence, Type C (assume double row along length of trench) 48" DIP Installed Above Ground 48" DIP Fittings (assume 5% of pipe costs) Pipe Anchor Blocks (assume 2 EA 3'x3'x3' conc @ 100' o.c.) Pipe Anchor Bands (assume 1 EA @ 100' o.c.) Pump Station (3 (+2) EA Flygt CP3400.835-830/335 HP EA w/Backup Generator installed in new facility) Pumping Station Facility and Power Supply Grassing (assume 20' wide x length of pipe) Energy Dissipation Structure, 4 & 8 CY/EA	LS LS AC LF LF EA EA LS LS AC EA	\$200,000 \$200,000 \$282 \$3.00 \$372 \$864.900 \$263 \$525 \$3,270,000 \$1,100,000 \$1,900 \$1,825	1 1 22 93,000 48,600 1 940 470 1 1 22 1	\$200,000 \$200,000 \$5,764 \$279,000 \$17,298,000 \$364,900 \$247,220 \$246,750 \$3,270,000 \$1,100,000 \$41,800 \$1,825	02230-200-0600 Recent experience 02510-730-3000 and American Pipe 03310-240-3800 05540-200-0300 (assume 1/4" x 12" band over pipe) Dana Reid of ITT Flygt Corporation, (Email Dated 3/28/05, 5:03 PM). Added 50% for installation, \$250,000 for Generator and \$20,000 for instrumentation Recent experience (Mirsada llic) 02920-320-0200 03310-240-4200, GDOI STD 1125 Table I	\$23,755,259
	SUBTOTAL: Contingency TOTAL:						\$33,116,016 \$9,934,805 \$43,050,821

1) Source of unit costs (unless otherwise noted): "Heavy Construction Cost Data 2004", by RS Means Company, Inc.

2) Approximately 24 hours required to empty pond at 69 cfs.

Preliminary Screening Level Opinion of Construction Cost

Prepared by: Roger O. Blackwell
Checked by: Stephen A. Lind
6/6/05

Option II. Reroute Only International Paper & Pump from Pond

ITEM	WORK DESCRIPTION	UNIT	UNIT PRICE	EST QTY	LINE TOTAL	COST SOURCE ¹	ITEM TOTAL
1.0	Option II-A-2, 12 Hr. HRT, Pumped to Discharge Point #2						
1.2	International Paper Pump Station and Piping to Pond (30 MGD, 36" DIP) Mobilization & Demobilization Temporary Facilities and Controls Clearing (assume minor clearing 20' wide x length of trench) Silt Fence, Type C (assume double row along length of trench) Trench Excavation (assume 4' bottom, 1:1 side slopes & 4' cover over pipe) 36" DIP, Class 150 installed in Trench 36" DIP Fittings (assume 5% of pipe cost) Trench Backfill Jacking/Receiving Pits (excludes dewatering) Microtunneling, 48" Diameter (includes casing) 36" DIP, Class 150 installed in Casing 8" Air Release Valve	LS LS AC LF CY LF LS CY EA LF LF EA	\$200,000 \$200,000 \$262 \$3,000 \$2,54 \$159 \$59,625 \$2,44 \$19,300 \$960 \$159 \$4,500	1 1 4 15,000 21,500 7,500 1 19,500 2 5,000 5,000 2	\$200,000 \$200,000 \$1,048 (02230-200-0600) \$45,000 Recent experience \$54,610 (02315-610-0610) \$1,192,500 (02510-730-3000 and American Pipe) \$59,625 \$47,580 (02315-610-3020, 02315-310-5040) \$38,600 (02445-300-1101) \$4,800,000 (02441-400-0110 (adverse conditions)) \$795,000 (02510-730-3000 and American Pipe) \$9,000 Doug Andrews at Apco Valves. 50% Added for Installation		\$8,326,343
	6' Dia Precast MH, 7' Deep Energy Dissipation Structure, 3:1 C/V/E Pumps w/Controls, Instrumentation and Backup Generator (3 (+2) Each Flglt CP3356/810 Impeller/480mm/135HP Each). Assume housed in existing facility with power from existing facility. Grassing (assume 20' wide x length of trench)	EA EA LS AC	\$2,300 \$1,180 \$870,000 \$1,900	2 1 1 4	\$4,600 (02630-400-1200&1210) \$1,180 (03310-240-4200, GDOT STD 1125 Table 1) \$870,000 Dana Reid and John Rodriguez of ITT Flygt Corporation, (Emails Dated 3/18/05, 2:46 PM and 3:03 PM). Added 50% for Installation, \$100,000 for Generator and \$20,000 for Instrumentation. \$7,600 (02920-320-0200)		
1.4	Pond Construction, HRT 12 Hrs, 5.1 AC x 9' Deep Mobilization & Demobilization Temporary Facilities and Controls Clearing (assume minor clearing) Silt Fence, Type C (assume double row around perimeter of work area)	LS LS AC LF	\$200,000 \$200,000 \$262 \$3,000	1 1 9 5,000	\$200,000 \$200,000 \$2,358 (02230-200-0600) \$15,000 Recent experience		\$1,034,414

ITEM	WORK DESCRIPTION	UNIT	UNIT PRICE	EST QTY	LINE TOTAL	COST SOURCE ¹	ITEM TOTAL
	Undercut (assume 2' under footprint of berm disposed of onsite) Stabilization Fabric (Synthetic Industries Geotex 4x4 or equal) Stabilization Stone Berm (Assume use of onsite dredge material) Fine grade bottom of pond Grassing	CY SY TN CY AC AC	\$3.09 \$2.75 \$17 \$3.45 \$2,904 \$1,900	12,900 21,500 19,500 43,500 5 9	\$39,861 \$59,125 \$336,375 \$150,075 \$14,520 \$17,100	02315-452-0300 Local Contractor 02370-450-0100 02315-520-0190, 02316-310-5040 02310-100-0100 02920-320-0200	
1.5	Pond Outfall Pump Station and Piping (69 CFS, 54" DIP)² Mobilization & Demobilization Temporary Facilities and Controls Clearing (assume minor clearing 20' wide x length of pipe) Silt Fence, Type C (assume double row along length of trench) 54" DIP Installed Above Ground 54" DIP Fittings (assume 5% of pipe costs) Pipe Anchor Blocks (assume 2 EA 3'x3'3" conc @ 100' o.c.) Pipe Anchor Bards (assume 1 EA @ 100' o.c.) Pump Station (3 (+2) EA Flygt CP3400 835-830/335 HP EA w/Backup Generator installed in new facility) Pumping Station Facility and Power Supply Grassing (assume 20' wide x length of pipe) Energy Dissipation Structure, 5.8 CY/EA	LS LS AC LF LF EA EA LS LS AC EA	\$200,000 \$200,000 \$262 \$3.00 \$456 \$1,675,800 \$263 \$525 \$3,270,000 \$1,100,000 \$1,900 \$2,205	1 1 34 147,000 73,500 1 1,470 735 1 1 34 1	\$200,000 \$200,000 \$8,908 \$441,000 \$33,516,000 \$1,675,800 \$386,610 \$395,875 \$3,270,000 \$1,100,000 \$64,600 \$2,205	 Recent experience 02230-200-0600 02510-730-3000 and American Pipe 03370-240-3800 05540-200-0300 (assume 1/4" x 12" band over pipe) Dana Reid of ITT Flygt Corporation, Email Dated 3/28/05, 5:03 PM), Added 50% for Installation, \$250,000 for Generator and \$20,000 for Instrumentation Recent experience (Mirsada Ilic) 02920-320-0200 03310-240-4200, GDOT STD 1125 Table I	\$41,250,998
	SUBTOTAL: Contingency TOTAL:					 30%	\$50,611,755 \$15,183,527 \$65,795,282

¹) Source of unit costs (unless otherwise noted): "Heavy Construction Cost Data 2004", by RS Means Company, Inc.

²) Approximately 24 hours required to empty pond at 69 cfs.

Preliminary Screening Level Opinion of Construction Cost

Prepared by: Roger O. Blackwell
Checked by: Stephen A. Lind 6/6/05

Option II, Reroute Only International Paper & Pump from Pond

ITEM	WORK DESCRIPTION	UNIT	UNIT PRICE	EST QTY	LINE TOTAL	COST SOURCE ¹	ITEM TOTAL
1.0	Option II-B-1, 30 Day HRT, Pumped to Discharge Point #1						
1.2	International Paper Pump Station and Piping to Pond (30 MGD, 36" DIP) Mobilization & Demobilization Temporary Facilities and Controls Clearing (assume minor clearing 20' wide x length of trench) Silt Fence, Type C (assume double row along length of trench) Trench Excavation (assume 4' bottom, 1:1 side slopes & 4' cover over pipe) 36" DIP, Class 150 installed in Trench 36" DIP Fittings (assume 5% of pipe cost) Trench Backfill Jacking/Receiving Pits (excludes dewatering) Microtunneling, 48" Diameter (includes casing) 36" DIP, Class 150 installed in Casing 8" Air Release Valve	LS LS AC LF CY LF LS CY EA LF LF EA	\$200,000 \$200,000 \$262 \$3,000 \$2,54 \$159 \$59,625 \$2,44 \$19,300 \$960 \$159 \$4,500	1 1 4 15,000 21,500 7,500 1 19,500 2 5,000 5,000 2	\$200,000 \$200,000 \$1,048 \$45,000 Recent experience \$54,610 \$1,192,500 \$59,625 \$47,580 \$38,600 \$4,800,000 \$795,000 \$9,000	02230-200-0600 Recent experience 02315-610-0610 02510-730-3000 and American Pipe 02315-610-3020, 02315-310-5040 02445-300-1101 02441-400-0110 (adverse conditions) 02510-730-3000 and American Pipe Doug Andrews at Apco Valves, 50% Added for installation	\$8,326,343
	6' Dia Precast MH, 7' Deep Energy Dissipation Structure, 3.1 CY/EA Pumps w/Controls, Instrumentation and Backup Generator (3 (+2) Each Flygt CP3356/810 Impeller/480mm/135HP Each). Assume housed in existing facility with power from existing facility. Grassing (assume 20' wide x length of trench)	EA EA LS AC	\$2,300 \$1,180 \$870,000 \$1,900	2 1 1 4	\$4,600 \$1,180 \$870,000 \$7,600	02630-400-1200&1210 SDOT STD 1125 Table I Dana Reid and John Rodriguez of ITT Flygt Corporation, (Emails Dated 3/18/05, 2:46 PM and 3:03 PM) Added 50% for Installation, \$100,000 for Generator and \$20,000 for Instrumentation 02920-320-0200	\$6,620,645
1.4	Pond Construction, HRT 30 Days, 307 AC x 3' Deep Mobilization & Demobilization Temporary Facilities and Controls Clearing (assume minor clearing) Silt Fence, Type C (assume double row around perimeter of work area)	LS LS AC LF	\$200,000 \$200,000 \$262 \$3,000	1 1 340 33,500	\$200,000 \$200,000 \$89,080 \$100,500	Recent experience 02230-200-0600	

ITEM	WORK DESCRIPTION	UNIT	UNIT PRICE	EST QTY	LINE TOTAL	COST SOURCE ¹	ITEM TOTAL
	Undercut (assume 2' under footprint of berm disposed of onsite) Stabilization Fabric (Synthetic Industries Geotex 4x4 or equal) Stabilization Stone Berm (Assume use of onsite dredge material) Fine grade bottom of pond Grassing	CY SY TN CY AC AC	\$3.09 \$2.75 \$17 \$3.45 \$2,904 \$1,900	99,500 164,500 148,000 335,500 315 340	\$307,455 \$452,375 \$2,553,000 \$1,157,475 \$914,760 \$846,000	02315-452-0300 Local Contractor 02370-450-0100 02315-520-0190, 02315-310-5040 02310-100-0100 02920-320-0200	
1.5	Pond Outfall Pump Station and Piping (69 CFS, 48" DIP) ² Mobilization & Demobilization Temporary Facilities and Controls Clearing (assume minor clearing 20' wide x length of pipe) Silt Fence, Type C (assume double row along length of trench) 48" DIP Installed Above Ground 48" DIP Fittings (assume 5% of pipe costs) Pipe Anchor Blocks (assume 2 EA 3'x3'x3' conc @ 100' o.c.) Pipe Anchor Bands (assume 1 EA @ 100' o.c.) Pump Station (3 (+2) EA Flygt CP1400 835-830/335 HP EA w/Backup Generator Installed in new facility) Pumping Station Facility and Power Supply Grassing (assume 20' wide x length of pipe) Energy Dissipation Structure, 4.8 C/EA	LS LS AC LF LF EA EA LS LS AC EA	\$200,000 \$200,000 \$282 \$3.00 \$372 \$809,100 \$263 \$525 \$3,270,000 \$1,100,000 \$1,900 \$1,825	1 1 20 87,000 43,500 870 435 1 1 20 1	\$200,000 \$200,000 \$5,240 \$261,000 \$16,182,000 \$809,100 \$228,810 \$228,375 \$3,270,000 \$1,100,000 \$38,000 \$1,825	Recent experience 02510-730-3000 and American Pipe 03310-240-3800 06540-200-0300 (assume 1/4" x 12" band over pipe) Dana Reid of ITT Flygt Corporation, Email Dated 3/28/05, 5:03 PM), -Added 50% for Installation, \$250,000 for Generator and \$20,000 for Instrumentation. Recent experience (Mrsada lic) 02920-320-0200 03310-240-4200, GDOT STD 1125 Table I	\$22,524,350
	SUBTOTAL ¹ Contingency TOTAL:					30%	\$37,471,338 \$11,241,401 \$48,712,739

1) Source of unit costs (unless otherwise noted): "Heavy Construction Cost Data 2004", by RS Means Company, Inc.

2) Approximately 60 days required to empty pond at 89 cfs.

Revised:

Prepared by:

Roger O. Blackwell

Checked by:

Stephen A. Lind
6/6/05

Preliminary Screening Level Opinion of Construction Cost

Option II, Reroute Only International Paper & Pump from Pond

ITEM	WORK DESCRIPTION	UNIT	UNIT PRICE	EST QTY	LINE TOTAL	COST SOURCE ¹	ITEM TOTAL
1.0	Option II-B-2, 30 Day HRT, Pumped to Discharge Point #2						
1.2	International Paper Pump Station and Piping to Pond (30 MGD, 36" DIP) Mobilization & Demobilization Temporary Facilities and Controls Clearing (assume minor clearing 20' wide x length of trench) Silt Fence, Type C (assume double row along length of trench) Trench Excavation (assume 4' bottom, 1:1 side slopes & 4' cover over pipe) 36" DIP, Class 150 Installed in Trench 36" DIP Fittings (assume 5% of pipe cost) Trench Backfill Jacking/Receiving Pits (excludes dewatering) Microtunneling, 48" Diameter (includes casting) 36" DIP, Class 150 Installed in Casing 8" Air Release Valve	LS LS AC LF CY LF LS CY EA LF LF EA	\$200,000 \$200,000 \$262 \$3,00 \$2,54 \$159 \$59,625 \$2,44 \$19,300 \$960 \$159 \$4,500	1 1 4 15,000 21,500 7,500 1 19,500 2 5,000 5,000 2	\$200,000 \$200,000 \$1,048 \$54,610 \$1,192,500 \$59,625 \$47,580 \$38,600 \$4,800,000 \$795,000 \$9,000	02230-200-0600 Recent experience 02315-610-0610 022510-730-3000 and American Pipe 02315-610-3020, 02315-310-5040 02445-300-1101 02441-400-0110 (adverse conditions) 02510-730-3000 and American Pipe Doug Andrews at Apco Valves, 50% Added for Installation	\$8,326,343
	6' Dia Precast MH, 7' Deep Energy Dissipation Structure, 3.1 CY/EA Pumps w/Controls, Instrumentation and Backup Generator (3 (+2) Each Flygt CP3356/810 Impeller/430mm/135HP Each). Assume housed in existing facility with power from existing facility. Grassing (assume 20' wide x length of trench)	EA EA LS AC	\$2,300 \$1,180 \$870,000 \$1,900	2 1 1 4	\$4,600 \$1,180 \$870,000 \$7,600	02630-400-1200&1210 02310-240-4200, GDOT STD 1125 Table 1 Dana Reid and John Rodriguez of ITT Flygt Corporation, (Emails Dated 3/18/05, 2:46 PM and 3:03 PM). Added 50% for Installation, \$100,000 for Generator and \$20,000 for Instrumentation. 02920-320-0200	
1.4	Pond Construction, HRT 30 Days, 307 AC x 8' Deep Mobilization & Demobilization Temporary Facilities and Controls Clearing (assume minor clearing) Silt Fence, Type C (assume double row around perimeter of work area)	LS LS AC LF	\$200,000 \$200,000 \$262 \$3,00	1 1 340 33,500	\$200,000 \$200,000 \$89,080 \$100,500	02230-200-0600 Recent experience	\$6,620,645

ITEM	WORK DESCRIPTION	UNIT	UNIT PRICE	EST QTY	LINE TOTAL	COST SOURCE ¹	ITEM TOTAL
	Undercut (assume 2' under footprint of berm disposed of onsite) Stabilization Fabric (Synthetic Industries Geotex 4x4 or equal) Stabilization Stone Berm (Assume use of onsite dredge material) Fine grade bottom of pond Grassing	CY SY TN CY AC AC	\$3.09 \$2.75 \$17 \$3.45 \$2,904 \$1,900	99,500 164,500 148,000 335,500 315 340	\$307,455 \$452,375 \$2,553,000 \$1,157,475 \$914,760 \$546,000	023115-452-0300 Local Contractor 02370-450-0100 023115-520-0190, 023115-310-5040 02310-100-0100 02920-320-0200	
1.5	Pond Outfall Pump Station and Piping (69 CFS, 54" DIP) ² Mobilization & Demobilization Temporary Facilities and Controls Clearing (assume minor clearing 20' wide x length of pipe) Silt Fence, Type C (assume double row along length of trench) 54" DIP Installed Above Ground 54" DIP Fittings (assume 5% of pipe costs) Pipe Anchor Blocks (assume 2 EA 3'x3'x3' conc @ 100' o.c.) Pipe Anchor Bands (assume 1 EA @ 100' o.c.) Pump Station (3 (+2) EA Flygt CP3400 835-830/325 HP EA w/Backup Generator installed in new facility) Pumping Station Facility and Power Supply Grassing (assume 20' wide x length of pipe) Energy Dissipation Structure, 5.8 CV/EA	LS LS AC LF LF EA EA LS LS AC EA	\$200,000 \$200,000 \$282 \$3,000 \$496 \$1,607,400 \$263 \$525 \$3,270,000 \$1,100,000 \$1,900 \$2,205	1 1 32 141,000 70,500 1 1,410 705 1 1 32 1	\$200,000 \$200,000 \$8,384 \$423,000 \$32,148,000 \$1,607,400 \$370,630 \$370,125 \$3,270,000 \$1,100,000 \$60,800 \$2,205	023115-452-0300 02230-200-0500 Recent experience 02510-730-3000 and American Pipe 02310-240-3800 05540-200-0300 (assume 1/4" x 12" band over pipe) Dana Reid of ITT Flygt Corporation, Email Dated 3/28/05, 5:03 PM). Added 50% for installation, \$250,000 for Generator and \$20,000 for Instrumentation. Recent experience (Misada llc) 02920-320-0200 03310-240-4200, GDOT STD 1125 Table I	\$39,760,744
	SUBTOTAL: Contingency TOTAL:						\$54,707,732 \$16,412,320 \$71,120,052

1) Source of unit costs (unless otherwise noted): "Heavy Construction Cost Data 2004", by RS Means Company, Inc.

2) Approximately 60 days required to empty pond at 69 cfs.

ITEM	WORK DESCRIPTION	UNIT	UNIT PRICE	EST QTY	LINE TOTAL	COST SOURCE ¹	ITEM TOTAL
	Undercut (assume 2' under footprint of berm disposed of onsite) Stabilization Fabric (Synthetic Industries Geotex 4/4 or equal) Stabilization Stone Berm (Assume use of onsite dredge material) Fine grade bottom of pond Grassing	CY SY TN CY AC AC	\$3.09 \$2.75 \$17 \$3.45 \$2,904 \$1,900	128,000 210,500 190,000 430,000 615 660	\$395,520 \$578,875 \$3,277,500 \$1,483,500 \$1,785,960 \$1,235,000	02315-452-0300 Local Contractor 02370-460-0100 02315-520-0100 02315-310-5040 02310-100-0100 02320-320-0200	
1.5	Pond Outfall Pump Station and Piping (92 CFS, 54" DIP) ² Mobilization & Demobilization Temporary Facilities and Controls Clearing (assume minor clearing 20' wide x length of pipe) Silt Fence, Type C (assume double row along length of trench) 54" DIP Installed Above Ground 54" DIP Fittings (assume 5% of pipe costs) Pipe Anchor Blocks (assume 2 EA 3'x3'x3' conc @ 100' o.c.) Pipe Anchor Bands (assume 1 EA @ 100' o.c.) Pump Station (3 (+2) EA Flygt CP3400-835-930/335 HP EA w/Backup Generator installed in new facility) Pumping Station Facility and Power Supply Grassing (assume 20' wide x length of pipe) Energy Dissipation Structure, 5.8 C/VEA	LS LS AC LF LF EA EA LS LS AC EA	\$200,000 \$200,000 \$262 \$3.00 \$456 \$534,800 \$263 \$525 \$3,270,000 \$1,100,000 \$1,900 \$2,205	1 1 19 32,000 41,000 820 410 1 1 19 1	\$200,000 \$200,000 \$4,978 \$248,000 \$18,696,000 \$934,800 \$215,660 \$215,250 \$3,270,000 \$1,100,000 \$36,100 \$2,205	 02230-200-0600 Recent experience 02510-730-3000 and American Pipe 03310-240-3800 05640-200-0300 (assume 1/4" x 12" band over pipe) Dana Reid of ITT Flygt Corporation, Email Dated 3/28/05, 5:03 PM), Added 50% for Installation, \$250,000 for Generator and \$20,000 for Instrumentation. Recent experience (Mirasada llc) 02920-320-0200 03310-240-4200, GDOT STD 1125 Table I	\$25,120,993
	SUBTOTAL: Contingency TOTAL:						\$42,902,991 \$12,870,897 \$55,773,888

1) Source of unit costs (unless otherwise noted): "Heavy Construction Cost Data 2004", by RS Means Company, Inc.

2) Approximately 60 days required to empty pond at 92 cfs.

Preliminary Screening Level Opinion of Construction Cost

Prepared by: Roger O. Blackwell
Checked by: Stephen A. Lind
6/6/05

Option II, Reroute Only International Paper & Pump from Pond

ITEM	WORK DESCRIPTION	UNIT	UNIT PRICE	EST QTY	LINE TOTAL	COST SOURCE ¹	ITEM TOTAL
1.0	Option II-C-2, 60 Day HRT, Pumped to Discharge Point #2						
1.2	International Paper Pump Station and Piping to Pond (30 MGD, 36" DIP) Mobilization & Demobilization Temporary Facilities and Controls Clearing (assume minor clearing 20' wide x length of trench) Silt Fence, Type C (assume double row along length of trench) Trench Excavation (assume 4' bottom, 1:1 side slopes & 4' cover over pipe) 36" DIP, Class 150 installed in Trench 36" DIP Fittings (assume 5% of pipe cost) Trench Backfill Jacking/Receiving Pits (excludes dewatering) Microtunneling, 48" Diameter (includes casing) 36" DIP, Class 150 Installed in Casing 8" Air Release Valve 6' Dia Precast MH, 7' Deep Energy Dissipation Structure, 3:1 CY/EA Pumps w/Controls, Instrumentation and Backup Generator (3 (+2) Each Flygt CP3356/810 Impeller/480mm/135HP Each). Assume housed in existing facility with power from existing facility. Grassing (assume 20' wide x length of trench)	LS LS AC LF CY LF LS CY EA LF LF EA EA EA LS AC	\$200,000 \$200,000 \$262 \$3,000 \$2,54 \$159 \$59,625 \$2,44 \$19,300 \$660 \$159 \$4,500 \$2,300 \$1,180 \$870,000 \$1,900	1 1 4 15,000 21,500 7,500 1 19,500 2 5,000 5,000 2 2 1 4	\$200,000 \$200,000 \$1,048 \$45,000 \$54,810 \$1,192,500 \$59,625 \$47,580 \$38,600 \$4,800,000 \$795,000 \$9,000 \$4,600 \$1,180 \$870,000 \$7,600	02230-200-0600 Recent experience 02315-610-0610 02510-730-3000 and American Pipe 02315-610-3020, 02315-310-5040 02445-300-1101 (adverse conditions) 02510-730-3000 and American Pipe Doug Andrews at Apco Valves. 50% Added for Installation 02630-400-1200&1210 03310-240-4200, GDOT STD 1125 Table I Dana Reid and John Rodriguez of ITT Flygt Corporation, (Emails Dated 3/18/05, 2:45 PM and 3:03 PM), Added 50% for Installation \$100,000 for Generator and \$20,000 for Instrumentation. 02920-320-0200	\$9,326,343
1.4	Pond Construction, HRT 60 Days, 614 AC x 9' Deep Mobilization & Demobilization Temporary Facilities and Controls Clearing (assume minor clearing) Silt Fence, Type C (assume double row around perimeter of work area)	LS LS AC LF	\$200,000 \$200,000 \$262 \$3,000	1 1 650 43,000	\$200,000 \$200,000 \$170,300 \$129,000	02230-200-0600 Recent experience	\$9,465,655

ITEM	WORK DESCRIPTION	UNIT	UNIT PRICE	EST QTY	LINE TOTAL	COST SOURCE ¹	ITEM TOTAL
	Undercut (assume 2' under footprint of berm disposed of onsite)	CY	\$3.09	128.000	\$395,520	02315-452-0300	
	Stabilization Fabric (Synthetic Industries Geotex 4x4 or equal)	SY	\$2.75	210.000	\$578,875	Local Contractor	
	Berm (Assume use of onsite dredge material)	TN	\$17	190.000	\$3,277,500	02370-450-0100	
	Fine grade bottom of pond	CY	\$3.45	430.000	\$1,483,500	02315-520-0190, 02315-310-5040	
	Grassing	AC	\$2,904	615	\$1,785,960	02310-100-0100	
		AC	\$1,900	650	\$1,235,000	02920-320-0200	
1.5	Pond Outfall Pump Station and Piping (92 CFS, 60" DIP)²						\$44,517,907
	Mobilization & Demobilization	LS	\$200,000	1	\$200,000		
	Temporary Facilities and Controls	LS	\$200,000	1	\$200,000		
	Clearing (assume minor clearing 20' wide x length of pipe)	AC	\$262	31	\$8,122	02230-200-0600	
	Silt Fence, Type C (assume double row along length of trench)	LF	\$3.00	135,000	\$405,000	Recent experience	
	60" DIP Installed Above Ground	LF	\$540	65,000	\$36,720,000	02510-730-3000 and American Pipe	
	60" DIP Fittings (assume 5% of pipe costs)	LF	\$1,836,000	1	\$1,836,000		
	Pipe Anchor Blocks (assume 2 EA 3'x3'x3' conc @ 100' o.c.)	EA	\$263	1,360	\$357,680	03310-240-3500	
	Pipe Anchor Bands (assume 1 EA @ 100' o.c.)	EA	\$525	680	\$357,000	05540-200-0300 (assume 1/4" x 12" band over pipe)	
	Pump Station (3 (+2) EA Flygt CP3400.835-830/335 HP EA w/Backup Generator installed in new facility)	LS	\$3,270,000	1	\$3,270,000	Dana Reid of ITT Flygt Corporation, Email Dated 3/28/05, 5:03 PM). Added 50% for Installation, \$250,000 for Generator and \$20,000 for Instrumentation.	
	Pumping Station Facility and Power Supply	LS	\$1,100,000	1	\$1,100,000	Recent experience (Misada llc)	
	Grassing (assume 20' wide x length of pipe)	AC	\$1,900	31	\$58,900	02920-320-0200	
	Energy Dissipation Structure, 5.8 CY/EA	EA	\$2,205	1	\$2,205	03310-240-4200, GDOT STD 1125 Table I	
	SUBTOTAL:						\$52,259,905
	Contingency					30%	\$18,689,972
	TOTAL:						\$60,989,877

1) Source of unit costs (unless otherwise noted): "Heavy Construction Cost Data 2004", by RS Means Company, Inc.

2) Approximately 60 days required to empty pond at 92 cfs.

**SAVANNAH HARBOR REOXYGENATION
DEMONSTRATION PROJECT**

SAVANNAH, GEORGIA

Prepared for:

GEORGIA PORTS AUTHORITY

Savannah, Georgia

January 8, 2008

**SAVANNAH HARBOR REOXYGENATION
DEMONSTRATION PROJECT**

SAVANNAH, GEORGIA

Prepared for:

GEORGIA PORTS AUTHORITY

Savannah, Georgia

Prepared by:

MACTEC ENGINEERING AND CONSULTING, INC.

January 8, 2008

MACTEC Project Number: 6110-07-0004

ACKNOWLEDGEMENTS

MACTEC Engineering and Consulting, Inc. (MACTEC) first approached the Georgia Ports Authority (GPA) about a Savannah Harbor reoxygenation (ReOx) demonstration design in late 2006. From these initial discussions, GPA director Doug Marchand was quick to recognize that a successful and timely ReOx demonstration in Savannah Harbor could directly prove the feasibility of large-scale dissolved-oxygen (DO) mitigation in support of GPA's critically-needed harbor-deepening expansion project. So rather than just a ReOx demonstration design as MACTEC had initially envisioned, GPA further challenged MACTEC to also assemble, operate, and monitor the envisioned ReOx demonstration system in time for the upcoming summer "critical season" of 2007. This was an exceptionally fast-track project from the outset and MACTEC deeply appreciates the trust and "can do" spirit that Doug Marchand and his Ports Authority team brought to all phases of the project.

We particularly want to recognize GPA's Hope Moorner, who made it possible to complete the demonstration project with such an accelerated schedule, and Dick Speece, inventor of the Speece Cone superoxygenation technology, whose wise counsel made it possible to quickly adapt the technology for full-scale application in such a large tidal system as Savannah Harbor.

MACTEC would also like to acknowledge the subcontractors and equipment suppliers who contributed to the work and participated to a major degree at one stage or another during the ReOx Demonstration Project as follows: Eco-Oxygen Technologies (ECO2), Savannah Marine Services, Georgia Power, Godwin Pumps, Air Liquide, The Industrial Company, YSI Instruments, and Pine Environmental. The individuals representing these companies contributed their time and, more importantly, their technical skills and knowledge without reservation and the successful and timely completion of the demonstration project is a direct result of their collective efforts.

In addition, MACTEC acknowledges the dedicated MACTEC employees who spent long hours on the harbor in the hot summer months to develop the documentation needed for this report.

ACRONYMS

cfs	cubic feet per second
DO	dissolved oxygen
DVD	Digital Versatile Disc
EPD	Georgia Environmental Protection Division
GPA	Georgia Ports Authority
gpm	gallons per minute
KITB	Kings Island Turning Basin
MG	million gallons
mg/L	milligrams per liter
O&M	operation and maintenance
ppd	pounds per day
ppt	part per thousand
QA/QC	quality assurance/quality control
ReOx	ReOxygenation
RM	River Mile
ROM	rough order of magnitude
SC DHEC	South Carolina Department of Health and Environmental Control
TMDL	Total Maximum Daily Load
USACE	U.S. Army Corps of Engineers, Savannah District
USEPA	U.S. Environmental Protection Agency Region IV
USGS	United States Geological Survey
YSI	Yellow Springs Instrument Company

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EXECUTIVE SUMMARY

Background

Modeling previously performed by the U.S. Army Corps of Engineers (USACE) indicated that proposed further deepening of Savannah Harbor would result in lost recreation capacity and that the lost recreation could be offset (i.e., mitigated) by the addition of approximately 20,000 pounds per day (ppd) of dissolved oxygen (DO) to the deepened harbor during the critical summer months. The 20,000 ppd figure is called the DO "mitigation amount", (TetraTech, 2007).

On March 23, 2007, MACTEC Engineering & Consulting, Inc. (MACTEC) was contracted by the Georgia Ports Authority (GPA) to conduct an accelerated full-scale demonstration of "Speece Cone" oxygenation technology in Savannah Harbor as possible DO mitigation in support of harbor deepening. A temporary re-oxygenation (ReOx) demonstration system was designed, assembled, and operated in the harbor for a 40-day test period beginning August 7, 2007 and ending September 16, 2007. The Savannah Harbor ReOxygenation Demonstration Project was performed so that questions regarding the performance of the Speece Cone technology could be addressed. This report presents the ReOx demonstration project results and provides recommendations for permanent ReOx installations.

Project Goal

The goal of the ReOx demonstration project was to prove that the DO mitigation amount of 20,000 ppd could be added to the harbor during the summer critical season and that the resulting instream DO response could be determined through instream DO monitoring.

ReOx demonstration system configuration

The ReOx demonstration system consisted of two custom-built, 12-foot diameter ECO2 Speece Cones with river water supplied by four 400-horsepower water intake pumps mounted on a 110-foot barge temporarily moored at The Industrial Company waterfront property on Hutchinson Island (river mile [RM] 14.1). Electrical power for the water intake pumps was supplied from a temporary on-shore transformer and oxygen for the Speece Cones was supplied from a liquid oxygen storage tank located on land. Liquid oxygen was delivered to the storage tank by truck every 24 to 36 hours during the 40-day demonstration period.

Speece Cone operating principles

The two Speece Cones have a combined pure oxygen dissolution maximum design capacity of approximately 30,000 ppd. The nominal water-flow capacity for the pump configuration was about 15,000 gallons per minute (gpm) at a hydraulic head of 150 feet (in the center of the cones). In operation, water was continuously pumped from the river at a depth of about 10 feet and delivered under pressure to the small-diameter top of the Speece Cones where pure oxygen bubbles are added to the incoming water flow. As the water and oxygen bubble mixture is forced downward inside the expanding cross section of the cones, the downward force of the flowing water counteracts the natural buoyancy of the pure oxygen bubbles and, thereby, suspends an oxygen "bubble swarm" inside the cones. The extended bubble-swarm contact time with the down-flowing water results in superoxygenation of the water exiting the bottom of the cones. This superoxygenated flow from the Speece Cones was piped directly back to the river to a depth of about 30 feet and mixed in the river by tidal action, without benefit of a diffuser. Some effervescence of oxygen was evidenced at the water surface in the form of rising fine bubbles. Toward

the end of the 40-day test period, additional coarse-bubble oxygen releases were episodically observed due to diminishing pump-flow capacity caused by the progression of intake-screen fouling.

Limited down time experienced

Over the 40-day demonstration period, the ReOx system operated for a total of 39 days. Down time was due to occasional equipment malfunction, running out of oxygen (twice), pump maintenance, and intake screen cleaning.

27,000 pounds per day of oxygen added to the harbor

A total of 1,272,080 pounds of oxygen was delivered and consumed over 39 days of ReOx system operation, giving an average oxygen consumption rate of 32,600 ppd. The overall transfer efficiency was 85 percent for the temporary demonstration system with some loss during tank filling, the average amount of oxygen added to the river was about 27,000 ppd. The oxygen concentration delivered from the cones to the river ranged from about 120 to 180 milligrams per liter (mg/L).

Instream monitoring to estimate DO improvement

Intensive instream DO monitoring was conducted before, during, and after the 40-day operating period in order to estimate the level of DO improvement resulting from operation of the ReOx demonstration system. Fixed-location continuous monitoring included shallow, middle, and deep zone multi-parameter recording instruments deployed at three near-shore locations: GPA Berth 20 dock at river mile (RM) 15.6, ReOx barge at RM 14.1, and USACE dock at RM 13.7. Periodic manual instream monitoring included repeated slack-tide longitudinal full-depth profiles at mid channel and cross-channel transects at five locations spaced along a three-mile river "target segment" centered on the ReOx barge location. Parameters measured or computed included: water temperature, DO concentration, DO saturation percentage, DO deficit, pH, conductivity, salinity, water density, and instrument depth.

Photosynthesis and respiration evident

The continuous near-shore monitoring results, at shallow and mid depth, often showed daily DO patterns indicative of light-driven photosynthesis and respiration with maximum DO concentrations occurring in the late afternoon and minimums occurring at dawn. This photosynthetic and respiration effect has no impact on the Speece Cone oxygen addition technology as long as instream DO concentrations at the shallow depth remain below saturation concentrations as was the case throughout the demonstration project.

ReOx system reduces target segment average DO deficit by 0.6 to 0.7 mg/L

Mid-channel low-tide longitudinal DO profiles show a target-segment average DO deficit (DO deficit is defined in Section 3.0, Page 3-1) of 3.9 mg/L just before the ReOx system began operation on August 7, 2007. After about one month of ReOx system operation, the average mid-channel low tide DO deficit was reduced to 3.3 mg/L and after the ReOx system had been shut down for about one week at the end of the 40-day demonstration period, the target segment low-tide DO deficit had returned back to the starting baseline deficit of 3.9 mg/L. This means that the ReOx system operation reduced the mid-channel average low tide DO deficit along the three-mile-long target segment by about 0.6 mg/L. Similarly, independent cross-channel transect monitoring at five locations along the target segment showed an average DO deficit reduction of about 0.7 mg/L during the ReOx demonstration period which compares favorably to the 0.6 mg/L DO deficit reduction determined from the longitudinal mid-channel profiles.

Delayed instream DO response a stabilizing benefit

Instream DO monitoring shows that it takes about three continuous days of oxygen addition to begin reducing mid-channel DO deficits and that some residual effects of oxygen addition remain locally evident near the ReOx barge for about one week after oxygen addition is ended. This delayed DO response is not unexpected for such a large and dispersive tidal system like Savannah Harbor and suggests that short interruptions of oxygen addition are not likely to cause an abrupt or significant DO decrease. This same dispersive nature of the harbor system might also be conducive to the timing of daily oxygen additions that coincide with off-peak electric power rates as a potential cost-savings measure.

Recommendations going forward

Overall, the 2007 ReOx demonstration project confirmed that the Speece Cone technology can effectively add the required DO mitigation amount to the harbor and reduce instream DO deficits during critical summer conditions. The demonstration also confirmed the soundness of the prototype design. We recommend the following actions:

- Develop a modular land-based ReOx station design specific to Savannah Harbor conditions, taking into account the "lessons learned" from the 2007 demonstration project.
- Identify, characterize, and acquire suitable shore locations for construction of two land-based dual cone ReOx stations.
- Obtain the necessary permits and approvals for construction and operation of the land-based ReOx stations.
- Construct the foundations and permanent shore-based infrastructure and service access for each ReOx station in advance and make the stations ready for subsequent seasonal installation and operation of the ReOx equipment in concert with harbor deepening.
- Until permanent land based ReOx systems are operational, temporary barge mounted systems could be used to provide oxygen for seasonal mitigation.

1.0 INTRODUCTION

The proposed deepening of Savannah Harbor is critically important to the Georgia Ports Authority (GPA) and the State of Georgia. Without deepening, the Port of Savannah and Georgia risk losing significant business and revenue to other east-coast ports that can accommodate the growing number of larger deep-draft ships. An aerial view of Savannah Harbor with river mile (RM) references is shown on Figure 1-1.

Harbor deepening will have the unintended consequence of reducing atmospheric reaeration into the harbor's deepened water. This reduced reaeration can result in reduced dissolved oxygen (DO) concentrations, particularly during the critical season from about mid June through mid October when river temperatures are higher and lower river flows are more prevalent. Three-dimensional hydrodynamic and water quality monitoring performed by the U.S. Environmental Protection Agency (USEPA) Region 4 and the U.S. Army Corps of Engineers, Savannah District (USACE) indicated that the proposed deepening of Savannah Harbor to 48 feet would result in lost reaeration capacity in the river that equates to a reduction of approximately 20,000 pounds per day in the river DO, (TetraTech, 2007).

The GPA contracted with MACTEC Engineering and Consulting, Inc. (MACTEC) to conduct the Savannah Harbor ReOxygenation (ReOx) Demonstration Project. The ReOx Project was performed to directly demonstrate the feasibility and effectiveness of pure oxygen injection technologies (specifically the Speece Cone) as a mitigation measure for the proposed deepening of the harbor. The ReOx Project was a full-scale temporary installation of the Speece Cone technology conducted in the summer of 2007. The ReOx demonstration system was designed and sized to provide sufficient quantities of oxygen to the harbor to mitigate the expected impacts to the DO levels attributed to the proposed harbor deepening.

As part of the ReOx project, MACTEC conducted extensive river water quality monitoring activities from June through September and evaluated various design features to assess performance of the ReOx system. This report summarizes the project activities and conclusions and presents conceptual design considerations for permanent ReOx systems in the harbor.

1.1 BACKGROUND

The mission of the Georgia Ports Authority is to develop, maintain, and operate ocean and inland river ports within Georgia; foster international trade and new industry for state and local communities; promote Georgia's agricultural, industrial and natural resources; and maintain the natural quality of the

environment. The Savannah River and the Port of Savannah have long been influential in the economic development of Georgia. The Port of Savannah is the second largest container port on the East Coast and is the 4th largest container port in the nation. To maintain its place as a world class container port, the GPA approached the USACE regarding further expansion of the harbor by increasing the capacity of the navigation channel. As part of the federal authorization to deepen the channel, mitigation for environmental impacts from the proposed action must be implemented. Currently, the GPA and the USACE are conducting the Savannah Harbor Expansion Project. Results of the Savannah Harbor Expansion Project have provided assessments of the projected impacts and mitigation requirements for the proposed harbor deepening project. As part of its mission, the GPA is committed to completing environmental mitigation related to further expansion of the harbor, including the expected impacts to the recreation capacity.

In 2005, MACTEC completed a feasibility level study for the USACE that identified and evaluated alternative techniques for improving DO concentrations in the harbor (MACTEC, 2005). Based on the MACTEC study, the USACE identified molecular oxygen injection using the Speece Cone technology as a cost effective technique to improve harbor DO.

In addition to the activities ongoing as part of the Savannah Harbor Expansion Project, the USEPA Region 4, the Georgia Department of Natural Resources, Environmental Protection Division (GA EPD), and the South Carolina Department of Health & Environmental Control (SC DHEC) are coordinating the development of new DO criteria for Savannah Harbor. The completion of this coordinated effort will result in the DO criteria being included in Georgia's Water Quality Standards. The quantity of oxygen added for mitigation of dredging is independent of the DO standard for the harbor because it is the quantity of additional dissolved oxygen needed to offset the predicted DO impacts of the proposed deepening.

1.1.1 SPEECE CONE OPERATING PRINCIPLES

The Speece Cones that were used were each capable of injecting up to 15,000 pounds per day (ppd) of oxygen. The estimate of the oxygen needed for DO mitigation associated with the proposed deepening is 20,000 ppd. The injection of this quantity requires the operation of at least two Speece Cones during summer critical conditions. The nominal water-flow capacity for the pump configuration that supplied water to the Speece Cone was about 15,000 gallons per minute (gpm) at a hydraulic head of 150 feet (in the center of the cones). In operation, water was continuously pumped from the river at a depth of about

10 feet and delivered under pressure to the small-diameter top of the Speece Cones where pure oxygen bubbles were added to the incoming water flow. As the water and oxygen bubble mixture is forced downward inside the expanding cross section of the cones, the downward force of the flowing water counteracts the natural buoyancy of the pure oxygen bubbles and, thereby, suspends an oxygen "bubble swarm" inside the cones. The extended bubble-swarm contact time with the down-flowing water results in superoxygenation of the water exiting the bottom of the cones (Figure 1-2). This superoxygenated flow from the Speece Cones was piped directly back to the river and discharged at a depth of about 30 feet where it was dispersed in the river by tidal action without benefit of a diffuser. Some effervescence of oxygen was evidenced at the water surface in the form of rising fine bubbles. Toward the end of the 40-day test period, additional coarse-bubble oxygen releases were episodically observed due to diminishing pump-flow capacity caused by the progression of intake-screen fouling.

1.1.2 ReOx SYSTEM DESIGN CONSIDERATIONS

The ReOx system was a temporary barge-mounted Speece Cone system capable of providing up to 30,000 ppd of oxygen using two separate Speece Cone systems and was assembled and demonstrated on an accelerated schedule. A barge-mounted ReOx system had several potential advantages that made this approach a good alternative for the GPA.

- Because oxygen addition is typically only a seasonal need (e.g., mid June through mid October), a flexible and modular barge-mounted ReOx system can potentially be dismantled into major components and removed to land storage during the off season, thereby making the barge available for other duty.
- A barge-mounted configuration substantially eliminates the need for landside disturbances. The only landside connection needed is a seasonal power-and-oxygen umbilical running from shore to the moored barge. There is no fixed intake or discharge pipe construction required because these assemblies are attached to the barge.
- A barge-mounted ReOx system can be positioned in the harbor to minimize potential navigation hazards and can be moved on fairly short notice to accommodate harbor emergencies such as approaching meteorological events.
- Obtaining permits and approvals for fabrication and operation of a floating barge-mounted seasonal system is less difficult and time consuming than obtaining the permits and approvals required for fixed land-based installations.
- The Speece Cones fabricated for a barge-mounted system can later be reused in a permanent land-based system.
- Design is easily expanded to meet additional oxygen requirements.
- Optionally, a barge mounted system design could be used until permanent land-based systems are constructed or as the permanent system design during the critical season.

2.0 DEMONSTRATION SYSTEM DESIGN

Because the ReOx demonstration system was a temporary installation, the original design concept incorporated the use of a barge as the base for the re-oxygenation station and the use of available rental equipment. It was determined that the test would require two Speece Cones each capable of transferring a maximum of 15,000 ppd, four 400 horsepower pumps, and a single liquid oxygen storage tank and vaporization system, Figure 2-1. The intake pipes leading to the pumps employed a screen to prevent foreign matter, including debris and fish, from being entrained in the system. The intake screens were mounted to the pipes approximately 8 feet below the water surface (top of the screen) and extended to approximately 12 feet below the water surface (bottom of screen) (Figure 2-2). The return pipes for the cones extended approximately 30 feet below the water surface (Figure 2-2) and were angled to direct the super-oxygenated water toward the center of the navigation channel in the river.

During the conceptual design stage, it was determined, due to the logistics of supply, safety, and environmental issues, that diesel powered pumps and generators were unsuitable. Therefore, electrical power was supplied from a stationary site on shore. Also, due to logistical considerations liquid oxygen converted from liquid to gas on shore, was supplied by use of an umbilical to the barge. Both of these elements were located at the temporary mooring site for the barge at river mile (RM) 14.1.

3.0 SYSTEM PERFORMANCE VERIFICATION

The ReOx system was operated from August 7 to September 16, 2007 and required a total of 1,272,080 lbs of oxygen (provided at the storage tank). This oxygen was dissolved into approximately 837 million gallons (MG) of river water that was reintroduced at a depth of 30 feet below the water surface. The amount of oxygen dissolved into the river system averaged 27,000 ppd over the 39 days of operation. The project demonstrated that it was possible to achieve the main project goal of reliably injecting a minimum of 20,000 ppd of oxygen into the Savannah Harbor system to offset the estimated DO impact from the proposed deepening.

To assess the amount of oxygen added to the river system three checks were in place: 1) A log was kept of the amount of oxygen that was supplied to the liquid oxygen storage tank; 2) Water quality meters (Yellow Springs Instrument Company [YSI] 6920 data sondes) were used to periodically measure a side stream sample of super-oxygenated water from the return pipes; and 3) A control panel attached to each cone recorded flow, temperature, pressure, and oxygen usage. In addition to the three oxygen usage checks, the intake river water DO concentration was also monitored.

As part of the evaluation of the performance of the Speece Cones, extensive instream water quality monitoring was conducted before, during, and after the demonstration period. In analyzing DO data sets for Savannah Harbor, there are many concurrent and variable influences on DO concentrations that can confound interpretation of DO monitoring results. Atmospheric oxygen is only sparingly soluble in water and the DO solubility limit, or DO saturation concentration, is a direct function of water temperature, salinity and barometric pressure for a water sample; colder water can hold more DO than warm water, fresh water can hold more DO than saline water, and all water can hold more atmospheric DO as barometric pressure increases.

The DO deficit is the difference between the calculated DO saturation concentration for the prevailing temperature, salinity, and barometric pressure and the directly measured DO concentration in a water sample. By normalizing the DO concentration data to DO deficit concentrations, the data are, thereby, automatically normalized for the direct and highly variable effects of changes in temperature, salinity, and barometric pressure. Therefore, changes in the DO deficit substantially reflect only those DO changes resulting from factors and processes other than changes in water temperature, salinity, and barometric

pressure. For these reasons, changes in the instream DO deficit distributions are considered the single best direct indicator of oxygen addition results. Therefore, representative measurement of the DO deficit distribution in the target segment of the harbor is a key monitoring objective.

The two Speece Cones (Cone 1 and Cone 2) were turned on August 7 and turned off September 16, 2007. Cone 1 was shutdown for a total of 2 days, 5 hours, and 58 minutes for an effective operation of 37 days, 13 hours, and 9 minutes. The total amount of water pumped through Cone 1 during operations was 418 MG. Cone 2 was shutdown for a total of 21 hours and 54 minutes for a total effective operation of 39 days. The total amount of water pumped through Cone 2 during ReOx operations was 419 MG. Thus, the total amount of water pumped through the pump configuration for two cones was 837 MG. On average the ReOx system pumped at a rate of 15,000 gallons per minute. The demonstration project consumed 960,000 kWh. The energy usage cost approximately \$89,000.

3.1 INFLUENT MONITORING

Continuous water quality monitoring was performed using the 6920 sondes. A sample of river water from the intake side of the cones was pumped to a monitoring station located on the barge deck. Monitoring of the influent began August 4, 2007, approximately three days before startup and continued until September 16, 2007, when the system was turned off. Influent water quality monitoring data are available in Appendix A Geodatabase referenced as Table Intake_Zone located on the Digital Versatile Disc (DVD) provided as part of this report.

Results from continuous monitoring of the intake water are shown in Figure 3-1. The water temperature intake data show a significant nighttime cooling effect on the Savannah River. Additionally, the data indicate that there was no significant short circuiting from the superoxygenated return flow to the intake. The intake DO deficit (daily average) was 3.4 milligrams per liter (mg/L) at startup on August 7, 2007. The smallest DO deficit (daily average) was observed on August 24, 2007 at 2.7 mg/L. During operations, the highest daily average DO deficit measured from the intake was on August 29, 2007 at 3.8 mg/L when the ReOx system was off for a brief time during the day for oxygen flow adjustments.

3.2 OXYGEN USAGE INFORMATION

A total of 1,272,080 pounds of oxygen was delivered and consumed over 39 days, from August 7 to September 16, 2007, of ReOx system operation, giving an average oxygen consumption rate of 32,600 ppd. The overall transfer efficiency was 85 percent for the temporary demonstration system with some loss during tank filling, the average amount of oxygen added to the river was about 27,000 ppd. The oxygen concentration delivered from the cones to the river ranged from about 120 to 180 milligrams per liter (mg/L). Return flow concentrations varied with flow rates through the cones.

3.3 SPEECE CONES DATA REPORTING

The control panel on each Speece Cone records oxygen flow rates entering the cone, the intake water flow rate, water temperature, and system pressure. These data are shown graphically on Figures 3-1 through 4-2 and the data are in Appendix A. Each cone was set to have a nominal oxygen flow of 15,000 ppd. During the ReOx system operation, it was noted that Cone 2 was not performing similar to Cone 1. The oxygen flow valve on Cone 2 (31 percent) was opened significantly less than Cone 1 (46 percent) and fewer bubbles were noted in the view ports on Cone 2. Discussions with the Speece Cone representatives concluded that the oxygen flow meter on Cone 2 was likely mis-calibrated and that the oxygen flow in Cone 2 was too low previously. Therefore, after several oxygen flow ramp-up tests on August 29 and August 30, 2007 were conducted, an appropriate setting for the percent open for the oxygen flow valve for Cone 2 was determined. Once completed, the oxygen flow range setting on the control panel was adjusted to represent a set oxygen flow of 15,000 ppd for Cone 2. Both flow meters (Cones 1 and 2) were returned to the manufacturer after completion of the demonstration project and recalibrated so that they can be reinstalled when the cones are redeployed at a later date.

3.4 SYSTEM PERFORMANCE

Water Intake System Performance

Biological growth, recognized as several species of hydroid (Class Hydrozoa), began to accumulate on the intake screens. The amount of biological growth on the intake screens was not anticipated by MACTEC or the screen manufacturers who had experience in the conditions in the harbor. Cleaning of the exterior of each intake screen box was performed twice by a diver. However, no contingencies were

made for cleaning the interior of the intake screen boxes. Therefore, there was notable progressive head loss in the pumping system, primarily in Cone 2. As part of the observations of the demonstration project, regular cleaning or replacement of the screens must be part of the design and operations of permanent systems. Photographs of the intake screens before and after the demonstration period may be found in Figure 3-2.

Maintenance was performed on the pumps approximately every 250 hours of operation. The system was turned off for maintenance on August 16, August 27, and September 6, 2007. In the beginning, the maintenance was performed one cone at a time thus the pumps for only one cone would be off at a time. Once it became necessary for a diver to remove biological growth from the intake screens, it was decided to shut down both systems during pump maintenance due to diver safety concerns.

Oxygen Delivery to Cones

During routine oxygen tank refills the pressure would drop in the liquid oxygen storage tank and result in a temporary loss of pressure in the oxygen supply lines. This pressure drop could result in system shutdown. By working with the liquid oxygen supply company it was possible to minimize occurrences of this problem. Also, the control panel settings were initially set to shut the system down when a change of 200 ppd of oxygen flow was detected. An oxygen flow drop of this magnitude would occur during the filling of the storage tank. Because it was more important to maintain system flow, the alarm/shutdown setting was adjusted to allow a maximum change of 1,000 ppd of oxygen before an automatic shutdown. Additional adjustments of the appropriate set points for the alarm system would be needed for permanent installations. Approximately 32,600 ppd of liquid oxygen were delivered to the liquid oxygen storage tank. Spot checks of oxygen concentrations in the discharge line showed concentrations from approximately 120 mg/L to 180 mg/L.

4.0 RIVER MONITORING

Various activities were going on during the demonstration project. The activities that occurred during the ReOx system demonstration period are shown on a timeline of events prepared as Figure 4-1. Events noted included USACE dredging schedule and system operations.

During the ReOx Demonstration Project water quality monitoring was conducted by MACTEC at three stationary near-bank locations (at GPA Berth 20 (RM 15.6), at the barge location (RM 14.1), and the USACE Dock (RM 13.7) shown in Figure 4-2. In addition to the stationary monitoring locations, periodic monitoring along mid-channel profiles (Figure-4-3, 4-3.1, and 4-3.2) including extended long run monitoring to the KITB (RM 19) and five cross-channel transects was conducted during low and high tide events (Figures 4-4, 4-4.1 and 4-4.2. Water quality parameters measured, or calculated from primary measurements, included: water temperature, DO, DO percent saturation, DO deficit, salinity, conductivity, pH, density, and instrument depth. Sampling locations for the periodic measurements are shown on Figures 4-3 and 4-4. Long run monitoring locations are shown on Figure 4-5.

Water quality monitoring was conducted to assess instream conditions before, during, and one week after the 40-day ReOx project demonstration period. At both the stationary locations and periodic locations, YSI 6290 multi-parameter sondes were used to monitor water quality parameters. Instrument calibration and maintenance was conducted in accordance with the manufacturer's instructions and the procedures specified in the Monitoring Plan in Appendix B. Additional instrument calibration checks were performed as site conditions dictated. Calibration data were recorded and filed with the project field records and may be found in Appendix A, Geodatabase. At the beginning and end of each sampling event, equipment was inspected for damage, or faulty parts, and problems reported to the monitoring team leader. The monitoring team leader was responsible for equipment, its repair status, and ordering of parts.

For the periodic monitoring events, quality control grab samples were taken at monitoring locations using a Kemmerer type water sampler to collect a corresponding DO sample for comparison with the water quality monitoring instrument (YSI 6920 sondes). This grab sample is taken to the field laboratory for testing using the EPA approved Winkler method. DO grab samples were fixed in the field and returned to the field laboratory for DO titration (Hach Water Analysis Handbook, 2003). Data from the Winkler titrations were used as a quality assurance/quality control (QA/QC) check of the field instrument measurements. A minimum of ten percent (10 percent) of the discrete monitoring points in the river had QA/QC water samples collected. The measurement of these "field duplicate samples" met the measure of

precision necessary to maintain and follow the quality control protocols for this water quality monitoring specified in the Savannah Harbor ReOxygenation Water Quality Monitoring Plan (Appendix B).

4.1 DREDGING ACTIVITIES

Dredging disturbs sediments on the bottom of the river and some are released to the water column. Such sediments generally contain an organic component that may cause an increased oxygen demand in the water column as dredging is under way. Therefore, dredging in the harbor is limited to times when the DO of the river is greater than 3 mg/L. Generally, dredging activities occur less during the summer when water temperatures are higher and DO concentrations are lower. When MACTEC activated the stationary background water quality monitoring stations on July 9, 2007, USACE dredging was occurring near the Marsh Island Turning Basin and this dredging continued until August 24, 2007. The USACE dredging began in the King's Island Turning Basin (KITB) on August 25 and continued through September 30, 2007, at several locations well after the ReOx system shutdown on September 16, 2007. The USACE measured water quality in the harbor during dredging operations. These USACE data are tabulated in Appendix C.

MACTEC was notified on August 25 that a break in the USACE dredge line had occurred. Increased sediment in the on-deck monitoring system at the ReOx barge location was noted from August 21 to August 24, 2007. The break in the dredge line released high concentrations of sediment to the water column. This high sediment load likely resulted in increased oxygen demand in the river system.

4.2 MONITORING AT STATIONARY LOCATIONS

Eighteen water quality sondes were deployed at the near-shore stationary monitoring stations (GPA Berth 20, the barge location, and the USACE Dock). Six sondes were used at each location. Sondes were placed in pairs (designated as primary and secondary) at selected depths (approximately 1 meter below the surface, near mid depth, and 1 meter from the bottom) to continuously monitor water quality (DO concentration, DO percent saturation, water temperature, conductivity, salinity, and depth). Each sonde was set to record water quality data at 15 minute intervals. The monitoring data collected at these stationary locations are available in electronic format in the Geodatabase (Appendix A) on the attached DVD. These data have been subjected to the appropriate QA/QC checks.

Due to the volume of the data collected, the data are summarized in graphical displays. Figure 4-2 (multiple figures for each stationary location) presents the continuous near-shore monitoring series:

- Figure 4-2.1 is based on data collected upstream from the ReOx system (at GPA Berth 20, RM 15.6);
- Figure 4-2.2 is based on data collected at the ReOx barge location, (RM 14.1); and
- Figure 4-2.3 is based on data collected downstream from the ReOx system (at the USACE Dock, RM 13.7).

The secondary sondes were deployed at each location and depth to duplicate the primary sonde readings in order to reduce the potential for data gaps resulting from instrument problems. Personnel checked on the sondes remotely (via internet) and visited the deployment locations approximately once per week to replace the sondes (one set at a time – primary or secondary) with recalibrated instrumentation. Sondes removed from a site underwent a calibration check (to check for potential instrument drift), data collection (downloaded from the memory of the sonde), cleaning, maintenance as needed, and were recalibrated prior to redeployment at a new location.

Monitoring Procedures

The reference standards for field instrument calibration are described in the monitoring plan (Appendix B). If there was evidence of fouling on the sondes or notable drift in the data, then the sondes were changed out more often than required by the standards. To allow for uninterrupted data monitoring, scheduling for the change out and recalibration of the sondes was such that a continuous monitoring sonde and its associated duplicate were not being changed at the same time. Calibration of the sondes was in accordance with the manufacturer's specification and the guidelines that are outlined for instrument calibration in the monitoring plan, Appendix B.

Findings From Stationary Locations

Monitoring data from the stationary locations show a noticeable diurnal pattern of the DO concentration. These diurnal DO swings are particularly noticeable on the shallow series data for each stationary location as shown in the Figure 4-2 series. This diurnal swing, not as notable in the mid or deep data, is likely caused by photosynthetic activity in the upper layers of the water column. Also observed are fairly stable and higher water temperatures prior to August 24, 2007 and a cooling trend afterward. This

indicates that the ocean boundary cooled and produced higher oxygen concentrations (lower DO deficits) near the ocean and during high tides.

Upstream of the ReOx system (at GPA Berth 20, RM 15.6):

The GPA Berth 20 monitoring station was approximately 1.5 miles upstream from the ReOx system. The station was attached to the Berth 20 dock located on the right side of water (city side). It was necessary to locate the continuous monitoring stations on fixed structures in the harbor and out of the navigation channel; therefore, the placement was not ideal to monitor the effects of the ReOx system in the navigation channel.

Prior to startup on August 6, 2007 the DO deficit was 3.7 mg/L (shallow zone), 4.0 mg/L (middle zone), and 4.2 mg/L (deep zone). Within 48 hours the average DO deficit was improved (decreased) at the GPA monitoring location (1.5 miles upstream from the ReOx system) by about 0.1 mg/L. After 4 days of reoxygenation the average DO deficit was improved by 0.4 mg/L. These comparisons use the daily average DO.

GPA (RM 15.6)	Prior to ReOx System Startup 8/6/2007 DO deficit (mg/L)	Elapsed time after ReOx system startup			
		48-hour DO deficit (mg/L)	48-hour DO Deficit improvement (mg/L)	4-day DO deficit (mg/L)	4-day DO deficit Improvement (mg/L)
Shallow zone	3.7	3.6	0.1	3.3	0.4
Middle zone	4.0	3.9	0.1	3.6	0.5
Deep zone	4.2	4.1	0.1	3.9	0.3

Prepared By: TRK 11/19/07
 Checked By: LMS 11/19/07

After running for about 10 days straight, the ReOx system was turned off for operations and maintenance (O&M) on August 16, 2007. At shutdown the DO deficit was 3.4 mg/L (shallow zone), 3.7 mg/L (middle zone), and 3.9 mg/L (deep zone). The ReOx system was reactivated on August 17, 2007. Forty-eight hours after restarting the ReOx system the average DO deficit across the water column at the GPA location was improved by 0.5 mg/L.

GPA (RM 15.6)	System shutdown	While system was off	Elapsed time after ReOx system restart	
	8/16/07 DO Deficit (mg/L)	8/18/2007 DO deficit (mg/L)	8/20/07 DO deficit (mg/L)	4-day DO Deficit improvement (mg/L)
Shallow zone	3.4	2.9	2.5	0.9
Middle zone	3.7	3.6	3.3	0.4
Deep zone	3.9	4.0	3.7	0.2

Prepared By: TRK 11/19/07
Checked By: LMS 11/19/07

On the day of final system shutdown (9/16/07), the DO deficit at the GPA monitoring location was 3.1 mg/L (shallow zone), 3.4 mg/L (middle zone), and 3.6 mg/L (deep zone). Eight days after the ReOx system was shutdown, the DO deficit averaged 3.6 mg/L in the water column which was significantly less than the 40 day earlier DO deficit average of 4.0 mg/L in the water column. This decrease in DO deficit is attributed to the influence of cooler ocean water with lower DO deficits during high tides.

At the ReOx system location, (Barge, RM 14.1):

Prior to startup on August 6, 2007 the DO deficit was 3.9 mg/L (middle zone) and 4.0 mg/L (deep zone). After 48 hours the DO deficit was improved at the ReOx monitoring location by 0.3 mg/L in the middle zone and 0.2 mg/L in the deep zone. After 7 days the ReOx system had improved the DO deficit by 0.5 mg/L in the middle zone and 0.6 mg/L in the deep zone.

After running for about 10 days straight, the ReOx system was turned off for O&M on August 16, 2007 at which time the DO deficit was 3.3 mg/L (shallow zone), 3.3 mg/L (middle zone), and 3.5 mg/L (deep zone).

On the day of final shutdown (9/16/07), the DO deficit at the ReOx barge location was 3.0 mg/L (middle zone) and 3.2 mg/L (deep zone). Eight days after shutting the system down, the DO deficit was still less than it was prior to startup conditions.

ReOx System (RM 14.1)	Prior to ReOx System Startup	Elapsed time after ReOx system startup				
		8/6/2007 DO deficit (mg/L)	48-hour DO deficit (mg/L)	7-day DO deficit (mg/L)	14-day DO deficit (mg/L)	9/16/07 Shutdown deficit (mg/L)
Shallow zone	No data		3.7	3.4	2.4	No data
Middle zone	3.9		3.6	3.4	3.0	3.0
Deep zone	4.0		3.8	3.5	3.3	3.2

Prepared By: TRK 11/19/07
 Checked By: LMS 11/19/07

The minimum DO deficits at the ReOx barge location were observed between September 12 and September 14, 2007. The deep zone had a DO deficit of 2.9 mg/L on September 12, 2007 began and the shallow and middle zone had a DO deficit of 2.3 mg/L and 2.8 mg/L respectively, on September 14, 2007, some 38 days after ReOx injection began.

Downstream of ReOx system (at the USACE Dock, RM 13.7):

Just prior to ReOx system startup the water temperature was rising and the DO deficit at the USACE dock was 3.7 mg/L in the middle zone and 3.8 mg/L in the deep zone. Approximately 24 hours later, after the system began operating, the DO deficit had decreased by 0.2 mg/L in both the middle and deep zones.

The ReOx system was shut down on August 18, 2007 for O&M. The water column average DO deficit was reduced by 0.3 mg/L about 24 hours after the system resumed normal operation on August 19, 2007 when water temperatures remained relatively constant. Forty-eight hours after operations were resumed August 20, 2007, the middle zone DO deficit daily average was 2.6 mg/L which was the best improvement noted during the demonstration project from the initial 3.7 mg/L DO deficit on August 6, 2007, thus the deficit was reduced by 1.1 mg/L. The best observed DO deficit daily average for the shallow zone was on August 22, 2007 at 2.4 mg/L and the minimum deficit for the deep zone was on August 24, 2007 at a deficit of 2.9 mg/L.

The system was operating at a steady rate on September 12, 2007, four days before shutdown, with the DO deficit daily water column average of 2.9 mg/L, which is similar to the water column four days after shutdown.

USACE Dock (RM 13.7)	Prior to ReOx System Startup	Elapsed time since ReOx system startup			
		8/6/2007 DO deficit (mg/L)	14 Day DO deficit (mg/L) 8/20/07	1 day after Shutdown DO deficit (mg/L)	4 days after Shutdown DO Deficit (mg/L)
Shallow zone	No data	2.5	3.1	2.7	3.3
Middle zone	3.7	2.6	3.3	2.9	3.5
Deep zone	3.8	2.9	3.2	2.8	3.4

Prepared By: TRK 11/19/07
Checked By: LMS 11/19/07

4.3 MONITORING ALONG MID-CHANNEL

Water quality sampling in the middle of the navigation channel was performed periodically (at least weekly) at 14 locations, V1 – V14, which extended from GPA Berth 20 to the USACE Dock (Figure 4-3). Due to the strength of the tides and the need to sample during slack tide conditions, the sampling was performed in a 2 to 3 hour window centered on a high or low slack tide.

Sampling locations were monitored using the hand held YSI 6920 sondes. These mid-channel DO measurements were taken at four (4) depths: 3 feet below water surface; 1/3 of total depth; 2/3 of total depth; and 3 feet above bottom. At the request of EPD, MACTEC assessed the potential for conducting more detailed water column measurements at 1-foot intervals for the top 10 feet and 2-foot intervals to the bottom. Since the mid-channel depths ranged from 48 feet (low tide) to 55 feet (high tide), the total number of measurements at one point would have been as high as 32 discrete measurements. Since it took a minimum of two to three minutes for the instrument to stabilize, the total time for measurement of one location approached one and a half hours. Since there were 14 sampling locations and it was important to keep the measurement period as short as possible so that the data were obtained under similar conditions and to avoid high currents (maximum time three hours per event), this methodology was not feasible, within available resources, for the periodic river sampling events.

The pH, specific conductivity, salinity, and DO instrumentation were calibrated prior to deployment and the calibration was checked after completion of the sampling event.

4.3.1 Mid-Channel Findings – DO Deficit

Table 4-1 summarizes the grid averaged DO deficit calculations. The grid average is the average DO deficit of the water column. The following details the Figures 4-3 s mid-channel isopleths.

Figure 4-3.1 a-b – Mid-Channel Monitoring DO Deficit at Low Tide

Figure 4-3.1 c-d – Mid-Channel Monitoring DO Deficit at High Tide

Figure 4-3.1 e-f – Mid-Channel Monitoring DO Concentration at Low Tide

Figure 4-3.1 g-h – Mid-Channel Monitoring DO Concentration at High Tide

Figure 4-3.1 i-j – Mid-Channel Monitoring DO Percent Saturation at Low Tide

Figure 4-3.1 k-l – Mid-Channel Monitoring DO Percent Saturation at High Tide

Low Tide Events

The results from the mid-channel monitoring events at low tide indicated that the improvement from August 6, 2007 to September 7, 2007 of the grid average DO deficit from the operation of the ReOx system was approximately 0.6 mg/L. The mid-channel low-tide monitoring event that occurred just prior to system startup indicated that the three-mile river segment being monitored had a grid average DO deficit of 3.9 mg/L. Once the effects of the ReOx system operation stabilized, on August 20, 2007, the grid average DO deficit after 13 days of reoxygenation was 3.3 mg/L, thus the DO deficit was improved by 0.6 mg/L. The average DO deficit based on all five low tide event grid averages was 3.4 mg/L, a DO deficit improvement of 0.5 mg/L, though after August 24, 2007 a cooling trend began to occur in the water temperature, which meant the stabilized condition on August 20, 2007 was more representative of the ReOx system effect during critical conditions than the period of time when the cooling trend began. The final monitoring event for the 3-mile segment 10 days post system shutdown indicated that the average DO deficit at low tide had returned to 3.9 mg/L, thus the effects of the system lasted for days after the system shut down.

These mid channel monitoring locations act as “snapshots” of the water quality profiles along the three-mile long target segment of the river centered on the ReOx barge location. Figure 4-3.1 graphically presents the low tide sampling results for all events.

High Tide Events

At mid-channel high tide improvement in DO was observed but was not as predominant and clear as the low tide measurements. Table 4-1 summarizes the grid average DO deficit calculations. Figures 4-3.2 present the high tide events. Prior to startup a DO deficit of 3.9 mg/L was observed a few weeks prior to startup during fairly steady critical conditions of high temperatures and low water flows. A week after the startup of the ReOx system, the DO deficit had been improved by 0.7 mg/L from July 16, 2007 to August 27, 2007. The average DO deficit from two high tide events during stable water temperature conditions was 3.2 mg/L. After August 24, 2007, the high tide deficits continued to further naturally decrease as a result of cooling sea temperatures and lower DO deficits.

4.3.2 Other Water Quality Data Findings

Mid-channel data for pH, salinity, and temperature are presented in a low and high tide series on Figures 4-3.2 as detailed below.

Figure 4-3.2 a-b – Mid-Channel Monitoring pH at Low Tide

Figure 4-3.2 c-d – Mid-Channel Monitoring pH at High Tide

Figure 4-3.2 e-f – Mid-Channel Monitoring Salinity at Low Tide

Figure 4-3.2 g-h – Mid-Channel Monitoring Salinity at High Tide

Figure 4-3.2 i-j – Mid-Channel Monitoring Temperature at Low Tide

Figure 4-3.2 i-j – Mid-Channel Monitoring Temperature at High Tide

Low Tide Events

During low tide conditions, the pH in the river is relatively neutral and is slightly greater at the bottom of the river. Salinity tends to have a low surface salinity and gradually increases with depth. The salinity ranges from approximately 6 parts per thousand (ppt) at the surface to 16 ppt at the bottom of the river. The temperature trends are very apparent on the Figure 4-3.2i-j; hotter temperatures appear red to yellow and cooler temperature appear green or blue.

At low tide the river was stratified through the first several weeks of monitoring (7/9/07 through 9/4/07). Salinity in the river was highest around August 20, 2007; this date 4900 cubic feet per second was observed (Figure 4-8.2) as a period of low flow as measured at the U.S. Geological Survey (USGS) Gage 02198500 near Clyn, GA. Water temperature was also highest during this same time. Figure 4-3.2 shows

effects of the ReOx project on the river temperatures on August 20, 2007. This gradient effect was likely due to the lower river flows (as measured at the USGS Gage near Clio, Georgia) and the fact that the intakes were located at the edge of water near the surface where water temperatures were warmer, particularly during daylight hours.

High Tide Events

Generally, high tide conditions brought a higher pH water into the harbor. The highest pH values occurred at the bottom of the river. Salinity at high tide conditions have a similar gradient as at low tide events, low values at the surface and higher at the bottom. However, a much higher salinity values are observed at high tide throughout the water column. Water temperatures during high tide events are generally cooler than during low tide events.

4.3.3 Long River Run Monitoring (RM 4 to RM 19)

In addition to the three-mile target segment in the vicinity of the ReOx system, monitoring over a 15 mile segment was also conducted. These "long run" monitoring events extended from approximately RM 4 to RM 19 as included at the end of Figure 4-3.1. Shortly after the ReOx system had been turned on, the USACE noticed an increased DO level at their KITB monitoring location approximately eight miles up river from the ReOx system location. After reviewing the data, it became apparent that long run monitoring would be helpful to assess a larger scope of the influence of the ReOx demonstration project. Beginning the week of September 6 to September 25, 2007, long run monitoring was completed weekly in Savannah Harbor. This was accomplished by beginning at RM 4 off Long Island upstream of Fort Pulaski and conducting a vertical profile (3 depths) every half mile until reaching RM 19 at the KITB (Figure 4-5). Profile readings were taken at shallow, middle, and deep depths. Long run results may be found in Appendix A, Geodatabase, Table Additional_Sampling_Water_Quality_Data.

Results from the long run monitoring indicated that DO levels were higher near the ocean and that the three-mile target segment under study for the ReOx Demonstration Project (USACE Dock to GPA Berth 20) was the critical segment identified in the TMDL report (USEPA, 2004). Also, data revealed that the KITB appeared to act as a storage location for higher DO water. As the flood tide moved upstream, the higher DO water from the ReOx system filled the KITB. As the tide moved out, the higher DO water was released and flowed downriver. A subset of the long run data (from RM 13 to RM 16) was incorporated in the mid-channel "target zone" series depicted on Figure 4-3. The long run monitoring data was

collected on September 6, 7, 13, 19, and 25, 2007 and referenced as “Long Run” on the Figure 4-3.1 low and high tide series.

4.4 CROSS SECTIONS

Water quality was measured at five cross-section transects (at Berth 20, upstream of the Talmadge Bridge, the barge location, the convention center, and the USACE Dock) were measured (Figure 4-4). Figure 4-4.1 shows transect sampling points as follows:

- Overbank (river left facing downstream at A1 and A2)
- Channel toe (river left facing downstream at B1 through B3)
- Mid-channel (T1 through T5 readings at C1 through C4)
- Channel toe (river right facing downstream at D1 through D3)
- Overbank (river right facing downstream at E1 and E2)

These cross section transects act as slack tide “snapshots” of water quality within the ReOx demonstration target zone. Figures 4-4.2 depicts the low and high tide transects monitoring results for all events.

As with the periodic mid-channel sampling events, the cross section monitoring events were timed to coincide with local slack tide conditions (low or high). The pH, specific conductivity, salinity and DO instrumentation were calibrated prior to sonde deployment and checked at the completion of the sampling event.

Cross-Section Monitoring Findings

Table 4-2 shows the average DO deficit within each cross section and for all five cross sections for each tidal event.

The cross check between the mid-channel readings and the cross section readings are quite similar. The low-tide cross section point averaged DO deficit prior to ReOx injection was 3.9 mg/L. The cross section transects DO deficit at low tide was reduced from 3.9 mg/L to 3.0 mg/L after 14 days of ReOx system operation. During relatively stable river water temperatures between 8/10/2007 and 8/21/2007 the average DO deficit was 3.3 mg/L. This indicates that the DO deficit improvement was 0.6 mg/L.

4.5 NEAR BARGE MONITORING

Additional river monitoring included near barge monitoring shown on Figure 4-4 during the demonstration period to evaluate the local instream extent of notably supersaturated water from the ReOx system. Near-barge monitoring included taking profile readings at locations (S0A- 4A, S0B-S2B, S0C – S2C) adjacent to the barge on the day of ReOx system start up, August 7, 2007. Monitoring was completed in the center of the return line flow on the river side of the barge as shown in Figure 4-5.1. Readings were taken from a radius of 25 feet to 100 feet surrounding the barge at shallow, middle, and deep readings. As shown on Figure 4-5.1, the reoxygenated water dispersed quickly into the river and no extreme initial gradients were observed. The near barge monitoring consisted of 33 points taken on the day of the ReOx system startup, which averaged a 46 percent DO percent saturation, 3.4 mg/L DO concentration, and a DO deficit of 3.8 mg/L. This DO deficit at startup is consistent with the 3.9 mg/L measured in the mid-channel and cross section transects data sets.

As observed during the demonstration project, some effervescence was occurring, particularly as noted during slack tide conditions (Figure 4-6). This effervescence was attributed to turbulence occurring around the gate valves that controlled system pressure and flow at the discharge end of the ReOx system return lines. The gate valves were closed about 80 percent to create sufficient pressure in the cones. Effervescence was not noticed at mid-tide conditions because there was substantially more mixing of the water as a result of tidal flow in the river for mixing. Estimates from Dr. Richard Speece indicated that the oxygen lost to effervescence was likely much less than five percent of the total oxygen input. During near-barge monitoring several readings were taken in the center of the noted effervescence bubbles to assess DO concentrations; the highest DO concentration measurement was 4.3 mg/L. A permanent system design may utilize valves with a smoother transition and a multiport diffuser to further limit the potential for effervescence.

4.6 QA/QC REVIEW

For the ReOx Demonstration Project, MACTEC achieved a greater than 98 percent data recovery. The field monitoring data collected from the continuous monitoring stations and weekly sampling stations are stored in a non-relational database in Appendix A, Geodatabase. These data were reviewed by MACTEC so that the necessary parameters, measurements, and analytical results were properly recorded; the analytical results were evaluated for completeness and accuracy and suspected errors were investigated and resolved, as possible.

Data from the YSI 6290 sondes were considered valid if the post deployment calibration check did not deviate from pre-deployment calibration by more than ten percent. Data from sondes that did deviate by more than 10 percent were considered outliers and the corresponding measurement from the duplicate sondes were used to fill such data gaps.

In addition, during sonde deployment at the USACE dock it was noted that tidal/wave actions were causing the sondes to bounce on the support bolt in the sonde standpipes. This caused damage to the sonde batteries resulting in some data loss before this problem was identified and rectified. Data lost includes:

- Stationary Monitoring Location USACE-Mid (8/11 5:45pm to 8/13 4:00 pm), (8/24 11:00am to 8/27 3:00pm), and USACEM (9/15 11:30am to 9/16 2:00pm);
- Stationary Monitoring Location USACE-Deep (7/30 9:30am to 8/1 4:30pm) and (8/24 11:30am to 8/27 2:30pm)

Additionally, there were occasional events where data was lost due to the following: a floating surface sonde was caught by river debris and restrained at depth or by the support rope and came out of the water during low tides; at The Industrial Company due to available location for sonde placement prior to the barge setup that resulted in sondes being out of the water; and the monitoring station on the barge coming loose from the supports as a result of a boat collision.

Data Quality Objectives

The data quality objective for the ReOx project was to obtain sufficient and credible data that would support, with a reasonable level of certainty, that the monitoring results are correct. The quality controls for the ReOx project included assessing the precision, representativeness, comparability, and accuracy of the monitored parameter values, with particular emphasis on changes in DO deficit concentrations. See Appendix B, Savannah Harbor ReOxygenation Water Quality Monitoring Plan, for more detail on the data quality objectives. These data quality objectives were met for the project and a greater than 98 percent data recovery for all data collected by MACTEC was achieved.

4.7 DYE TEST OBSERVATIONS

A dye test was conducted near the end of the operation period to assess the dispersion characteristics of the superoxygenated water in the river. This test was planned as a qualitative observation of the behavior

of the dye as it was released in the return lines. The dye test on September 12, 2007, was conducted at low slack conditions and as the river started flowing upriver toward the Kings Island Turning Basin. At approximately 17:05 hours on September 12, 2007, 55 gallons of permaillon blue dye was injected into the ReOx system. Observations were made of the visible dye movement in the river.

Photograph log:

- Digital photographs were taken during the test every minute for the first 10 minutes and every 5 minutes thereafter until the dye had dispersed.
- Photographs were taken from the following locations during the dye test:
 - Barge location
 - Hyatt Hotel (located on River Street directly across the river)
 - Talmadge Bridge (upstream of the barge)
 - Boat

Visual observations did not note substantial quantities of dye at the surface of the river; this indicated that the superoxygenated return flow was entrained at deeper depths. There was some drag up of dye from the effervescence but the color noted indicated a large dilution of dye injected. To compare the injected dye color noted at the surface to the potential color if the flow had short-circuited to the surface, five gallons of dye were released from a boat to the surface of the river. Figure 4-7 shows the comparison of the deep dye injection versus the surface dye release.

In addition to field observations, water samples taken with a Kemmerer type sampler were also collected at 1 foot, 10 feet, 20 feet, 30 feet, and 40 feet below the river surface and placed in glass sample bottles. Visual observations of the samples indicated that the darkest dye color was noted at 30 feet and 20 feet. Medium color (as compared to the darkest samples) was noted at 40 feet and 1 foot. Samples collected at 10 feet were the lightest indicating that the surface color noted was likely due to drag up of dye from the effervescence noted during slack tide conditions and that the bulk of the supersaturated water was dispersed in the mid-depth of the water column that corresponded to the return line outlet depth.

Observations were made to determine if the dye was noticeable upstream of the ReOx System. Observations made showed that the only visual evidence was from the surface release. There was little evidence at the GPA Berth 20 Dock of the dye. This confirmed the hypothesis that the superoxygenated water remained largely within the navigation channel.

4.8 OTHER MONITORING AND ANALYSES

4.8.1 USGS Gage at USACE Dock

Provisional water quality data from the USGS Gage 021989773 Savannah River at USACE Dock, at Savannah, GA matched very closely the data from deep monitoring zone USACE monitoring station data collected by MACTEC, Appendix B Geodatabase, referenced as Table USGS_Gage_Data. The USGS station was set at approximately 4 feet from the bottom at the USACE dock. Figure 4-8.1 presents the USGS provisional water quality data at the USACE dock (USGS, 2007a).

4.8.2 USACE Kings Island Turning Basin Monitoring

The USACE provided water quality data taken at various locations in the Savannah River while dredging was occurring upstream from the ReOx barge location. These data are shown in Appendix C.

4.8.3 USGS Gage at Clyo

The USGS gage station data from the Savannah River near Clyo, GA, USGS 02198500, for July 9, 2007 through September 25, 2007, are provided in Appendix A, Geodatabase, referenced as Table USGS at Clyo and are provisional. Figure 4-8.2 depicts streamflow data for the Clyo gage. The data showed an average flow rate of 5086 cubic feet per second (cfs) during the ReOx project (USGS, 2007b). The maximum flow, 5650 cfs, on 7/14/2007 and the minimum flow, 4590 cfs, on 7/25/2007 at the Clyo gauge were both prior to the ReOx system startup. During the monitoring period of July 9 through September 25, 2007, instream flow was observed at and sometimes below critical instream flow conditions of 5000 cfs.

4.8.4 Rainfall Monitoring

The rainfall data have been included on Figures 4-2 of the stationary monitoring locations. These data are provided in Appendix A Geodatabase as provisional from the USGS Gage 021989773 Savannah River at USACE Dock, at Savannah, GA weather station, referenced as Table USGS_Gage_Data. The maximum rain event between July and September 2007 was on 7/30/2007 with 12.59 centimeters (approximately 5 inches) of precipitation. The maximum weekly rain event occurred between July 30th to August 5th with a total weekly precipitation of 18.84 centimeters (7.4 inches) (USGS, 2007a).

4.8.5 Data Analysis by Georgia Tech Students

- Data provided by GPA to Civil and Environmental Engineering students at Georgia Tech.
- Reviewed/analyzed only data from continuous near-bank monitoring locations. and did not analyze more-representative centerline or cross section monitoring.
- Compared DO percent saturation before, after, and during project for all tides combined such that progressive sea cooling effect on high tide data masked low-tide deficit reductions
- Concluded there was not a statistically strong positive impact on DO as a result of oxygen addition.
- While MACTEC appreciates the contribution of the Georgia Tech students, it is important to note that their conclusions are based entirely on the near-bank monitoring while the dominant influence of the ReOx project was on the central part of the river (USACE, 2007).

5.0 FULL-SCALE DESIGN CONSIDERATIONS

Locations for permanent stations will require certain infrastructure to support the operations of the ReOx systems. For example, a station incorporating liquid oxygen will require a road so that the tanker trucks delivering the liquid oxygen would be able to have access to the site. A station incorporating an oxygen generator would be able to utilize a more rudimentary road for access for the personnel who will be servicing and operating the system. Electrical service will be needed to supply power for the pump system.

The ReOx discharge lines should be placed as deep in the river as possible and preferably discharge toward the navigation channel or river bottom. For example, the design of the demonstration project included discharge lines that sloped downward approximately 10 degrees (from horizontal), and the momentum of the water flow transported the supersaturated water into the navigation channel. A similar approach should be considered for the permanent installation to simplify the discharge pipe layout. Discharge lines should be placed so they present the least possible impact on normal river operations (ship traffic, dredging, etc.) and may be seasonally deployed.

5.1 CONCEPTUAL DESIGN SCHEMATICS

Based on the results of the demonstration project, MACTEC anticipates that two permanent installations would be sufficient to provide oxygen to mitigate the effects of harbor deepening, with one station having one cone (but designed with the contingency of adding a second cone) and the other station having two cones (an extra to allow one cone to be down for maintenance at either station). Additionally, each system should have a backup pump system so that operation could continue during pump maintenance or failure.

Depending on the sites selected for permanent installation of ReOx stations, there are several possible design scenarios to consider, including:

- River bank below ground installation of the Speece Cone (Figure 5-1)
- Above ground installation of the Speece Cone (Figure 5-2)
- Barge mounted systems similar to the demonstration project

Each of these alternatives, depending on site location and access, could take advantage of various design alternatives such as: a single or dual cone design; intake screen type; and oxygen generation or liquid

oxygen supply. Figures 5-1 and 5-2 provide a general conceptual layout of two types of mounting configurations for single cone systems that may be adapted to dual cones systems as needed. Final design layouts for a permanent system will depend on site-specific requirements.

5.2 ESTIMATED COSTS TO CONSTRUCT

As a planning tool, MACTEC has prepared rough order of magnitude (ROM) estimated costs for one cone stations based on the conceptual designs presented in Figures 5-1 and 5-2. Table 1 presents the ROM estimated costs for a basic one-cone land-based ReOx Station. These costs do not include land procurement, utility installation, or roadway construction as these are highly dependent on the actual sites selected. Costs presented in Table 5-1 are summarized below:

- Above Ground Installation – Oxygen Generator: \$1.90 million
- Above Ground Installation – Liquid Oxygen Supply: \$2.05 million

- Below Ground Installation – Oxygen Generator: \$4.80 million
- Below Ground Installation – Liquid Oxygen Supply: \$4.95 million

Additional considerations for the design of each permanent ReOx station location would be the annual O&M requirements. Estimated ROM annual O&M costs per cone are presented in Table 5-2 and are summarized below.

- Oxygen Generator: \$24,000
- Liquid Oxygen Supply: \$131,000

Additional costs would include the cost of a support building at each ReOx Station. The support building would house equipment, control panels, oxygen generation equipment (if applicable), and provide off-season storage of ReOx pumps, Specce Cone(s), and other equipment. Building costs will vary depending on the type (prefabricated, block, or concrete) and the finish required (some areas may have specific design requirements, i.e. brick, rock, etc.) for a specific location selected. These costs range from \$150,000 to \$300,000 or more. The below ground installation is more expensive because sheet piling and dewatering would be required during installation.

6.0 ANECDOTAL INFORMATION

- The Nature Conservancy conducted sturgeon monitoring in the vicinity of the ReOx project using underwater receivers to monitor whether tagged fish pass by a particular Savannah River section. No tagged sturgeons were noted during the ReOx demonstration project.
- It was necessary to scrape off barnacles from the continuous monitoring sondes routinely as part of the operation and maintenance procedures.
- When the ReOx system return lines were disassembled and brought to the surface, blue crabs were noticed on the return lines which they were using as habitat structure.
- The mid-channel and cross section transect data were collected from a registered boat and carefully coordinated with the United States Coast Guard and other pilots navigating the Savannah River.
- The ReOx demonstration project used four 400 horsepower pumps that were mounted on the barge deck. The rated decibel levels were 72-76 decibels for each pump at 30 feet. It is expected that the vertical pumps planned for the permanent installations would generate approximately 65 decibels for each pump at the pumps on the barge deck.

7.0 CONCLUSIONS

1. **The ReOx system was able to meet the target oxygen mitigation quantity of 20,000 ppd.** The goal of adding enough oxygen, approximately 20,000 ppd, to mitigate the effects of harbor deepening was achieved using two Speece Cones each designed for up to 15,000 ppd.
2. **Operation of the ReOx system resulted in an average decrease of the DO deficit of 0.6 mg/L.** Mid channel DO profiling along the river study length indicated that about three days of continuous oxygen injection were needed to initiate measurable DO deficit reduction and that an overall average deficit reduction of approximately 0.6 mg/L was achieved during the demonstration period as compared to pre- and post- monitoring data.
3. **The positive effects on water quality from the ReOx system were notable after system shutdown.** For at least seven days after the ReOx system was shut down, residual positive effects of oxygen addition were still clearly evident in nearby cross-section transects taken at low tide. Ten days after ReOx system shut down there was no continuing evidence of residual instream DO improvement, and mid-channel low tide DO deficits had substantially returned to pre start-up deficit levels of 3.9 mg/L.
4. **Near barge monitoring did not detect excessively high DO concentrations in the river.** Immediately after startup, the near barge monitoring performed around the ReOx system at the request of EPD indicated that the superoxygenated river water was dispersing quickly into the tidal flow of the Savannah River system. Continuous stationary and periodic mid-channel and cross section monitoring also indicated that the superoxygenated river water was dispersing quickly into the river system.
5. **Influent monitoring concluded no short circuiting of the reoxygenated water.** The influent water pumped into the system from the river was not oxygen rich, thus, tidal movement effectively transported new water into the target injection area.
6. **Data collected by project monitoring activities was verified by USGS monitoring.** USGS water quality gaging station data closely matched MACTEC water quality deep monitoring data at the USACE dock.

8.0 REFERENCES

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TABLES

Table 4-1
Mid-channel
DO Deficit
Grid Average Calculations

Calculated Grid Average - RM 4 to 20, Full depth					Calculated Grid Average - RM 13 to RM 16, Full depth				
River Mile Range	Date	DO Concentration	DO Deficit	DO Percent Saturation	River Mile Range	Date	DO Concentration	DO Deficit	DO Percent Saturation
		(mg/L)	(mg/L)	(%)			(mg/L)	(mg/L)	(%)
Low Tide Event									
13-16	7/9/2007	-	-	-	13-16	7/9/2007	3.65	3.75	49.29
13-16	8/6/2007	-	-	-	13-16	8/6/2007	3.46	3.91	46.91
13-16	8/11/2007	-	-	-	13-16	8/11/2007	3.35	3.72	47.36
13-16	8/20/2007	-	-	-	13-16	8/20/2007	3.54	3.30	51.67
13-16	9/4/2007	-	-	-	13-16	9/4/2007	3.74	3.56	51.22
4-19	9/6/2007	4.32	2.94	59.5	4-19 Subset (13-16)	9/6/2007	4.12	3.22	56.1
4-19	9/7/2007	4.50	2.76	62.1	4-19 Subset (13-16)	9/7/2007	4.10	3.26	56.7
4-19	9/25/2007	4.41	3.02	59.5	4-19 Subset (13-16)	9/25/2007	3.93	3.64	51.9
13-16	9/26/2007	3.71	3.86	49.0	13-16	9/26/2007	3.68	3.90	48.6
High Tide Event									
13-16	7/16/2007	-	-	-	13-16	7/16/2007	3.46	3.91	46.91
13-16	8/14/2007	-	-	-	13-16	8/14/2007	3.71	3.19	53.81
13-16	8/27/2007	-	-	-	13-16	8/27/2007	3.67	3.22	53.23
13-16	9/10/2007	-	-	-	13-16	9/10/2007	4.14	3.02	57.86
4-19	9/13/2007	4.76	2.27	67.9	4-19 Subset (13-16)	9/13/2007	4.50	2.64	63.1
13-16	9/17/2007	-	-	-	13-16	9/17/2007	4.14	3.02	57.86
4-19	9/19/2007	5.32	1.74	75.4	4-19	9/19/2007	4.95	2.15	59.7

Notes:

mg/L milligram per liter
% Percent

Table 4-2
Cross Section Transect
Point Average Calculations

Transect	DATE	Tide Event	Average Point DO Percent Saturation (%)	Average Point DO Concentration (mg/L)	Average Point DO Deficit (mg/L)	Count of points
T1	7/10/2007	low	50.08	3.71	3.70	14
T2	7/10/2007		48.05	3.56	3.84	14
T3	7/10/2007		50.16	3.73	3.69	14
T4	7/10/2007		51.65	3.84	3.59	14
T5	7/10/2007		52.01	3.86	3.55	14
Total Average	7/10/2007		50.39	3.74	3.67	
T1	7/17/2007	high	54.39	3.87	3.25	14
T2	7/17/2007		53.45	3.83	3.33	14
T3	7/17/2007		53.74	3.84	3.30	14
T4	7/17/2007		54.15	3.90	3.30	14
T5	7/17/2007		53.34	3.85	3.37	14
Total Average	7/17/2007		53.81	3.86	3.31	
T1	8/7/2007	low	46.29	3.35	3.88	14
T2	8/7/2007		47.89	3.51	3.81	14
T3	8/7/2007		46.16	3.39	3.94	14
T4	8/7/2007		47.80	3.52	3.83	14
T5	8/7/2007		47.92	3.53	3.82	14
Total Average	8/7/2007		47.21	3.46	3.86	
T1	8/10/2007	low	44.69	3.19	3.95	14
T2	8/10/2007		49.36	3.56	3.63	14
T3	8/10/2007		44.41	3.17	3.96	14
T4	8/10/2007		45.53	3.26	3.89	14
T5	8/10/2007		45.99	3.30	3.86	14
Total Average	8/10/2007		46.00	3.30	3.86	
T1	8/13/2007	high	56.14	3.87	3.02	14
T2	8/13/2007		55.49	3.82	3.07	14
T3	8/13/2007		58.19	4.01	2.88	14
T4	8/13/2007		55.00	3.80	3.11	14
T5	8/13/2007		54.01	3.76	3.20	14
Total Average	8/13/2007		55.77	3.85	3.06	
T1	8/21/2007	low	55.06	3.77	3.07	14
T2	8/21/2007		57.43	3.94	2.91	14
T3	8/21/2007		57.07	3.89	2.92	14
T4	8/21/2007		54.56	3.75	3.11	14
T5	8/21/2007		55.88	3.85	3.03	14
Total Average	8/21/2007		56.00	3.84	3.01	
T1	8/28/2007	high	50.99	3.52	3.38	14
T2	8/28/2007		50.54	3.50	3.42	14
T3	8/28/2007		53.52	3.70	3.21	14
T4	8/28/2007		51.64	3.58	3.35	14
T5	8/28/2007		50.63	3.52	3.43	14
Total Average	8/28/2007		51.46	3.56	3.36	
T1	9/5/2007	low	49.44	3.65	3.73	14
T2	9/5/2007		54.88	4.06	3.33	14
T3	9/5/2007		51.97	3.83	3.54	14
T4	9/5/2007		55.04	4.07	3.33	14
T5	9/5/2007		54.76	4.03	3.33	14
Total Average	9/5/2007		53.22	3.93	3.45	

Table 4-2
Cross Section Transect
Point Average Calculations

Transect	DATE	Tide Event	Average Point DO Percent Saturation (%)	Average Point DO Concentration (mg/L)	Average Point DO_Deficit (mg/L)	Count of points
T1	9/11/2007	high	60.03	4.32	2.88	14
T2	9/11/2007		60.32	4.36	2.87	14
T3	9/11/2007		61.26	4.43	2.80	14
T4	9/11/2007		59.23	4.32	2.97	14
T5	9/11/2007		58.09	4.24	3.06	14
Total Average	9/11/2007		59.79	4.33	2.92	
T1	9/18/2007	high	63.66	4.59	2.62	14
T2	9/18/2007		64.14	4.62	2.58	14
T3	9/18/2007		63.21	4.54	2.64	14
T4	9/18/2007		63.35	4.58	2.65	14
T5	9/18/2007		63.99	4.64	2.61	14
Total Average	9/18/2007		63.67	4.59	2.62	
T1	9/24/2007	low	52.04	3.90	3.59	14
T2	9/24/2007		51.15	3.84	3.67	14
T3	9/24/2007		50.08	3.77	3.76	14
T4	9/24/2007		50.32	3.80	3.75	14
T5	9/24/2007		51.01	3.86	3.70	14
Total Average	9/24/2007		50.92	3.83	3.69	

Notes:

mg/L

milligrams per liter

%

percent

Table 5-1
ReOx Station Installation ROM Cost Estimate

Data Release : Year 2007

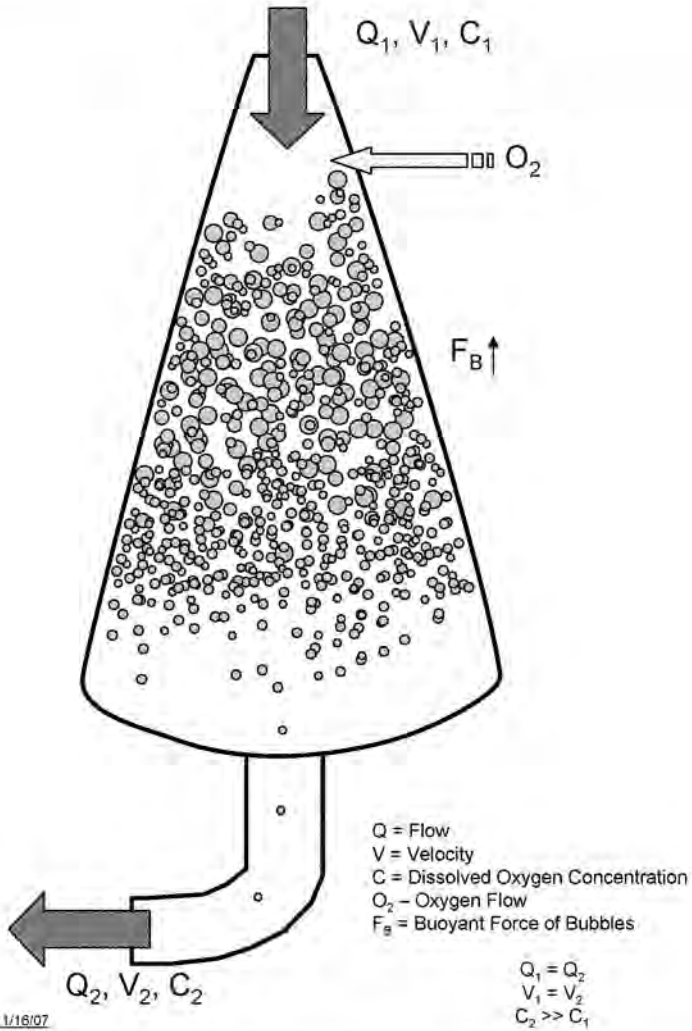
Description	Well Option		Above Ground Option	
	Liquid Oxygen	Oxygen Generator	Liquid Oxygen	Oxygen Generator
Speece Cone	\$720,000	\$720,000	\$720,000	\$720,000
Oxygen Generator	Not Applicable	\$125,000	Not Applicable	\$125,000
Compressor	Not Applicable	\$10,000	Not Applicable	\$10,000
Air Dryer	Not Applicable	\$5,000	Not Applicable	\$5,000
Liquid Oxygen (installation of tank & evaporator only)	\$50,000	Not Applicable	\$50,000	Not Applicable
Concrete Slab	\$180,000	\$125,000	\$180,000	\$125,000
Concrete Well	\$500,000	\$500,000	\$50,000	\$50,000
Pumps (2 per cone)	\$185,000	\$185,000	\$185,000	\$185,000
Piping	\$80,000	\$80,000	\$80,000	\$80,000
Electrical	\$125,000	\$200,000	\$125,000	\$200,000
Cofferdam	\$1,856,000	\$1,856,000	\$75,000	\$75,000
Contingency (30%)	\$1,108,800	\$1,141,800	\$439,500	\$472,500
Total	\$4,804,800	\$4,947,800	\$1,904,500	\$2,047,500

Notes:
 Prepared by: DGU 11/19/07
 Checked by: SAL 11/19/07

1. This estimate based on Costs provided by RS Means Costworks 2007 and actual vendor pricing where possible. These costs are preliminary in nature and are intended to give a rough order of magnitude (ROM) for construction of the two types of facilities. Actual costs may differ depending on location, existing conditions, and unknown elements not yet included in the proposed design.
2. Temporary dam for construction of well will need to be designed, as placement in the river at bottom depth exceeds design limits on prefabricated cofferdams. Cost here is conceptual, based on known elements required to allow excavation and construction of the well. Costs may vary considerably once an actual site specific designs are developed.

FIGURES





Prepared by: LMS 11/16/07
 Checked by: MET 11/16/07

SAVANNAH HARBOR
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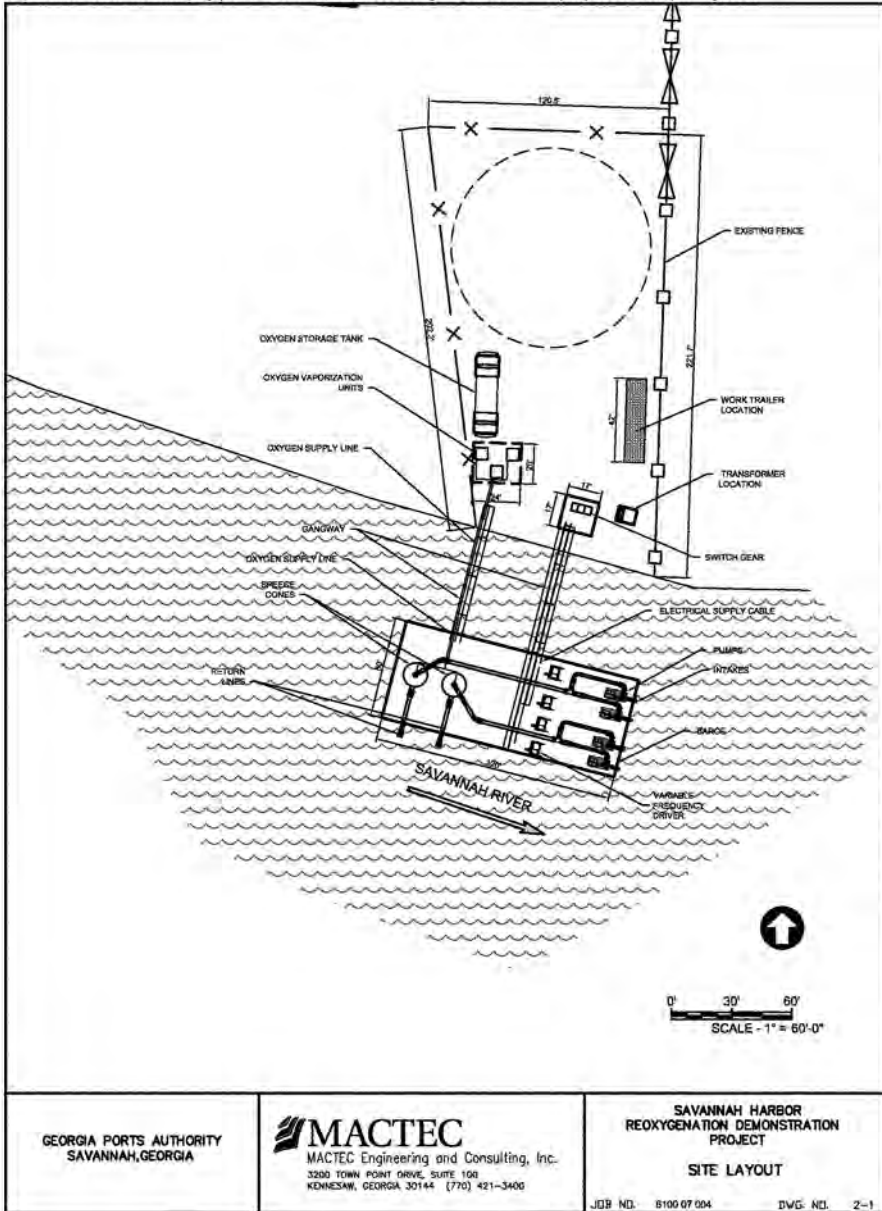
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Speece Cone Operating
 Principles Schematic

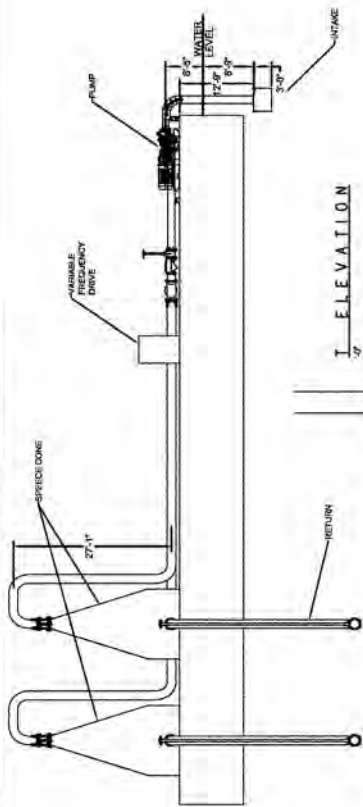
Project Number: 6110070004

Figure: 1-2

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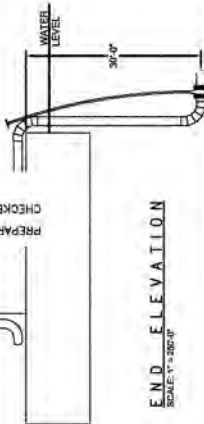
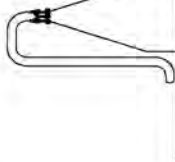


J:\Savannah River Harbour\dwg\Elevations_8.5x11.dwg - Layout1 01/09/2008 2:26pm lgads/cg



ELEVATION

DOU 11/16/07
CHECKED BY/DATE MET 11/16/07



END ELEVATION
SCALE 1"=30'-0"

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MACTEC Engineering and Consulting, Inc.
3200 TOWN POINT DRIVE, SUITE 100
KENNESAW, GEORGIA 30144 (770) 421-3400

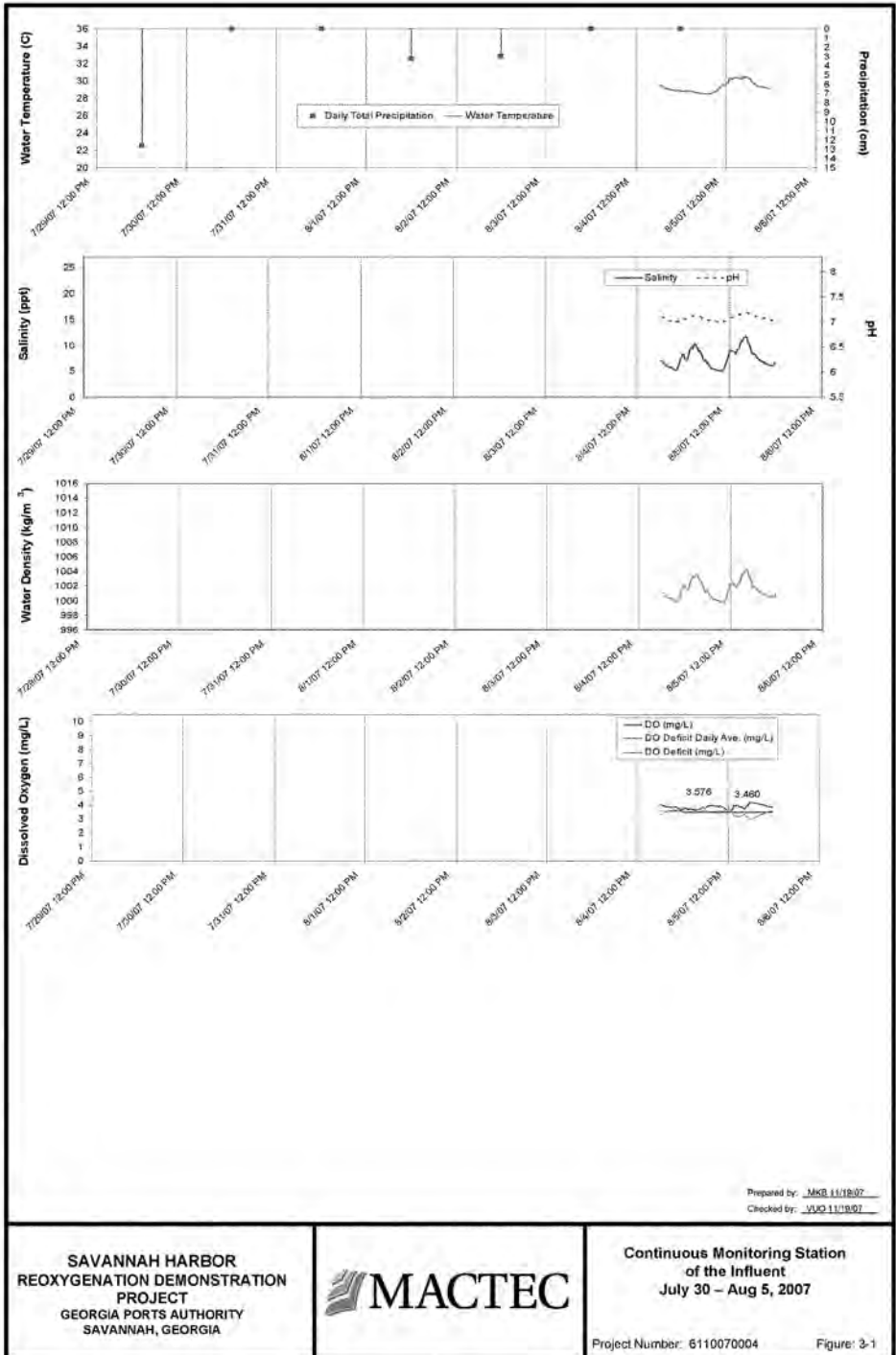
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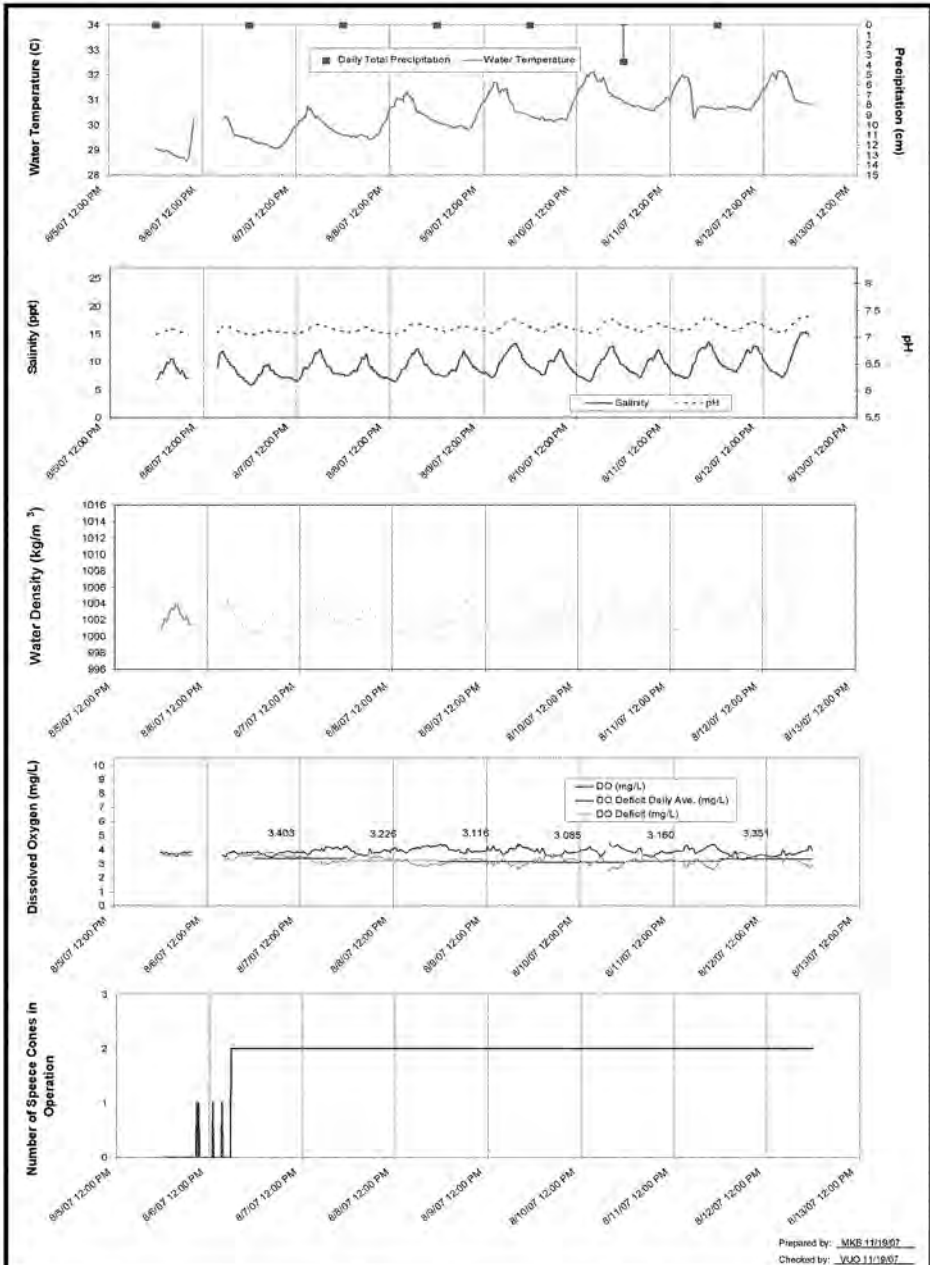
BARGE ELEVATIONS

JOB NO. 6100 07 004

DWG. NO. 2-2

PREPARED BY/DATE DOU 11/16/07
CHECKED BY/DATE MET 11/16/07





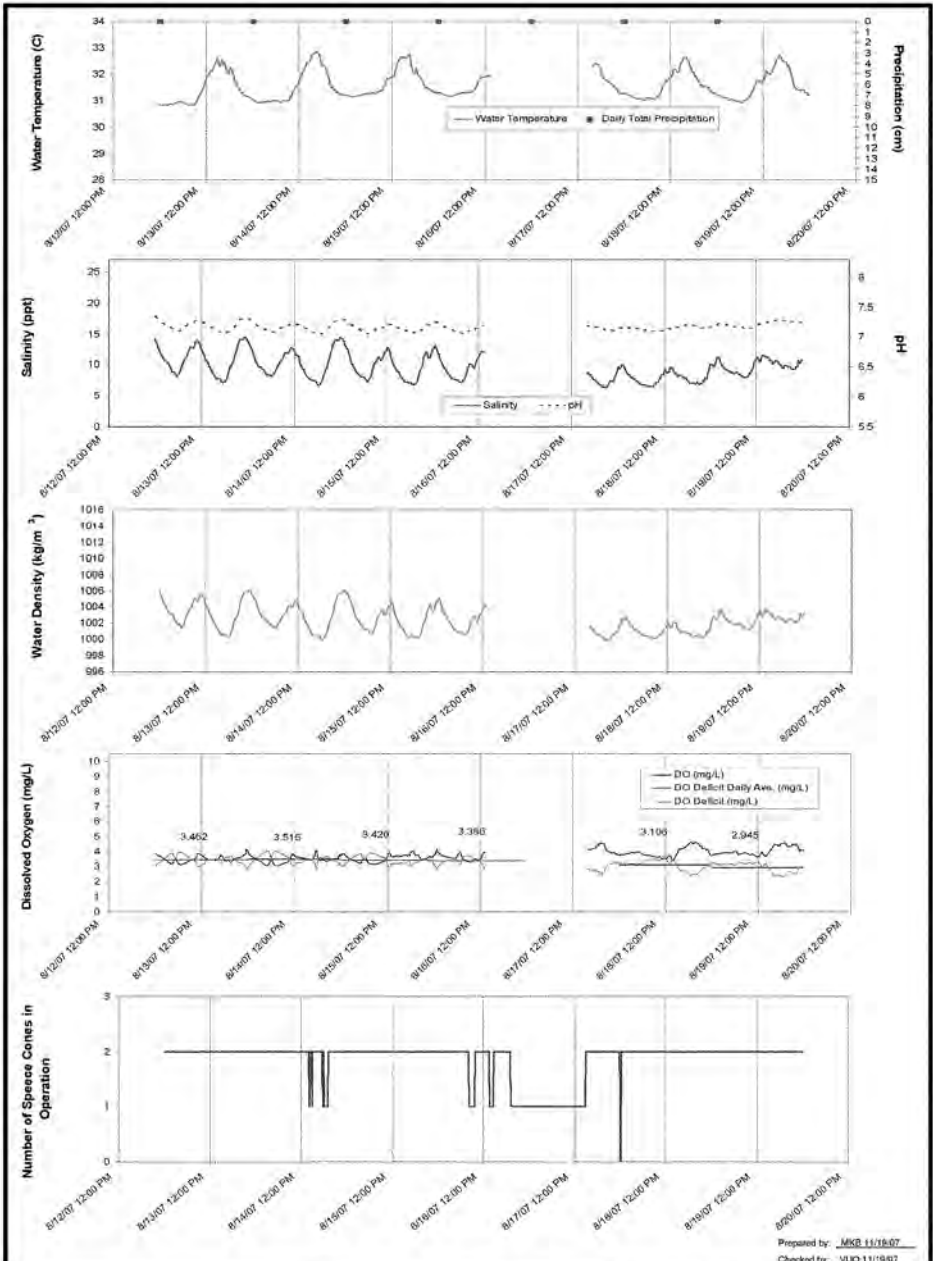
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Continuous Monitoring Station
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 Aug 6 – 12, 2007

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Figure 3-1



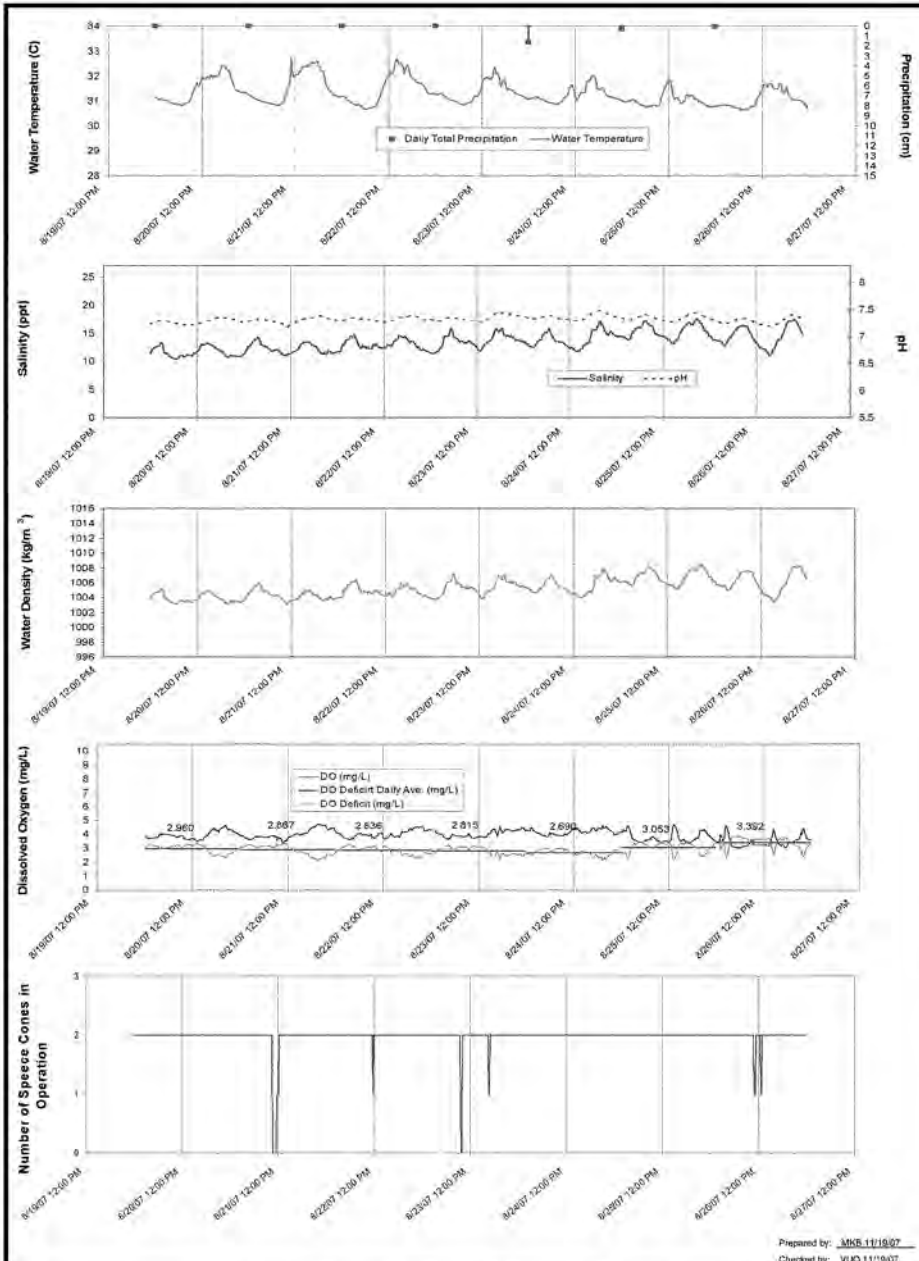
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Figure 3-1



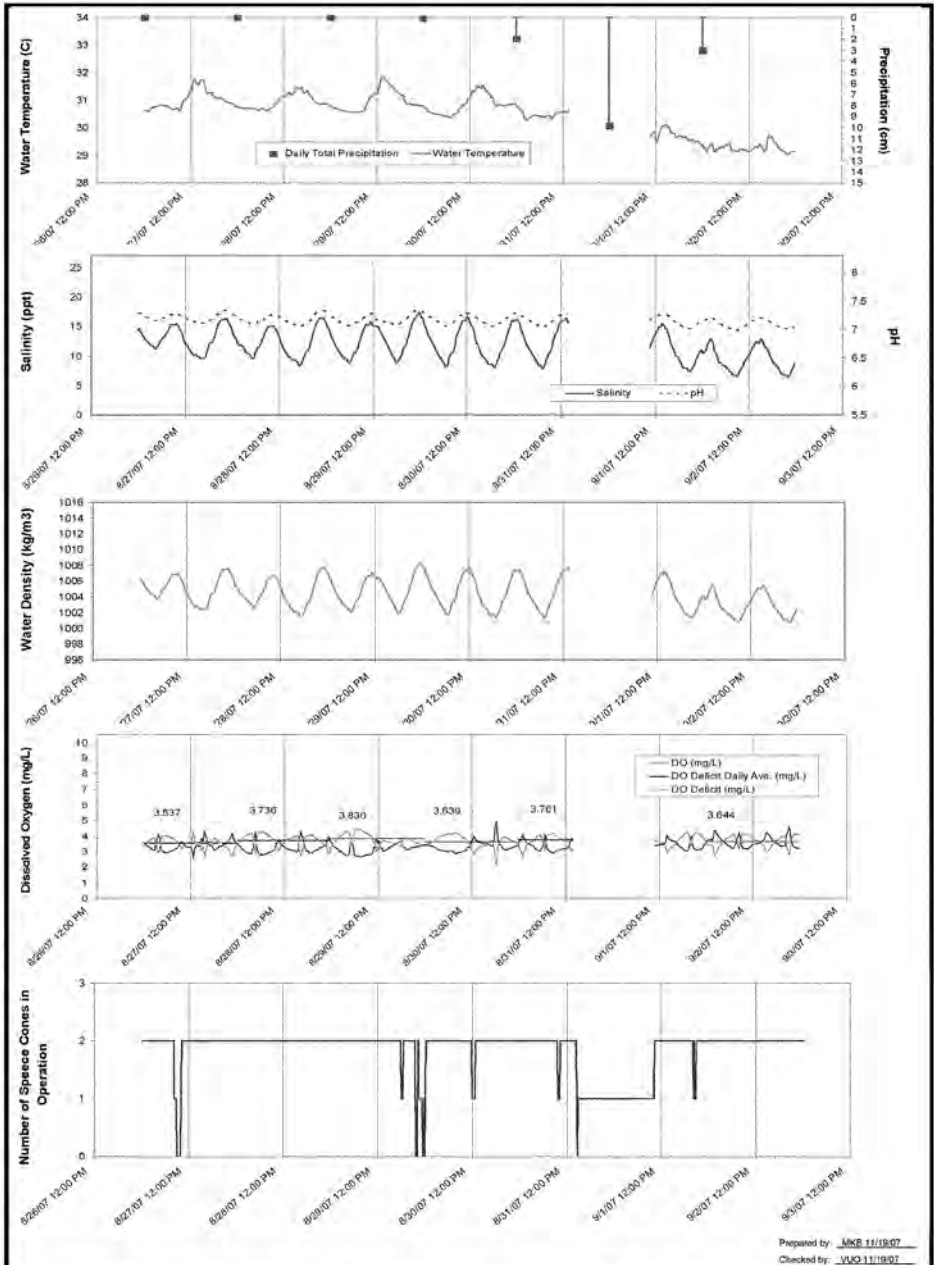
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Figure 3-1



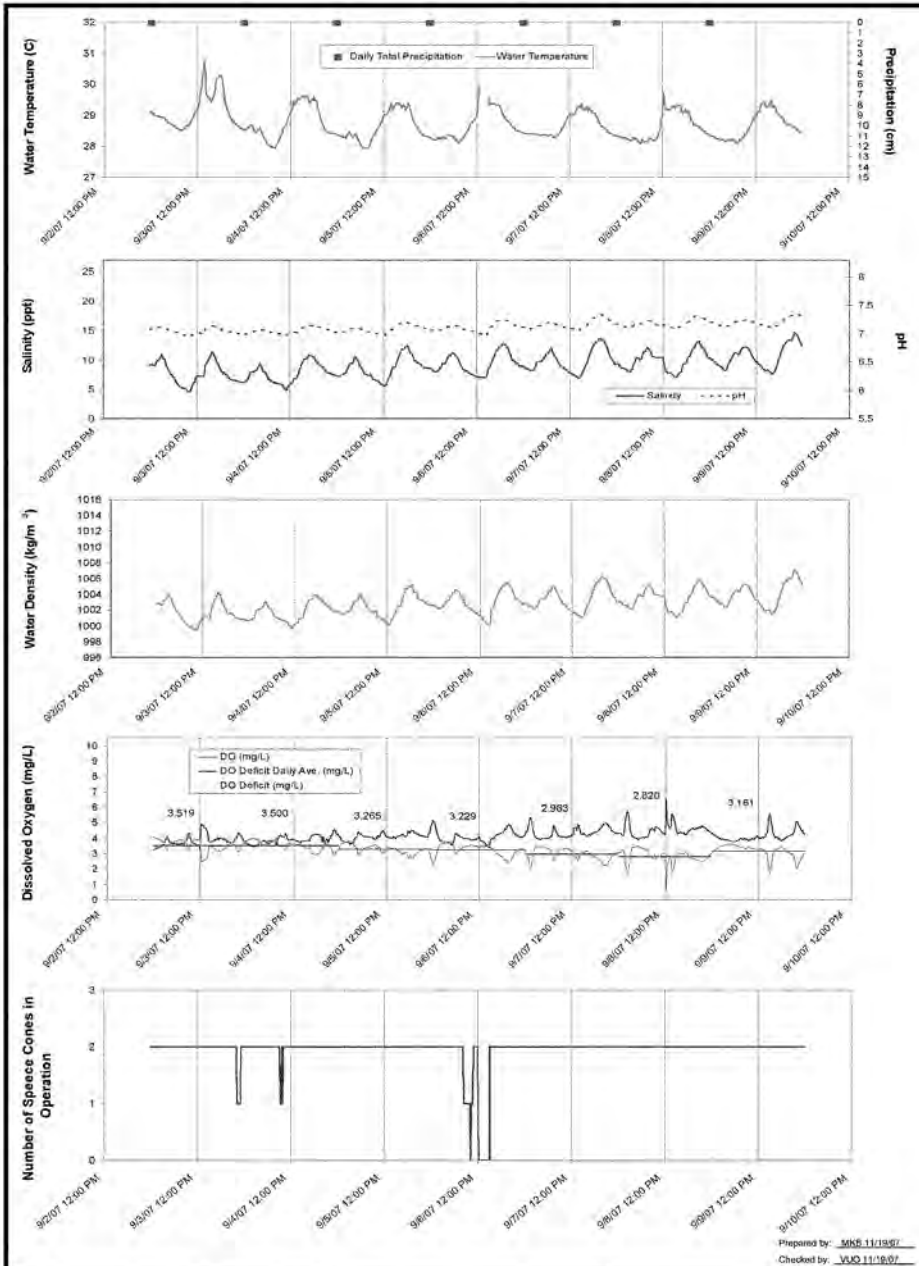
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Figure 3-1



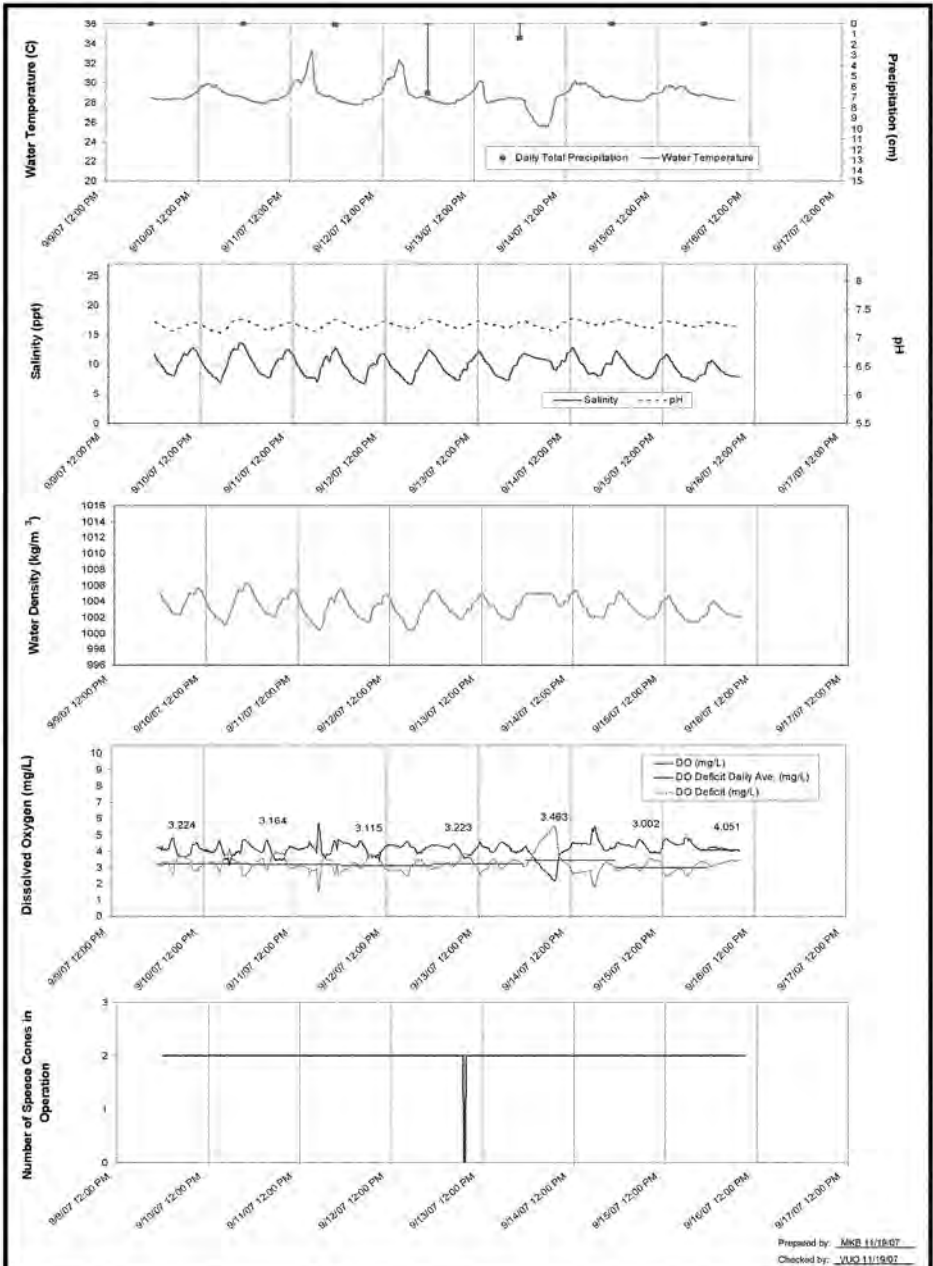
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Figure 3-1



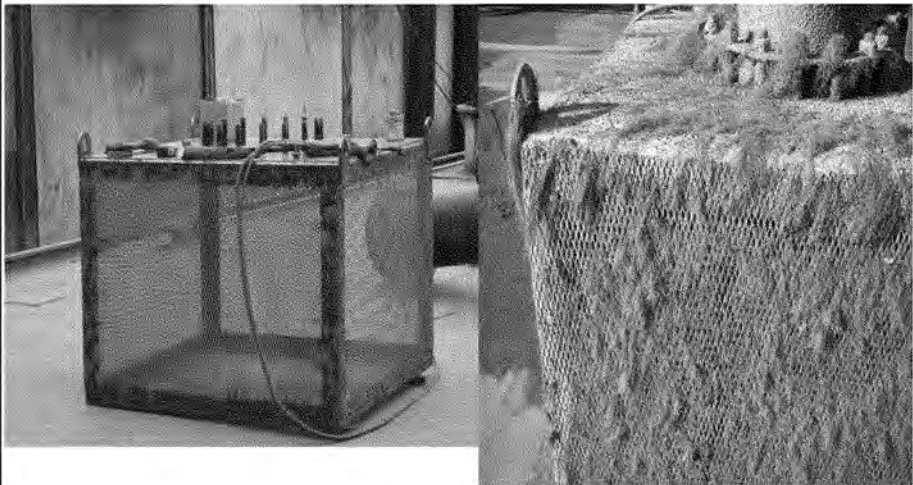
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Figure 3-1



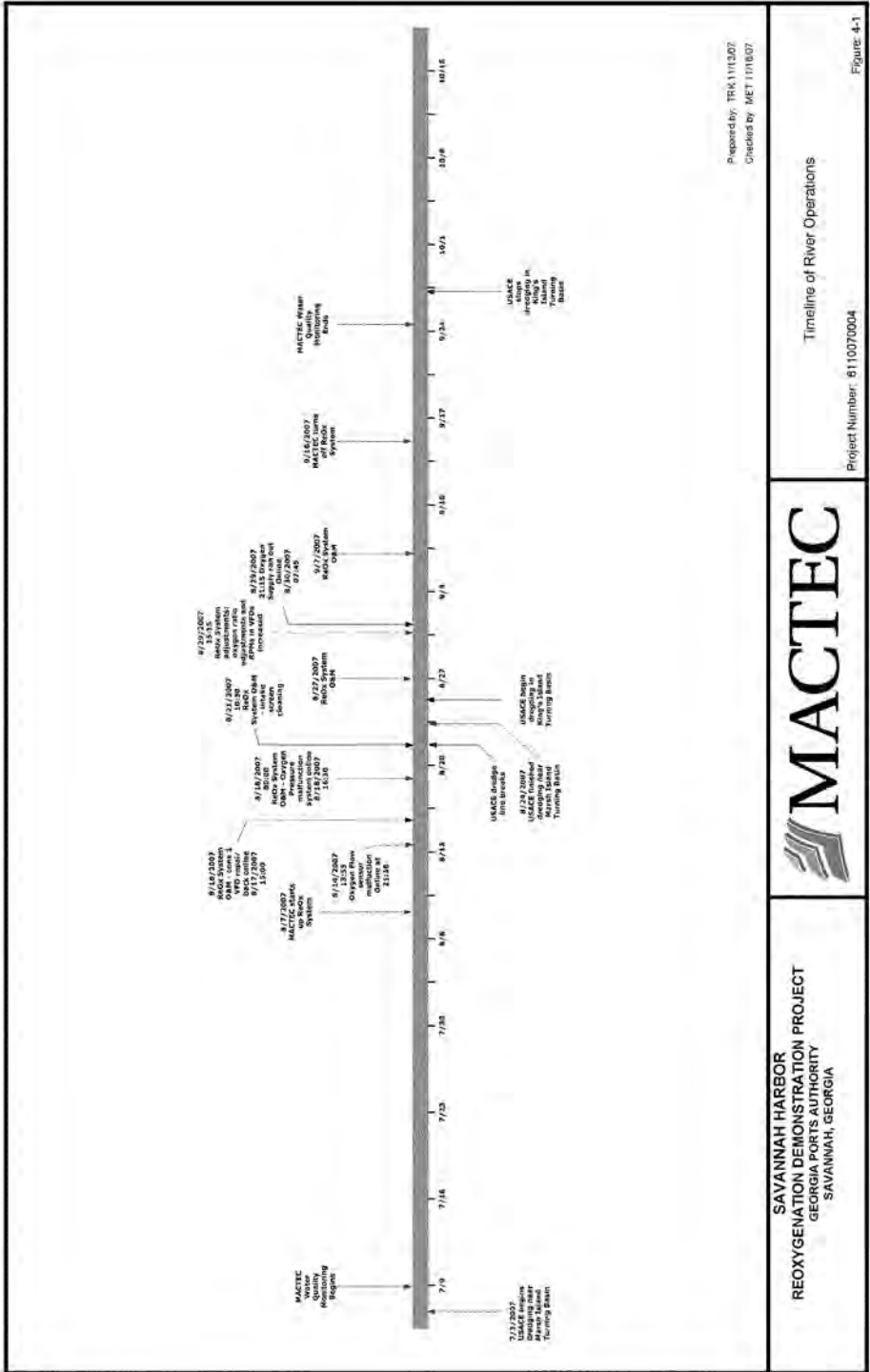
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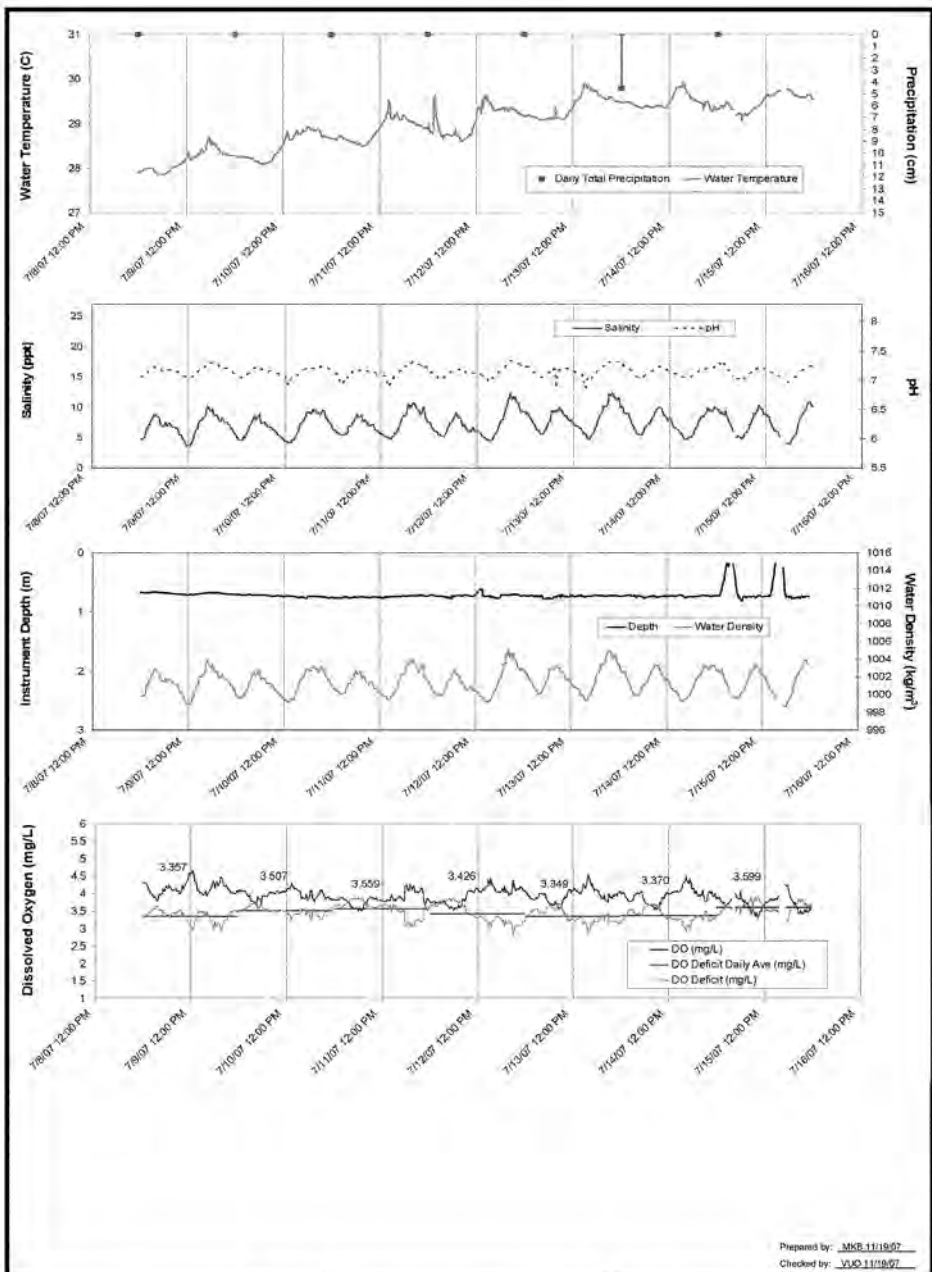
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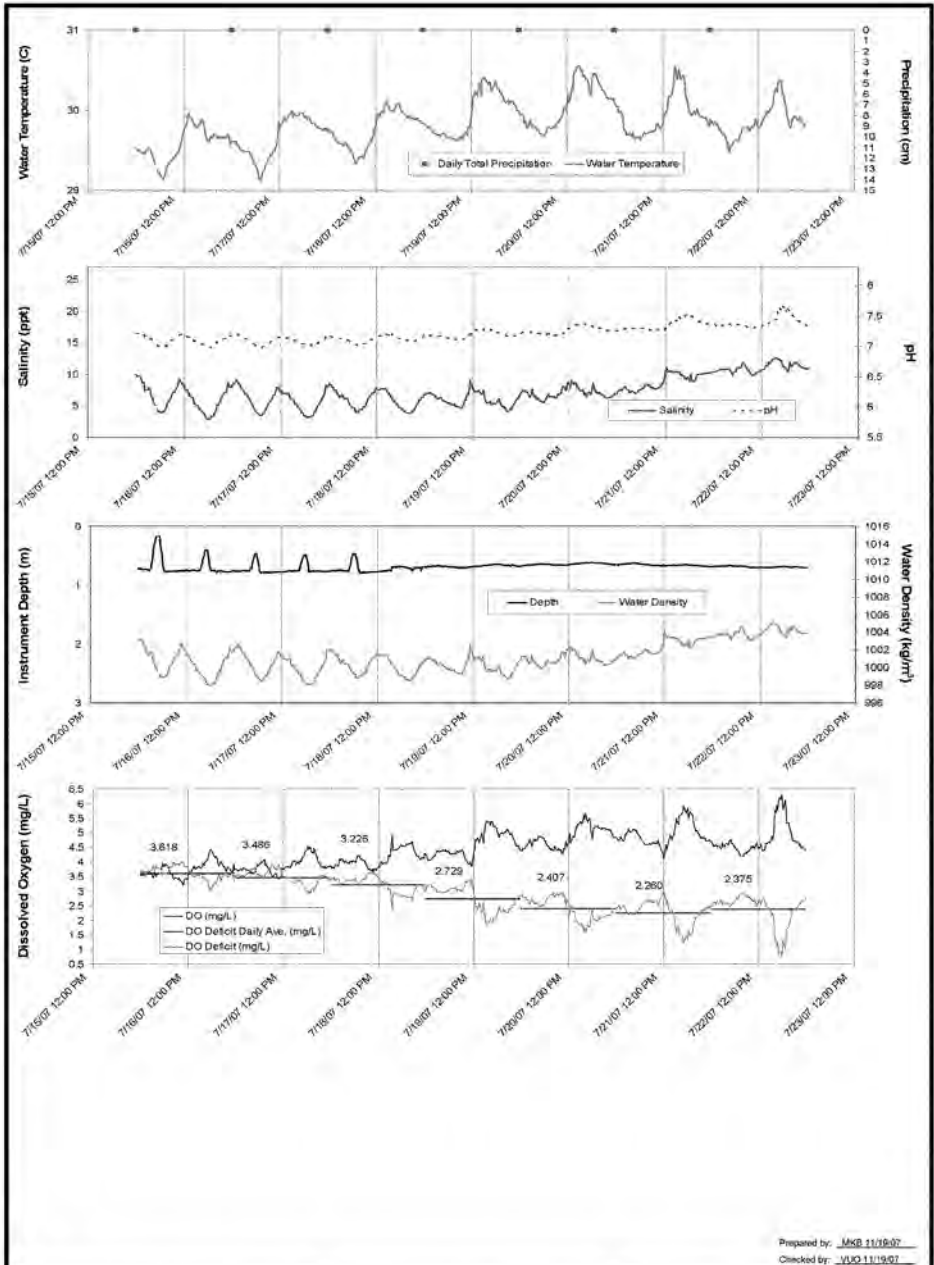
Intake Screens - Before and After

Project Number: 6110070004 Figure 3-2





Prepared by: MCR.11/19/07
Checked by: VJD.11/19/07



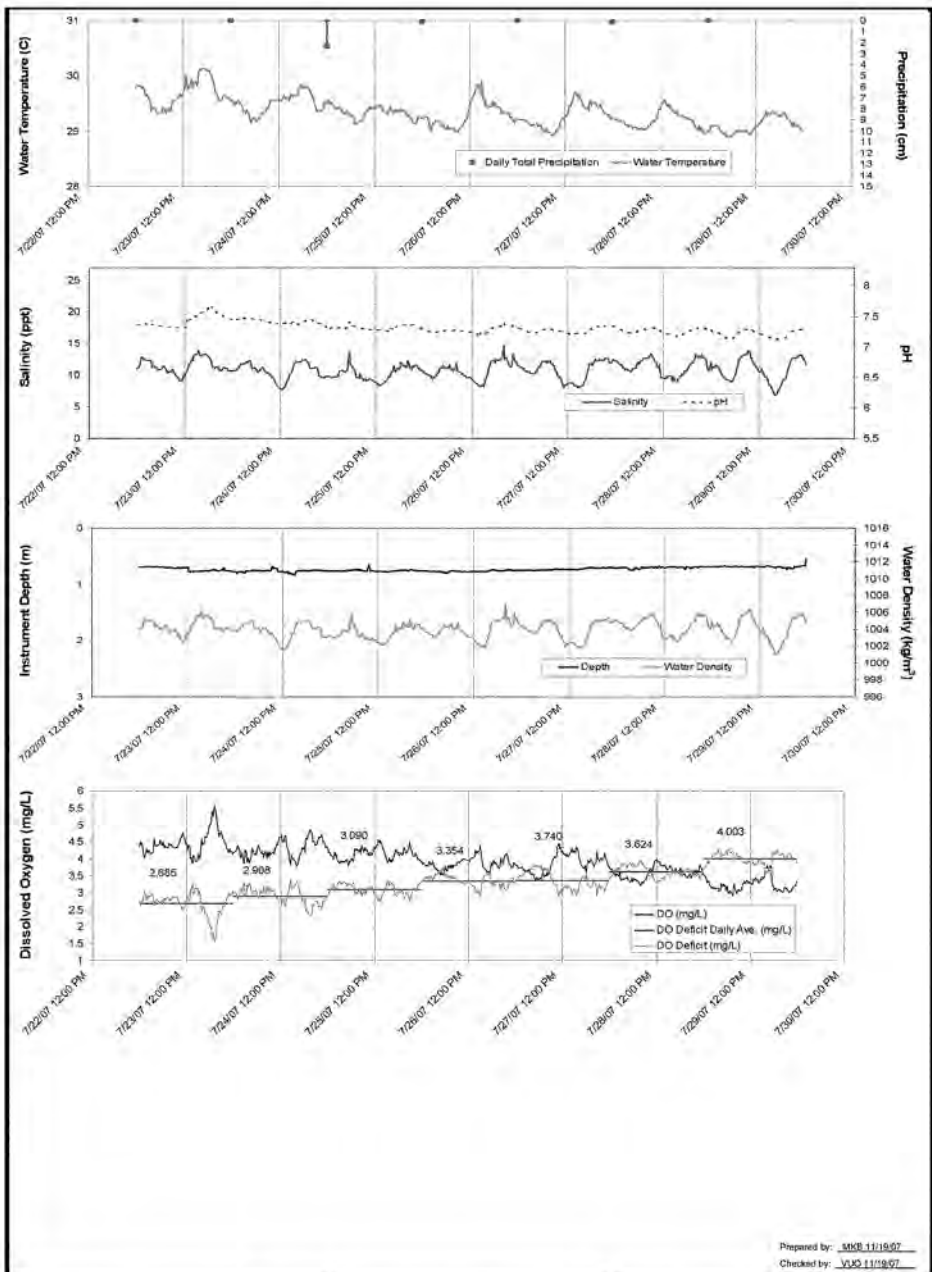
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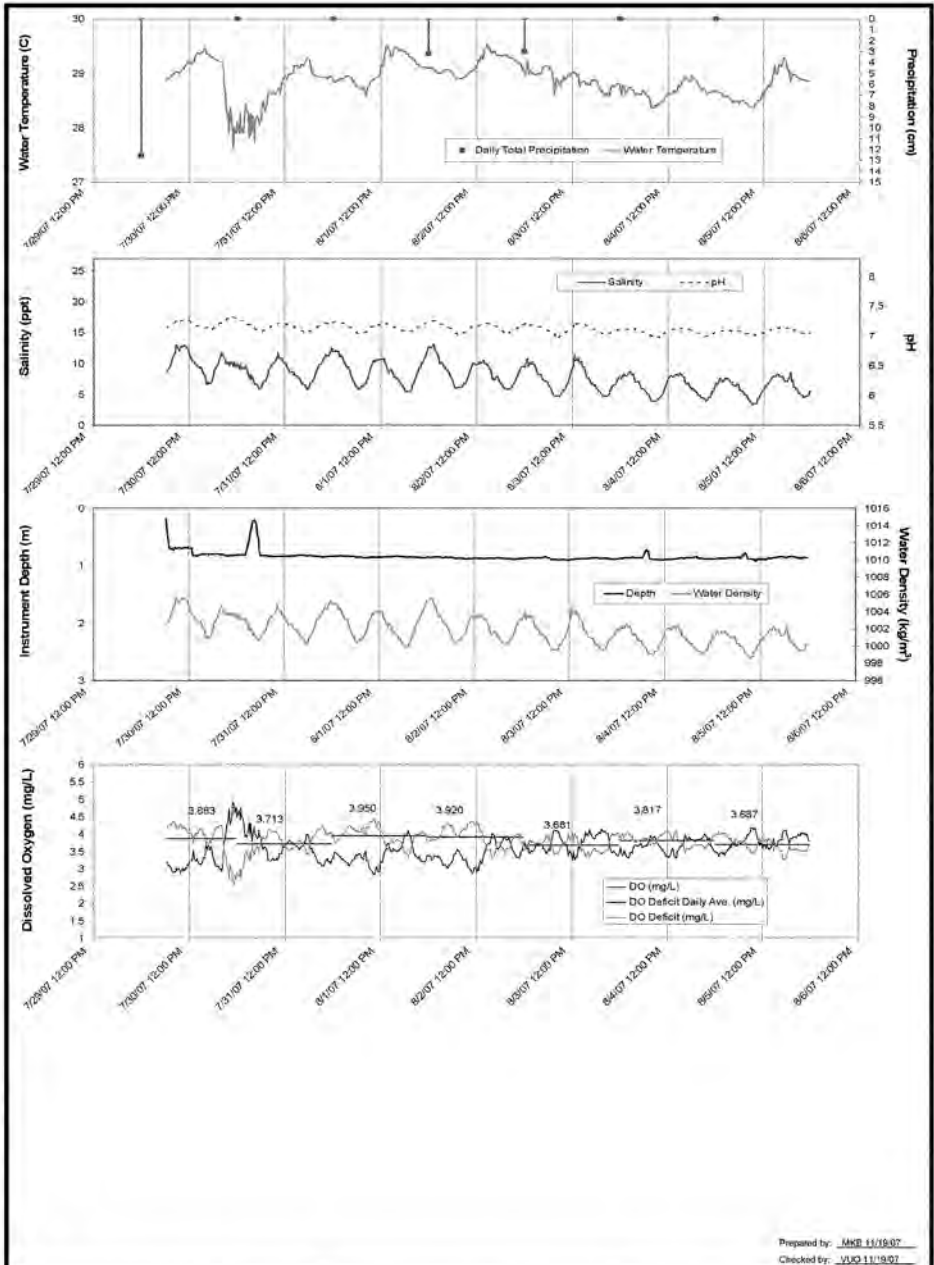
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Figure: 4-2.1





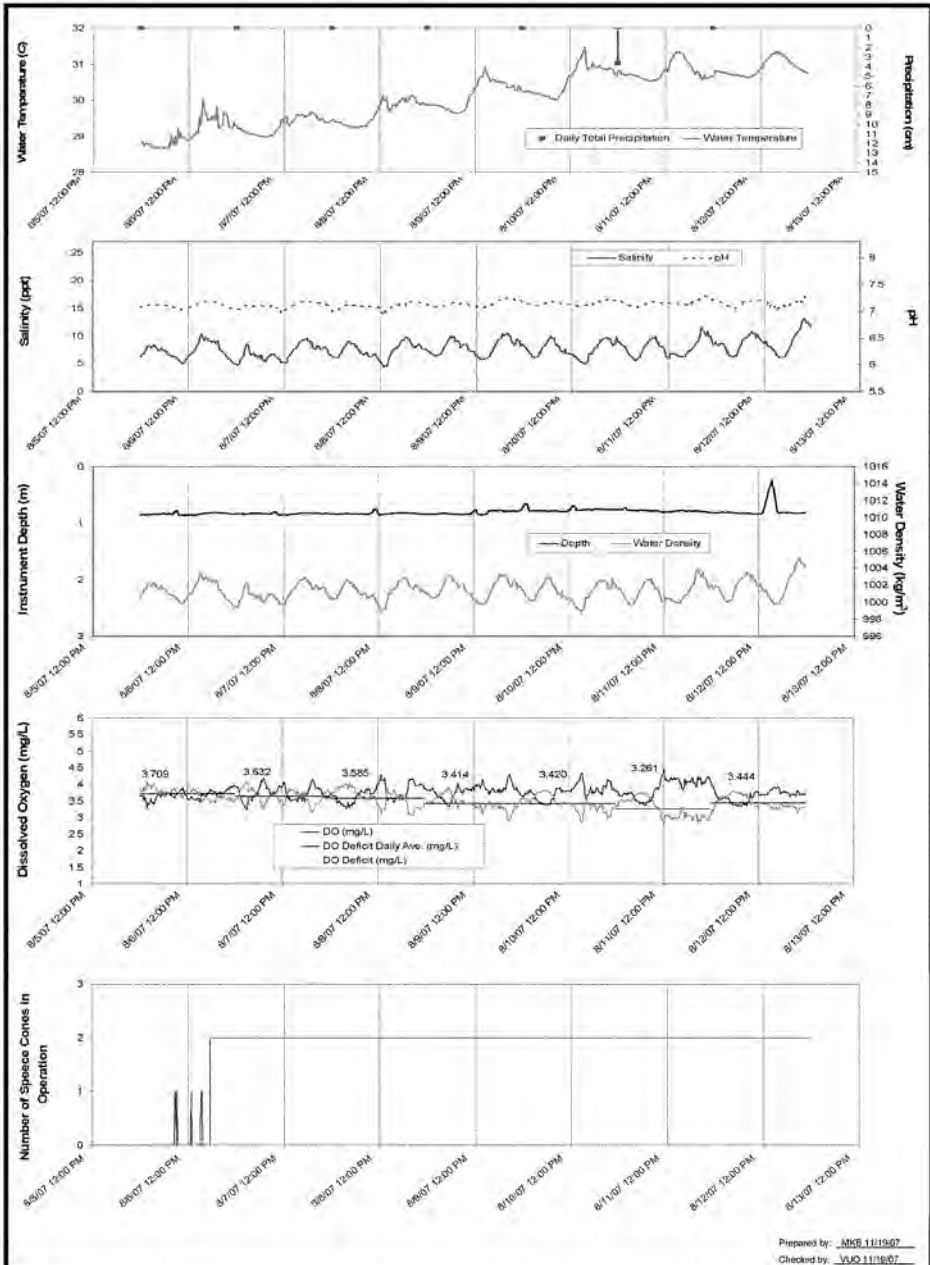
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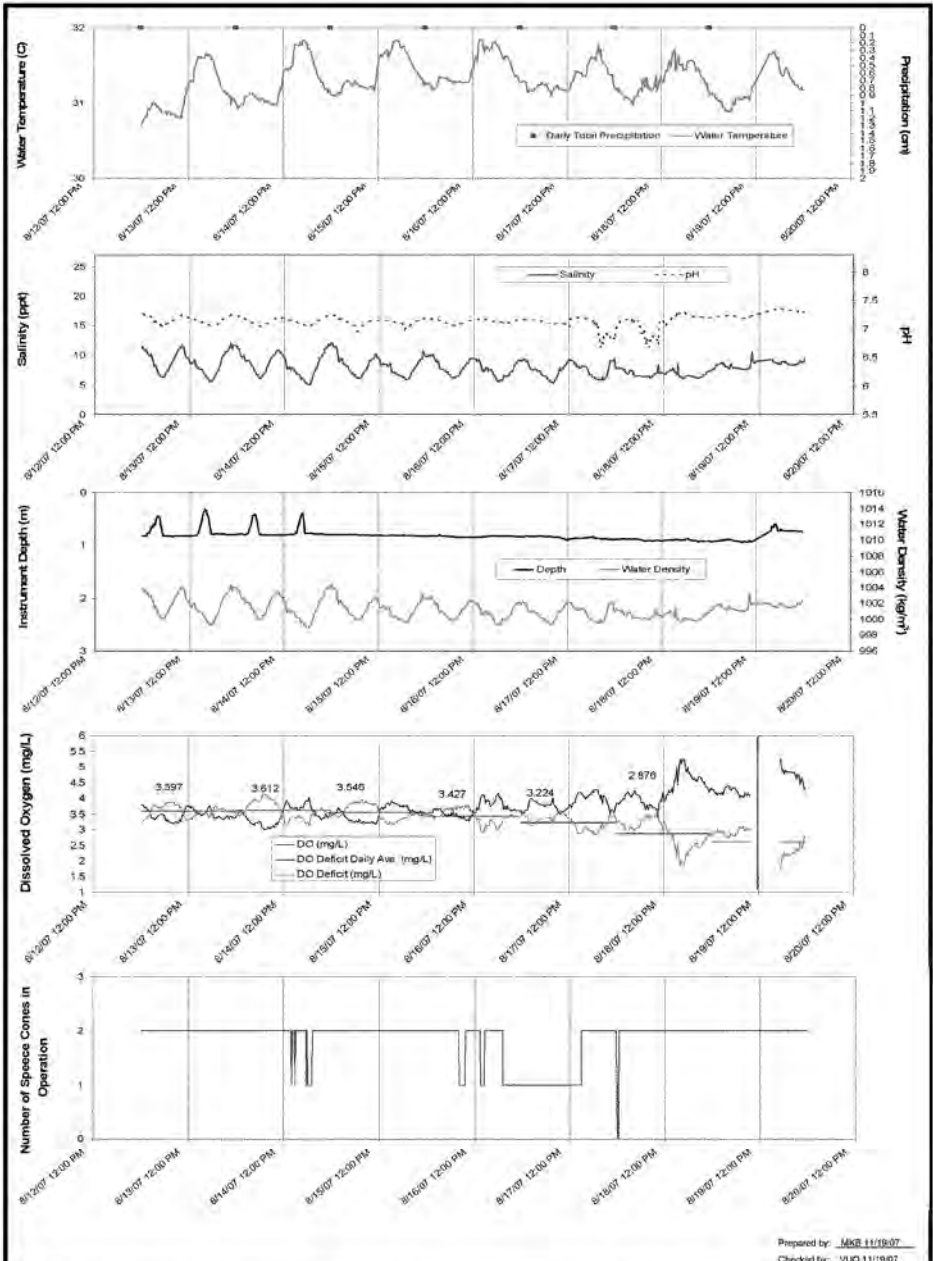
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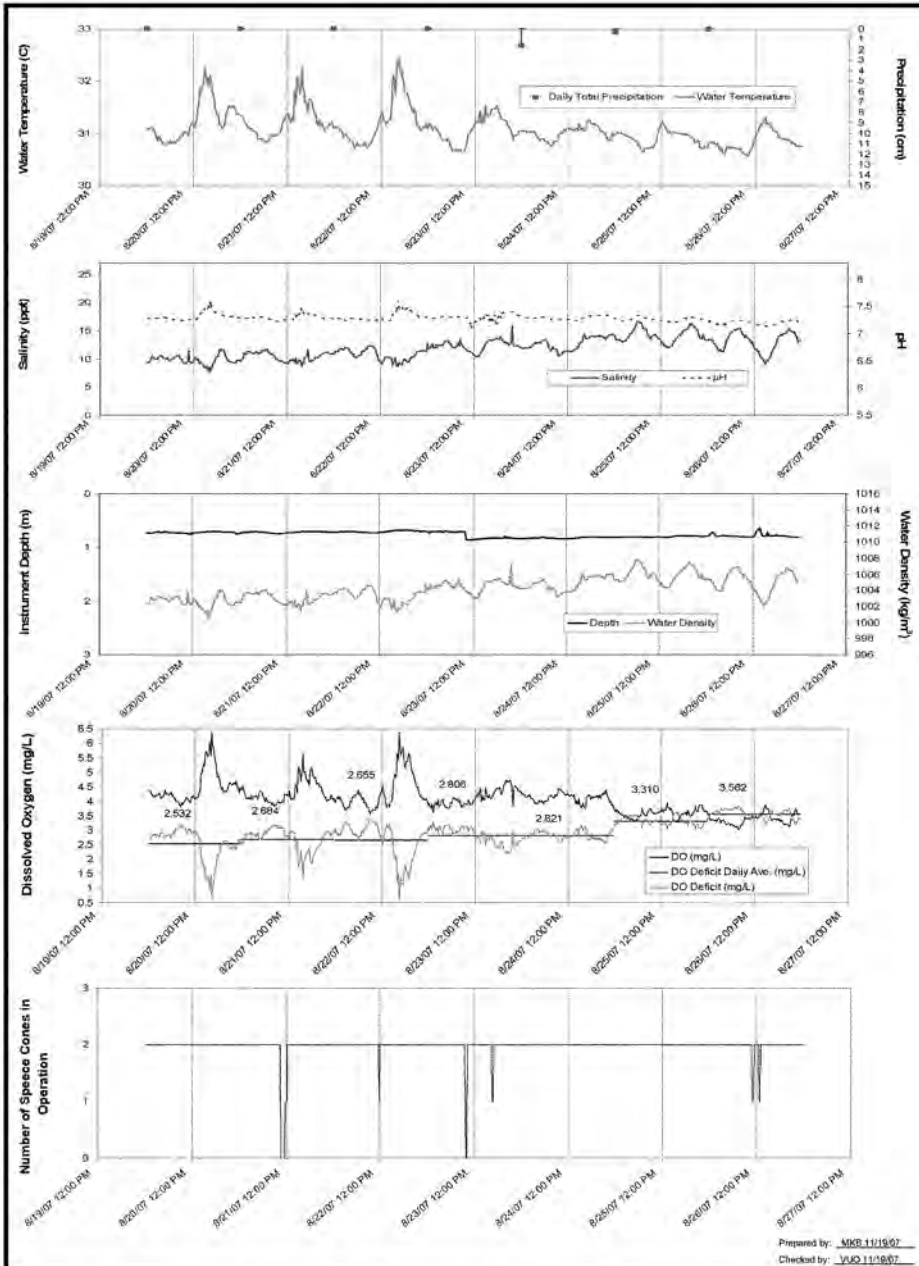
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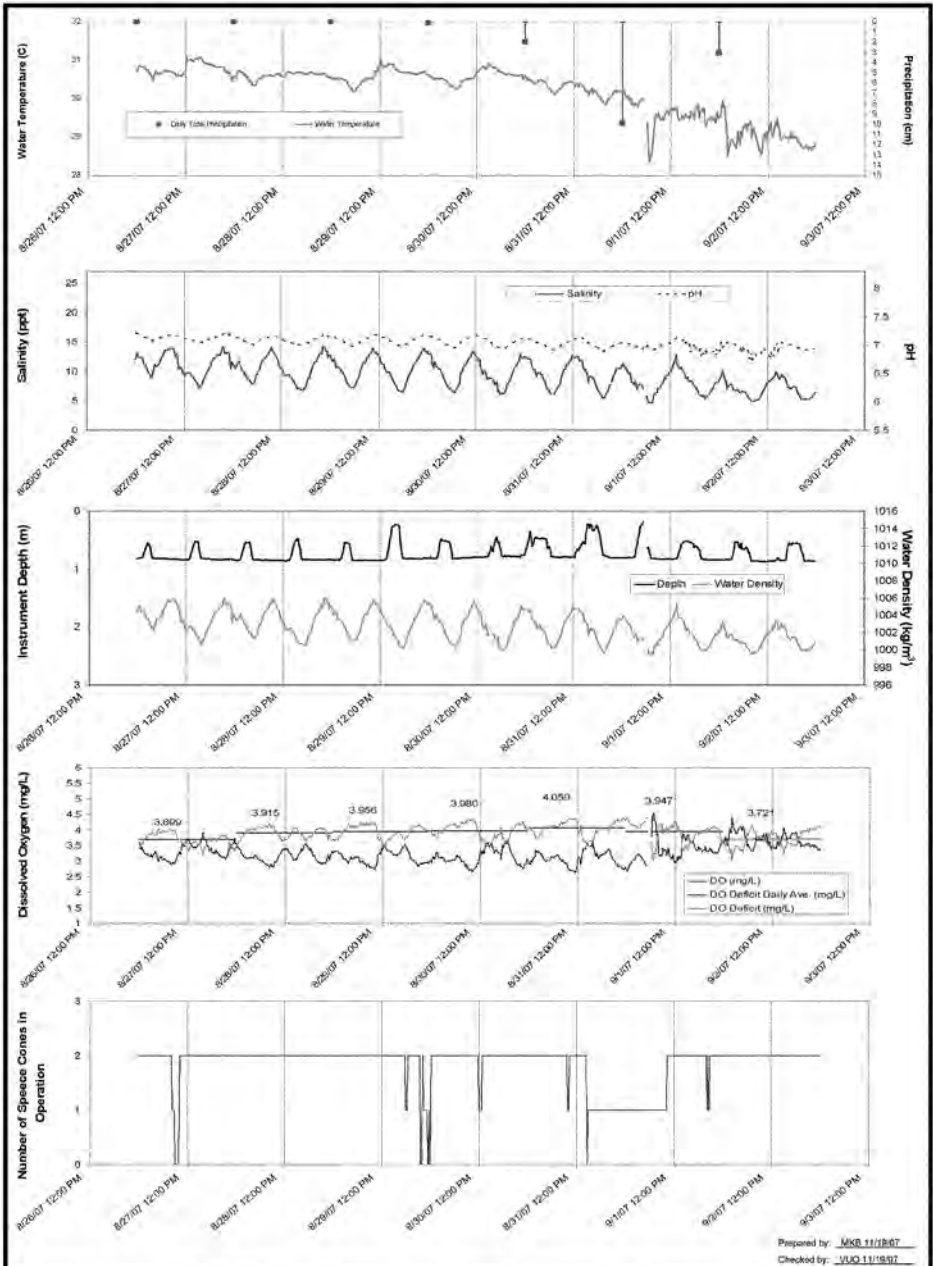
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Figure: A-2.1



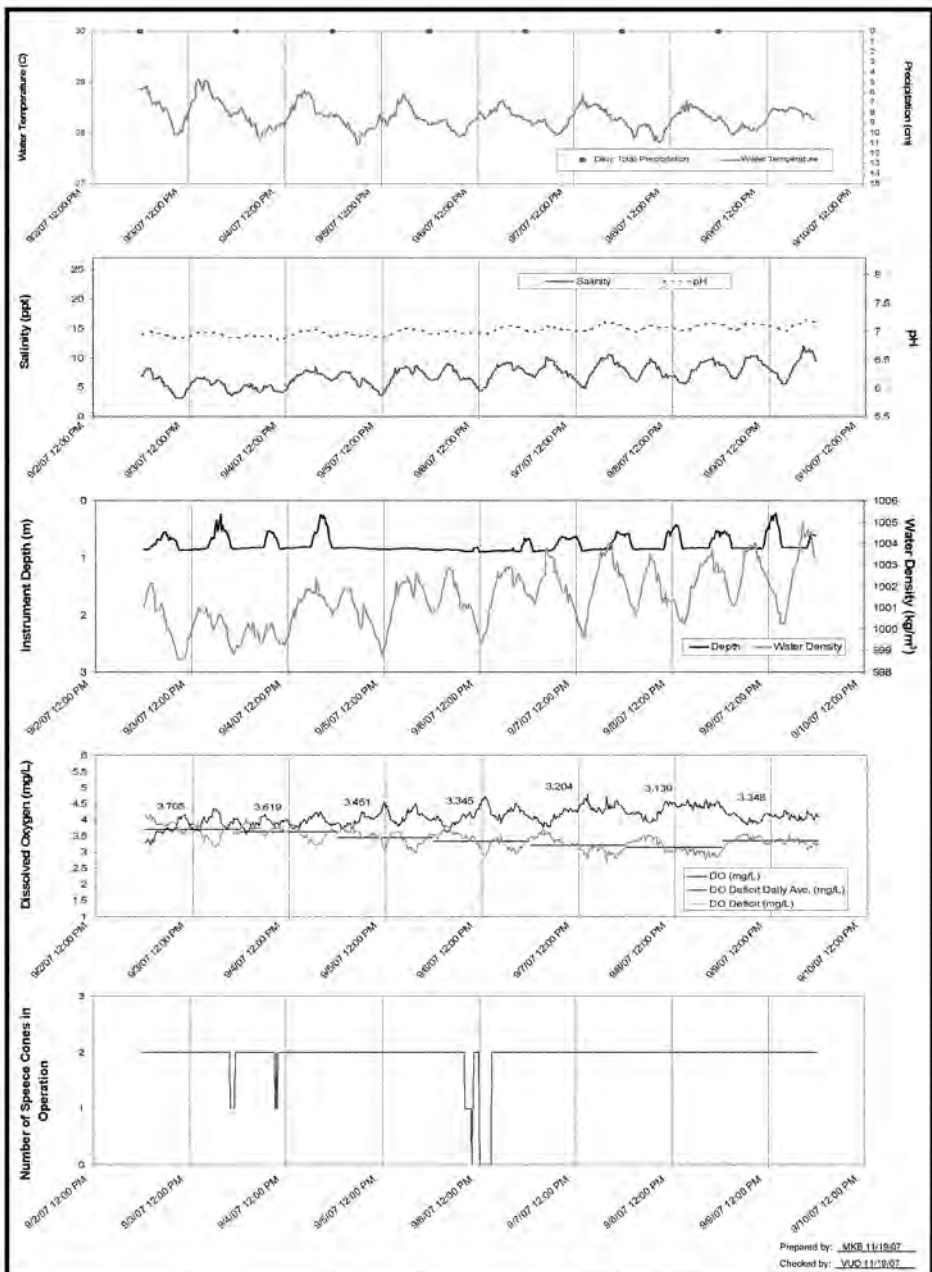
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Figure: 4-2.1

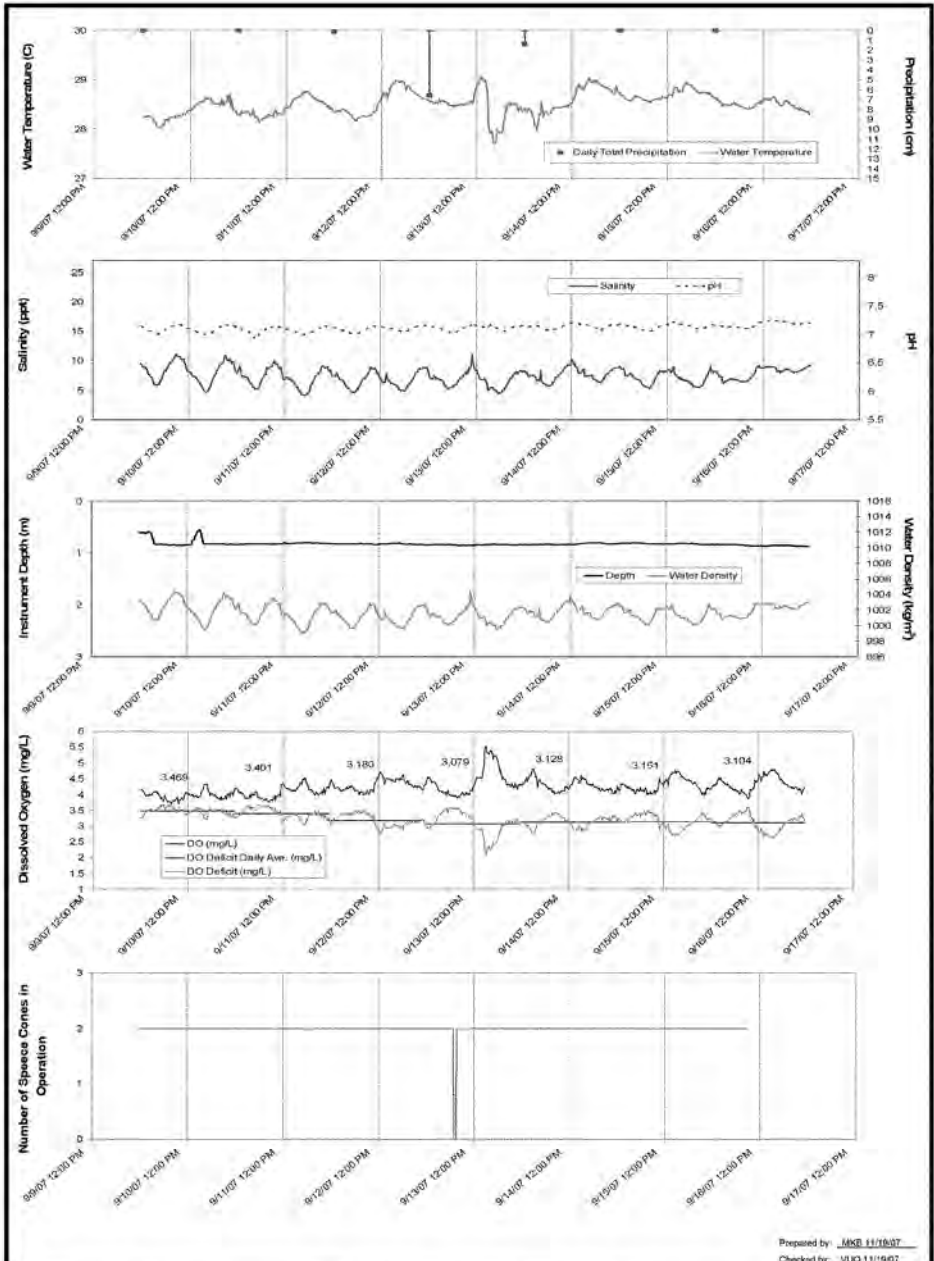


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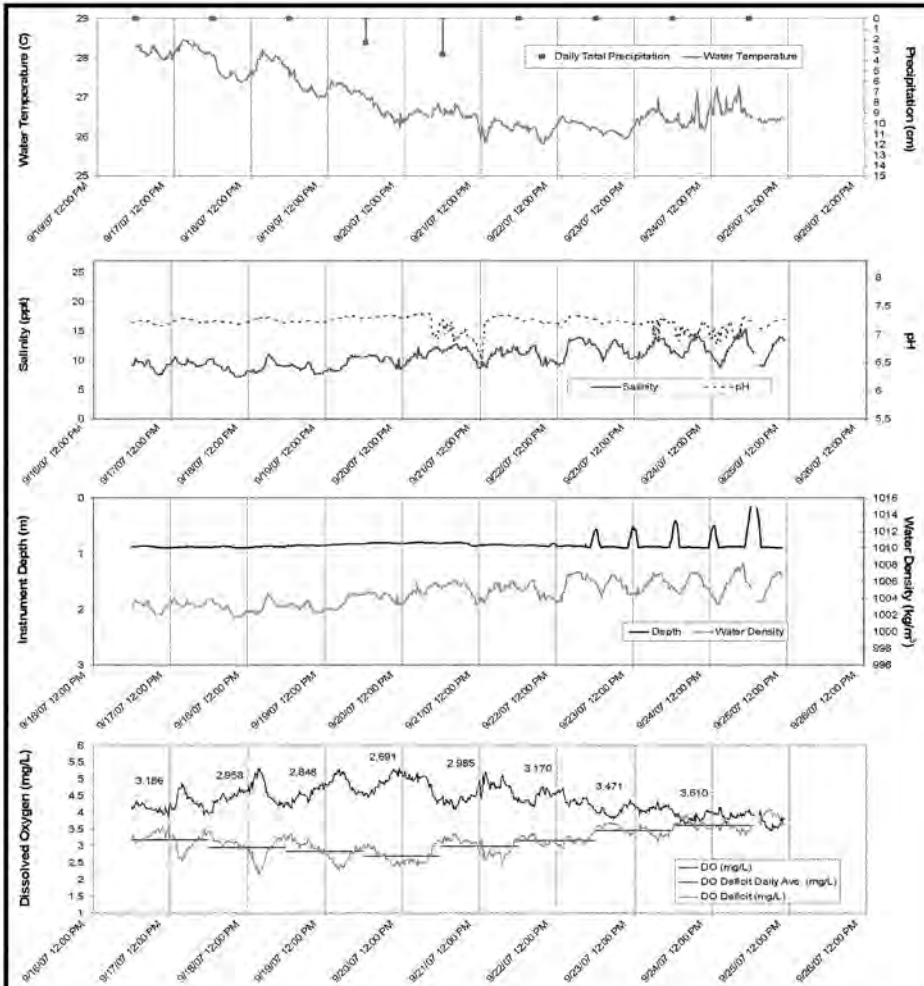
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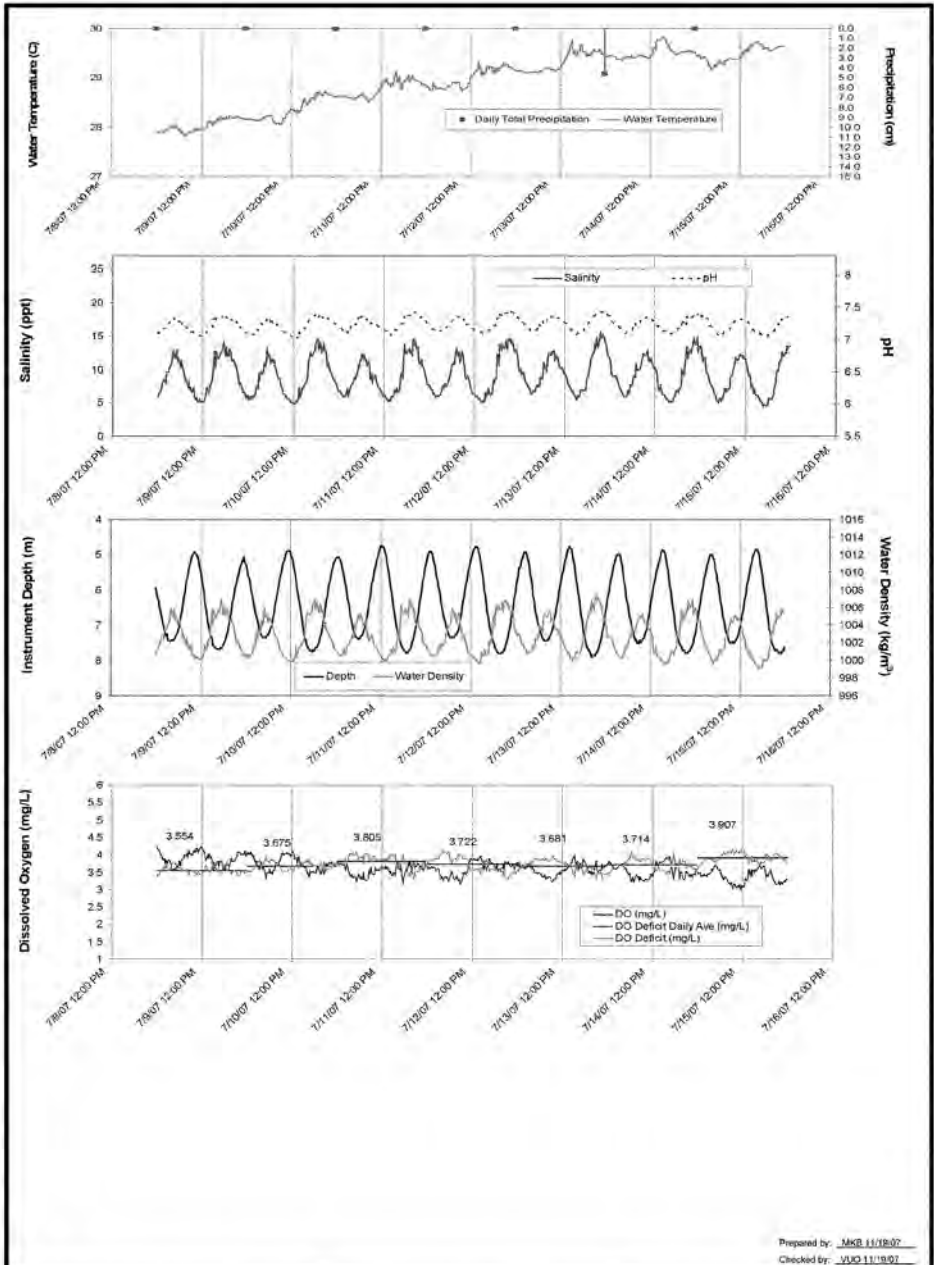
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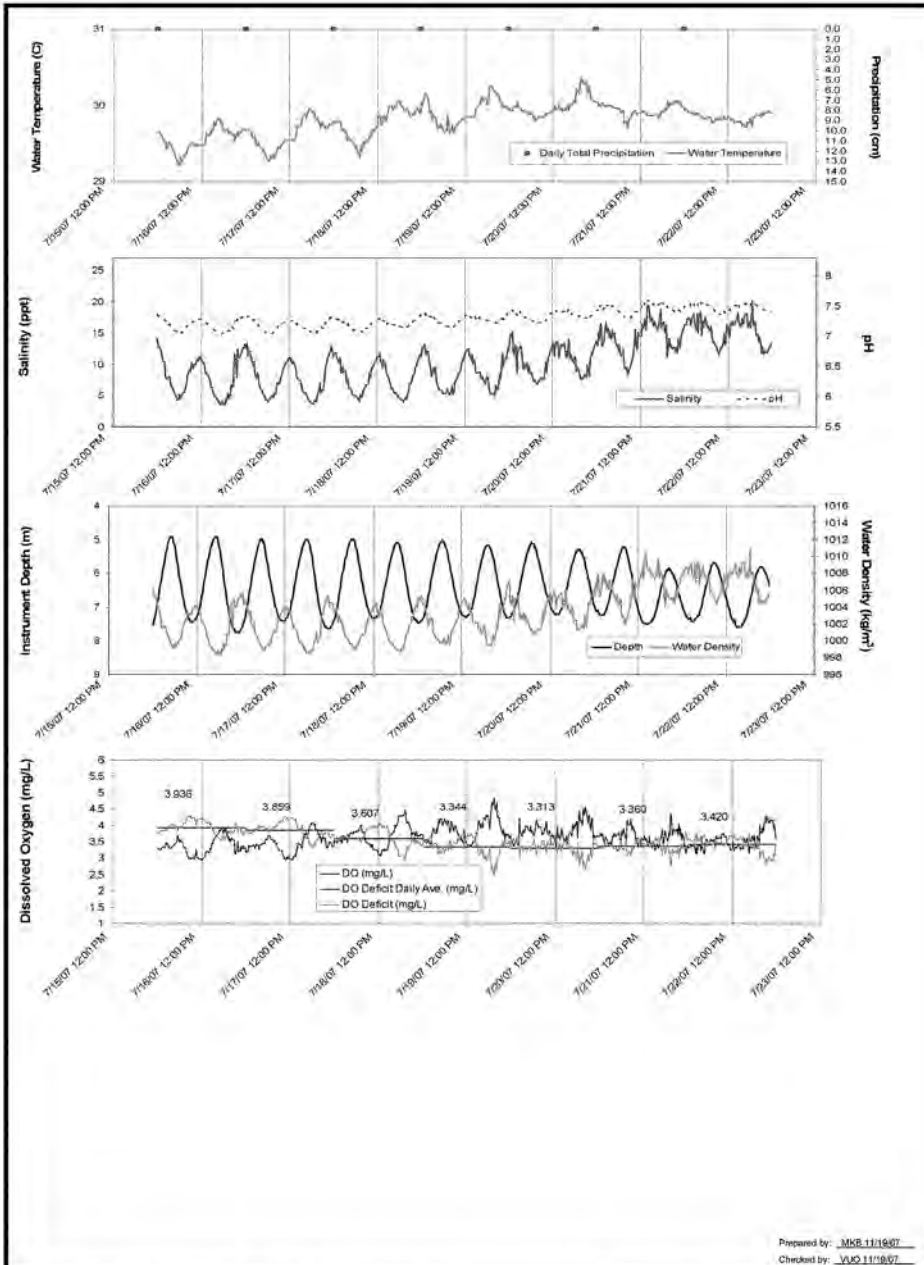
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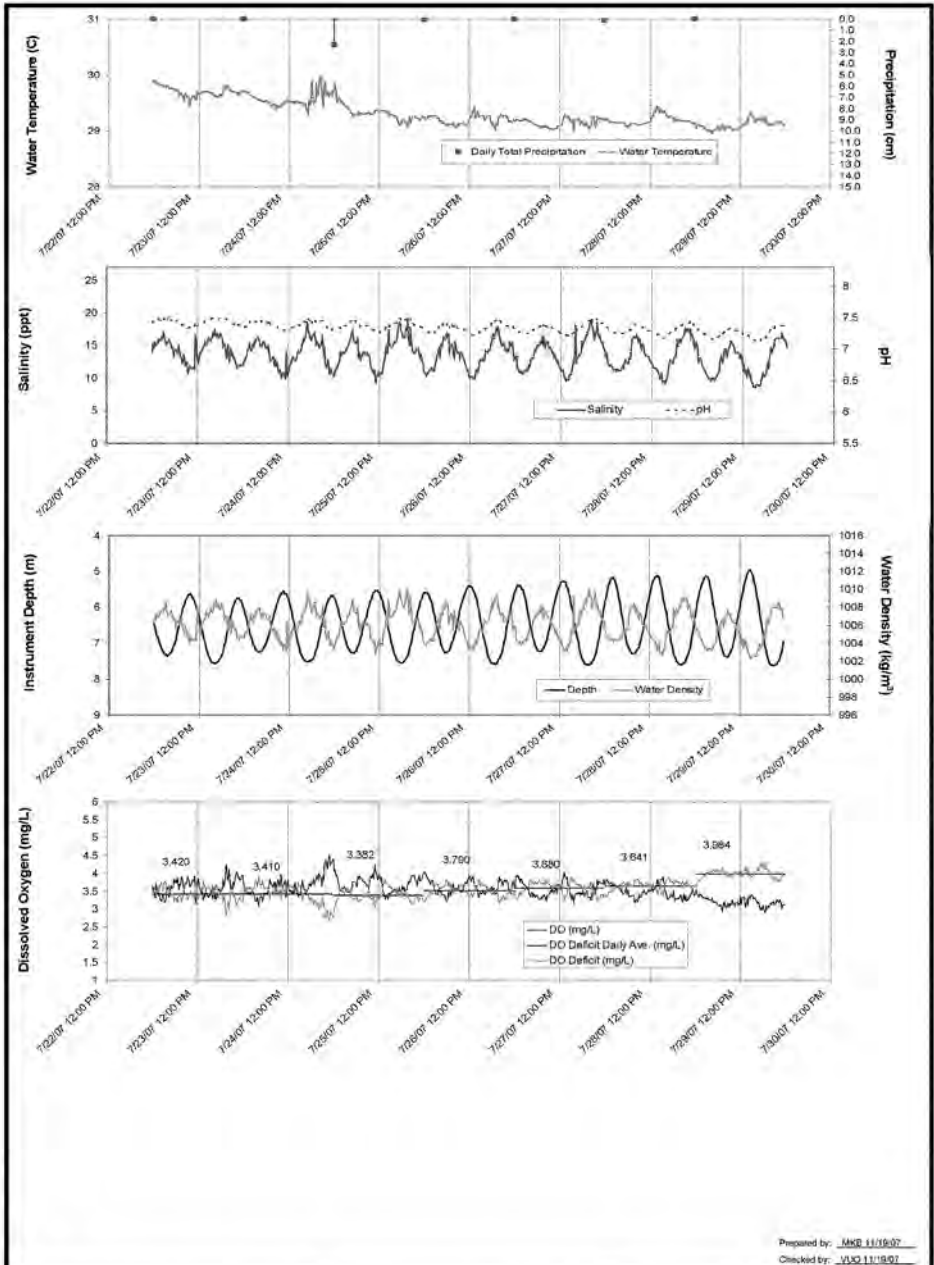


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Project Number: 6110070004 Figure: 4-2.1



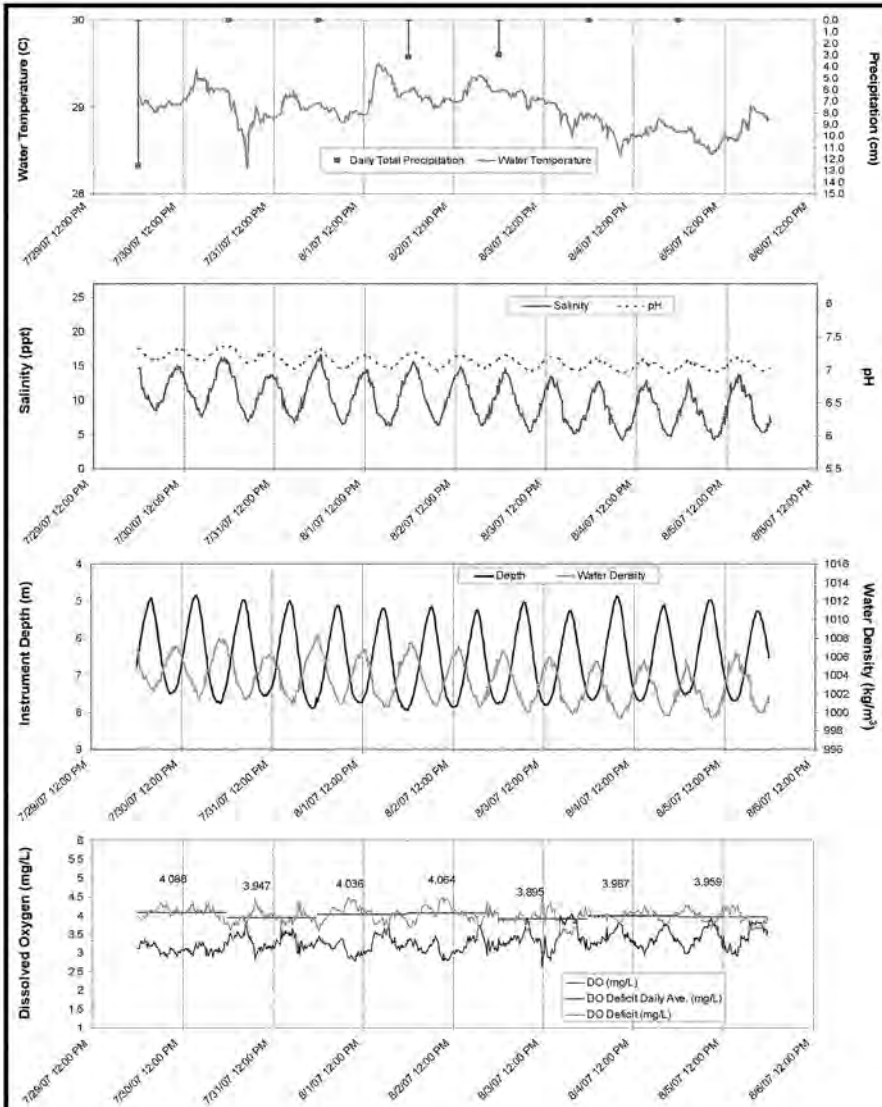
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Continuous Monitoring Station
 GPA - Mid Zone
 July 23 - 29, 2007

Project Number: 6110070004

Figure: 4-2.1



Prepared by: MKR.11/19/07

Checked by: VUD.11/19/07

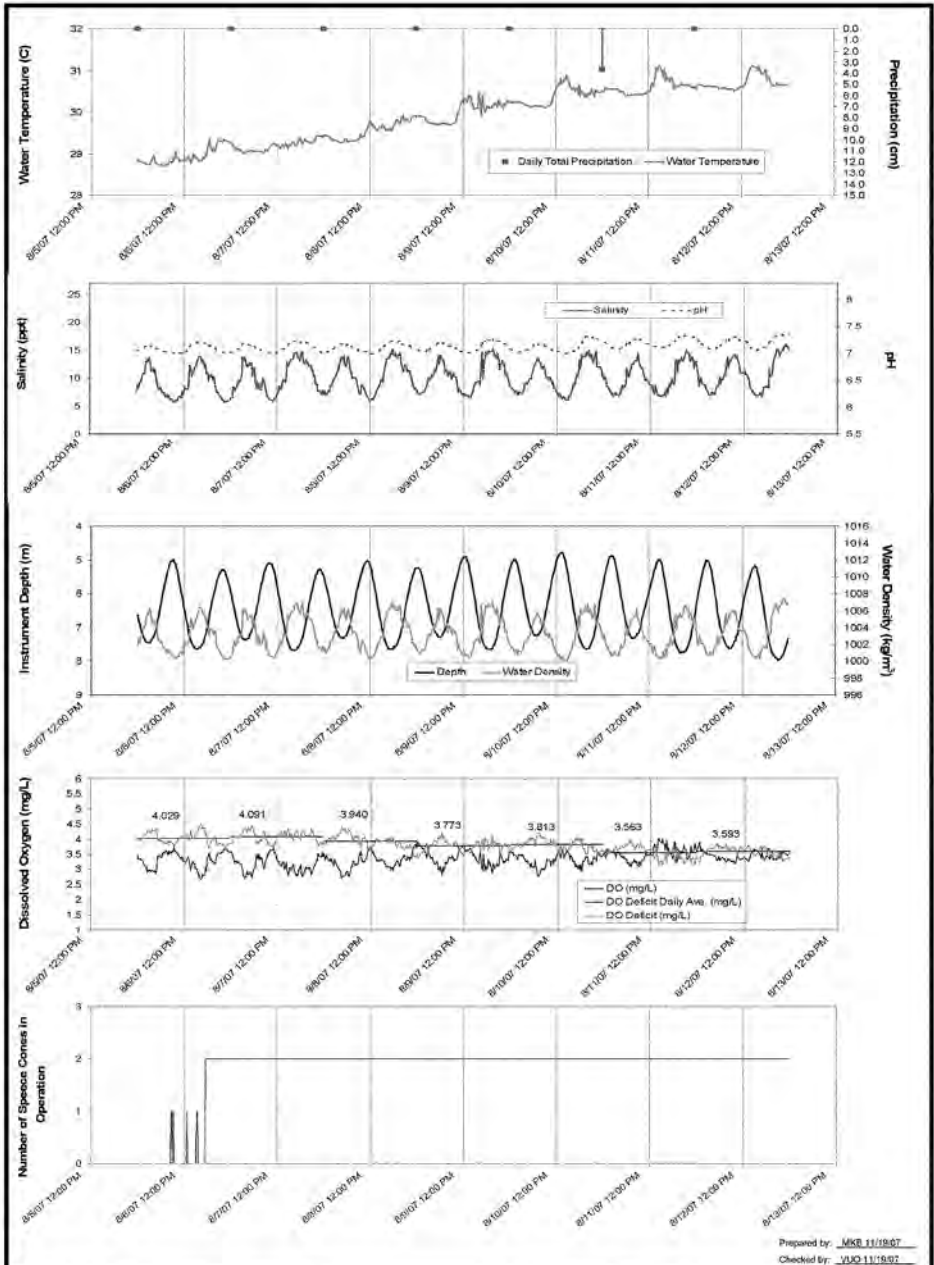
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Continuous Monitoring Station
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Figure: 4-2.1



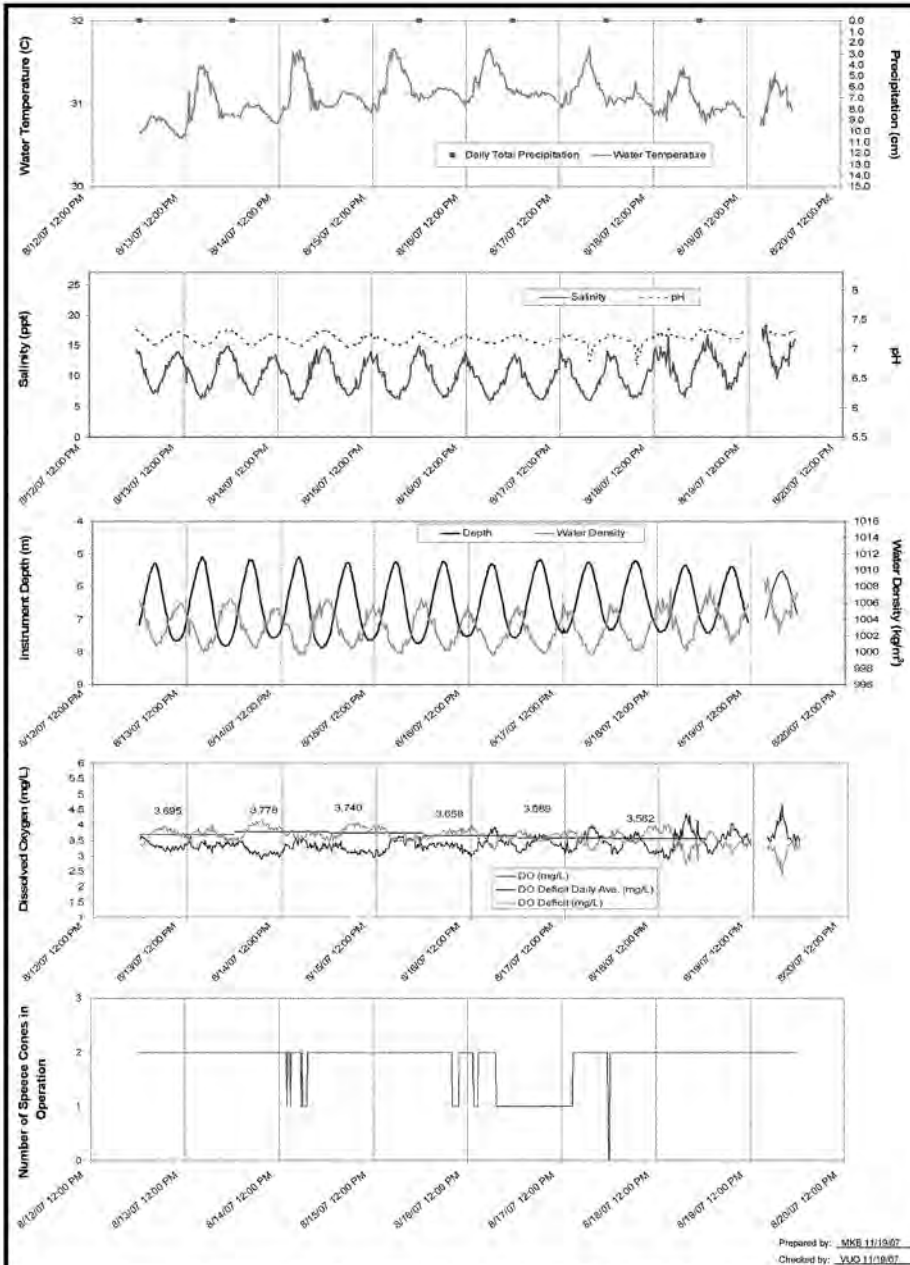
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August 6 - 12, 2007

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Figure: 4-2.1



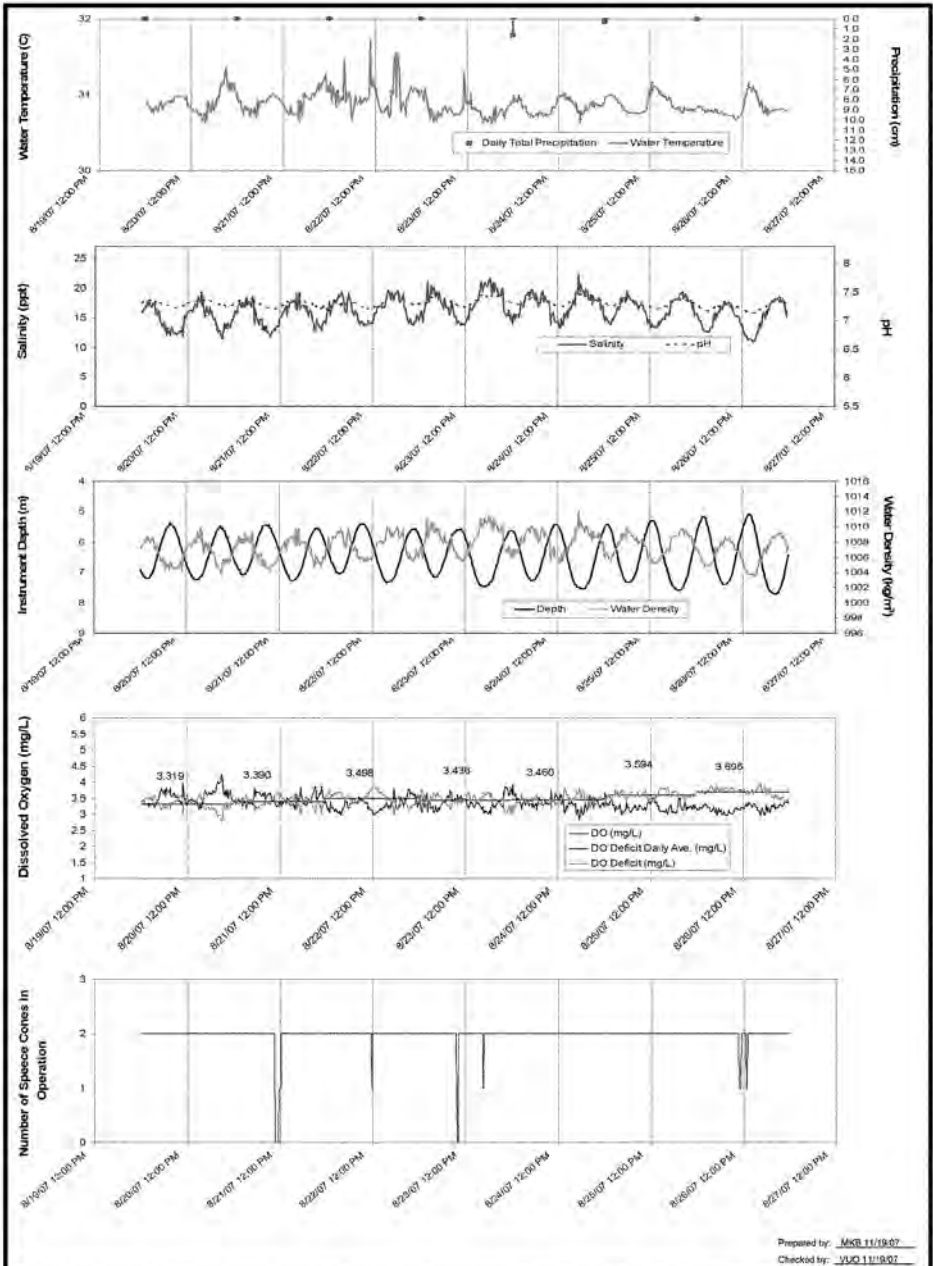
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Figure: 4-2.1



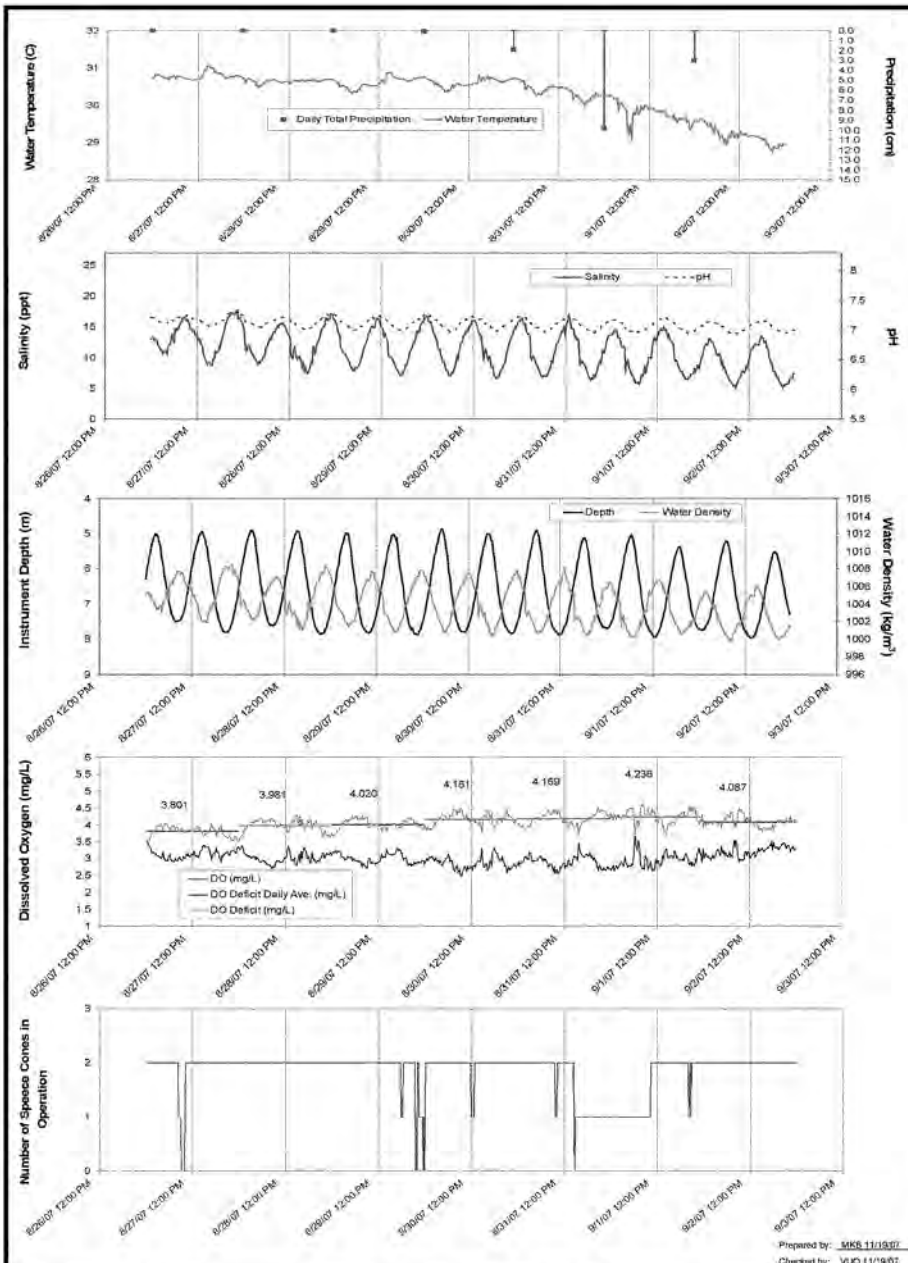
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Figure: 4-2.1



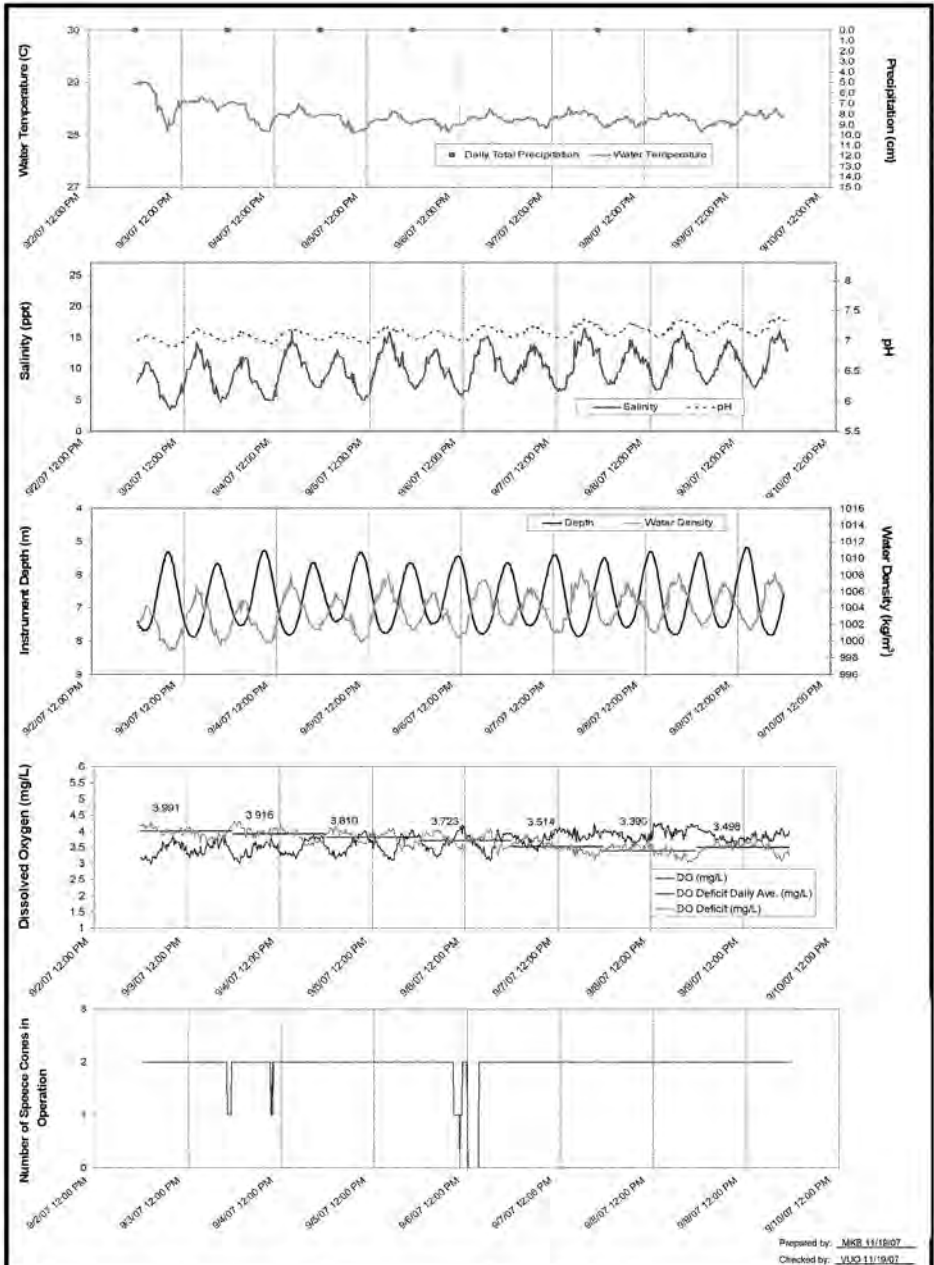
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Figure: A-2.1



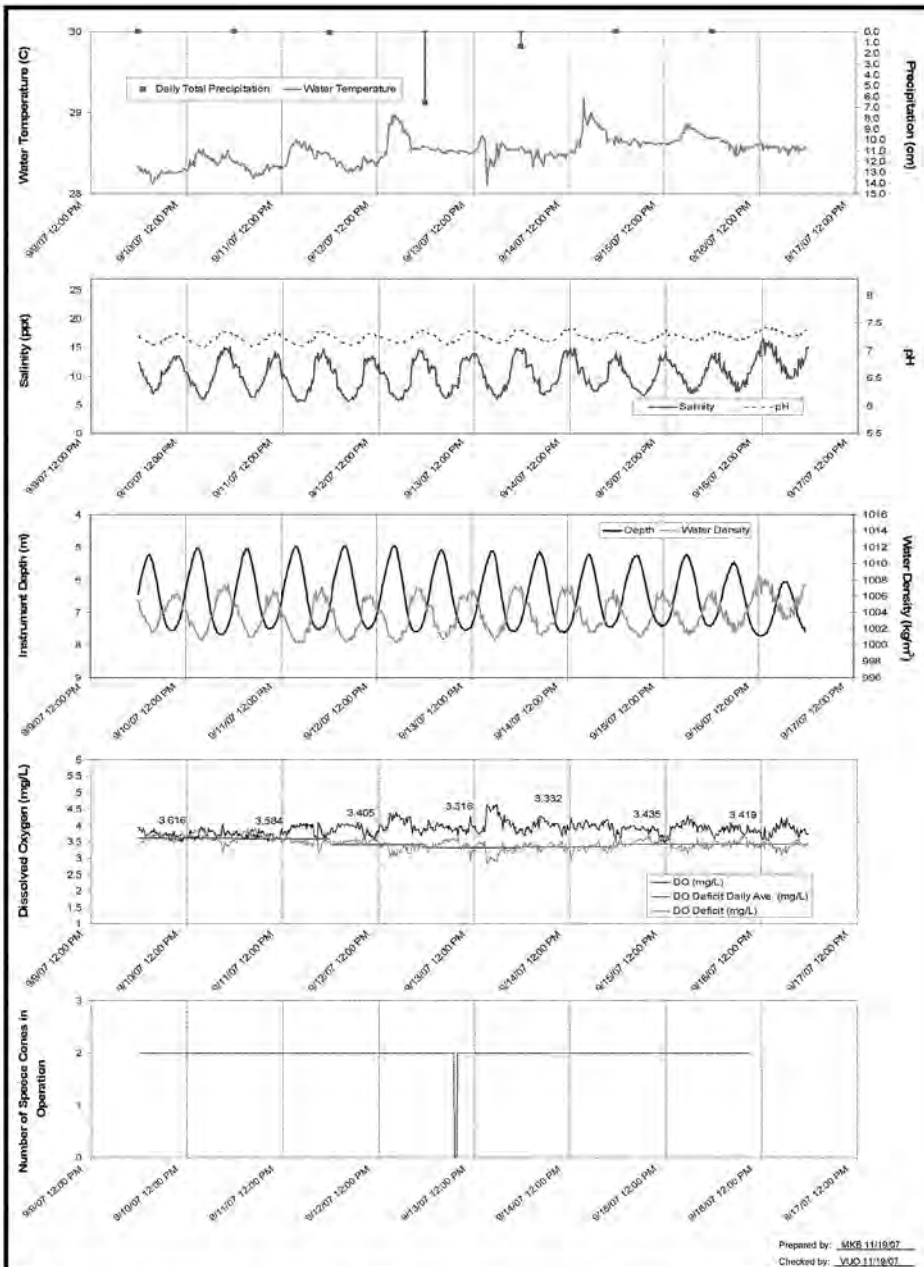
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Figure: 4-2.1



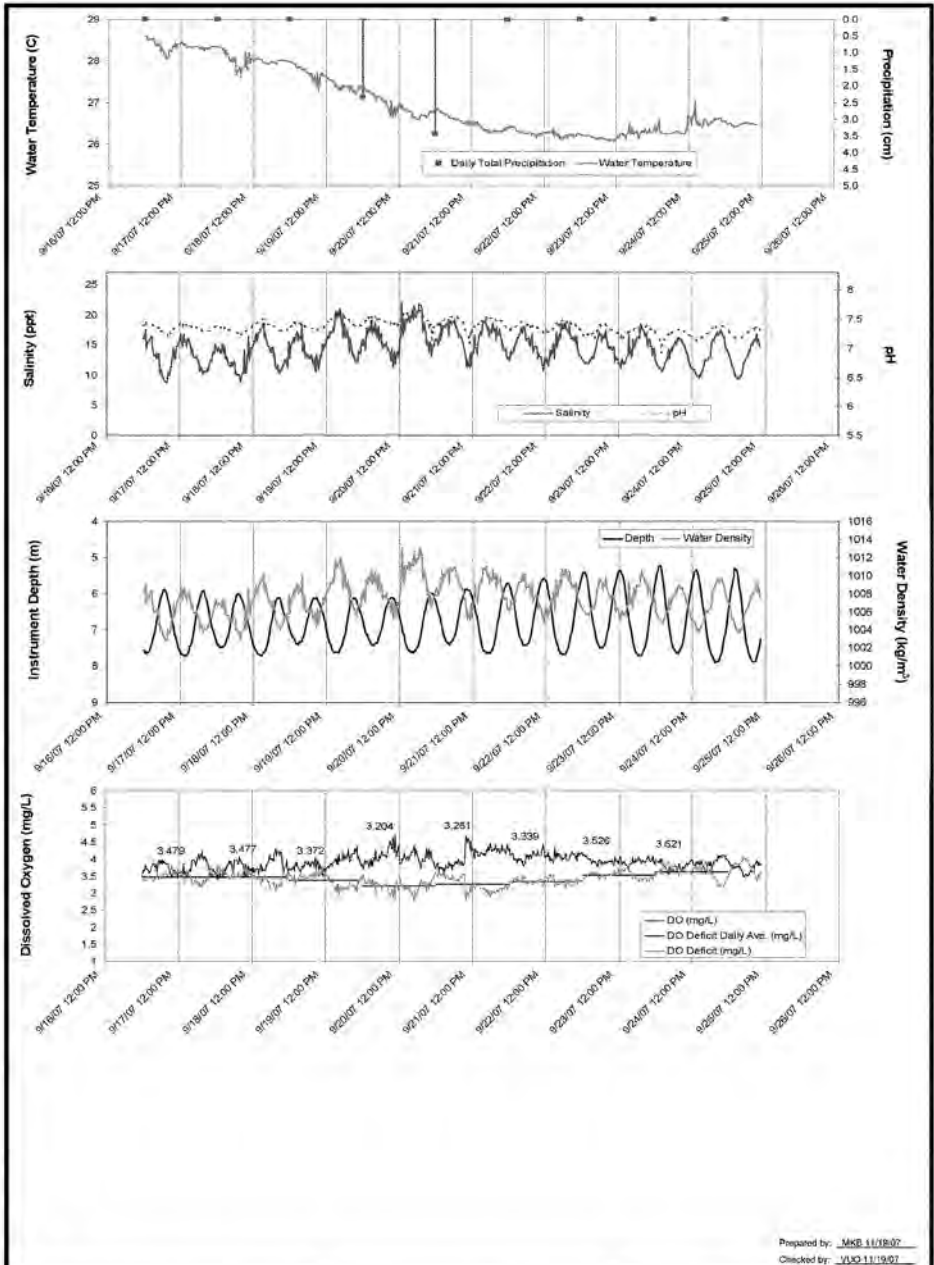
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Figure: A-2.1



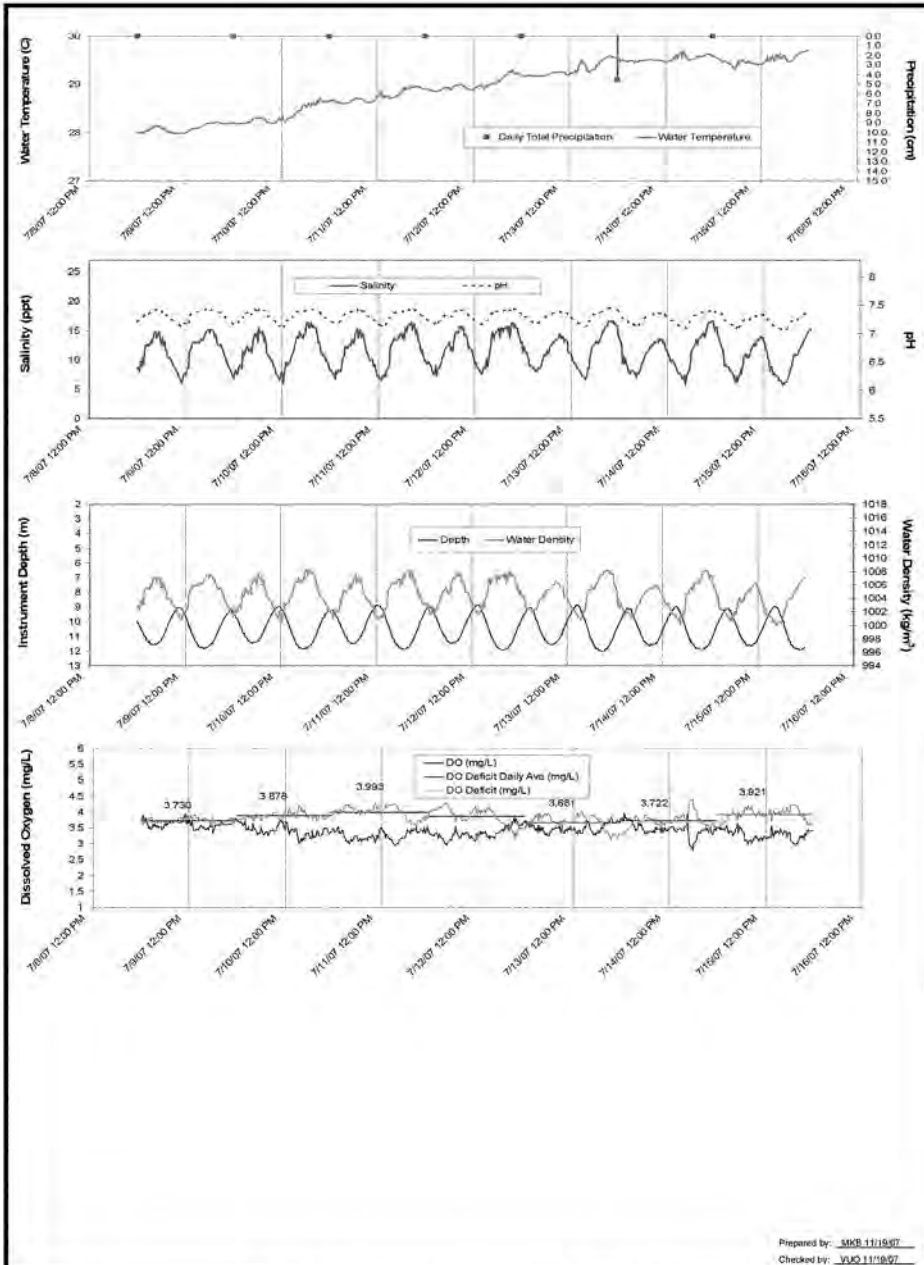
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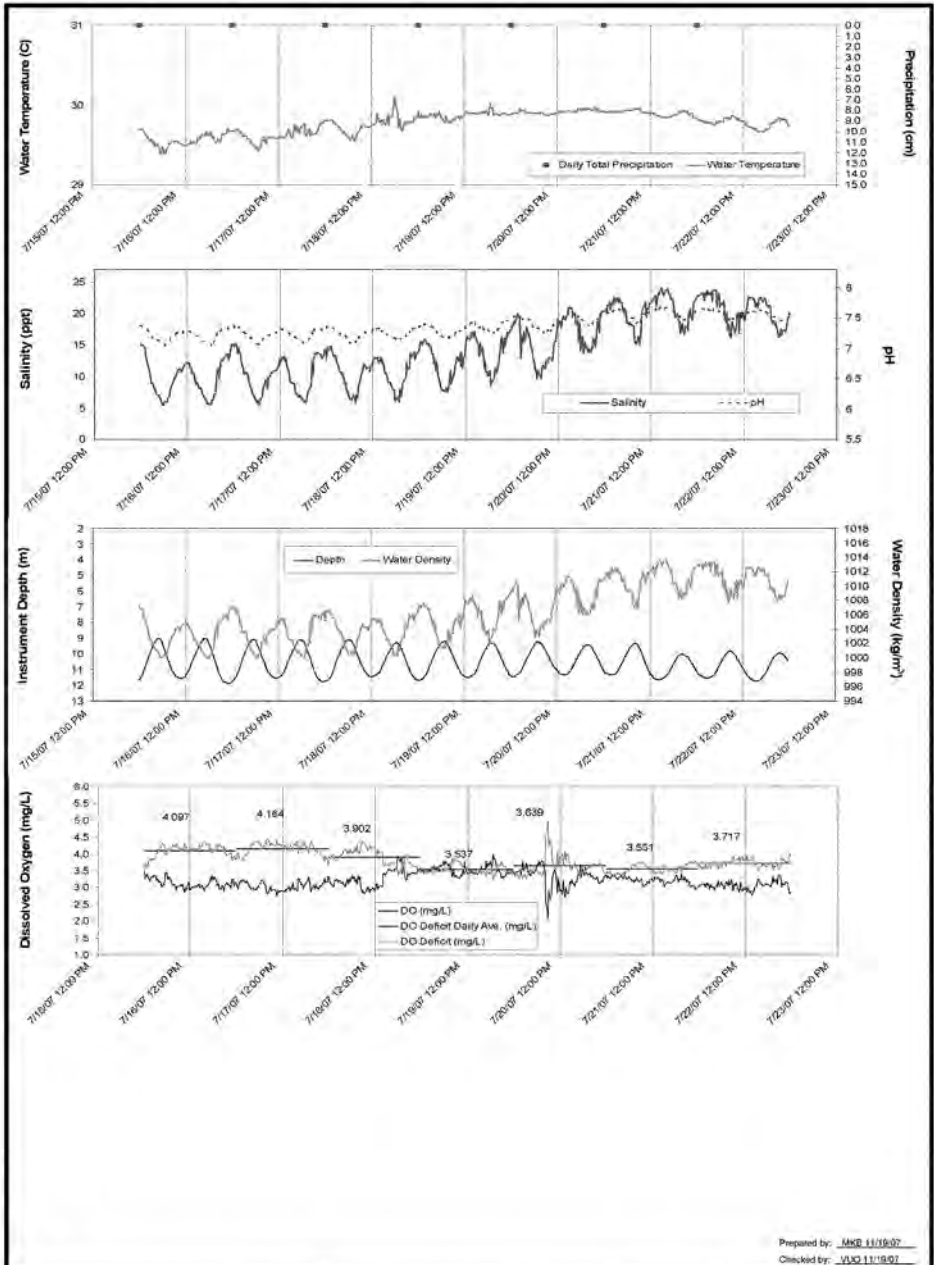
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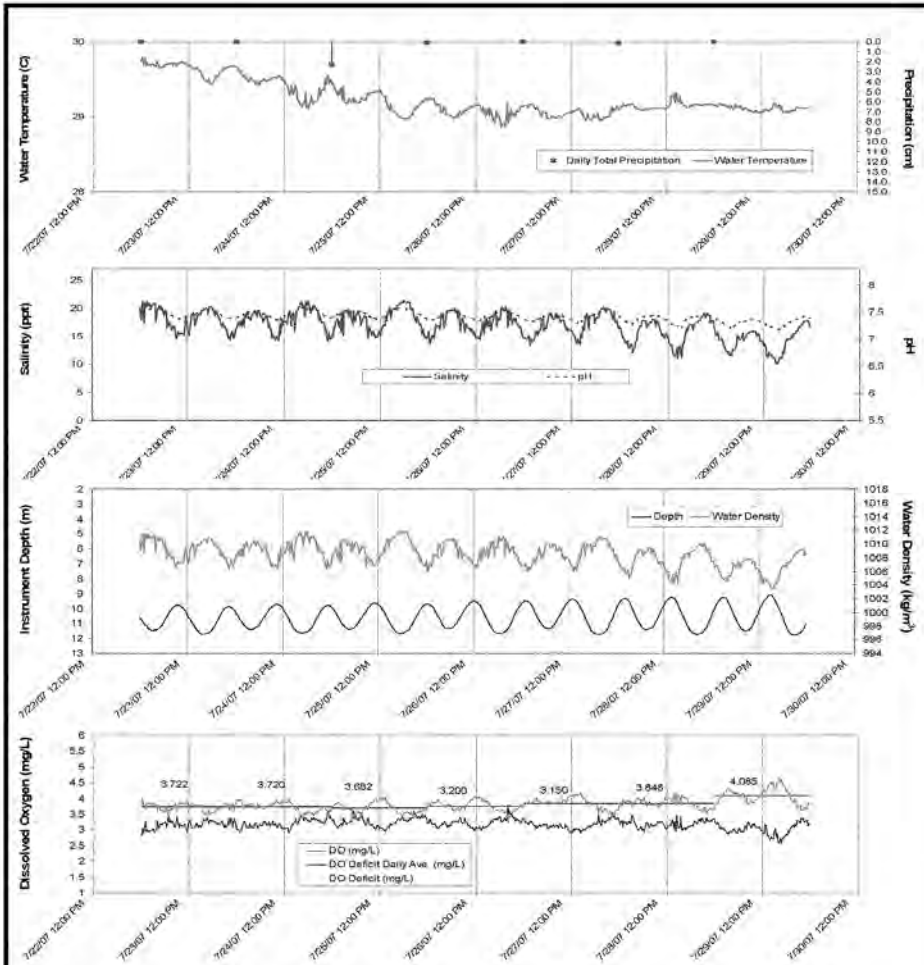
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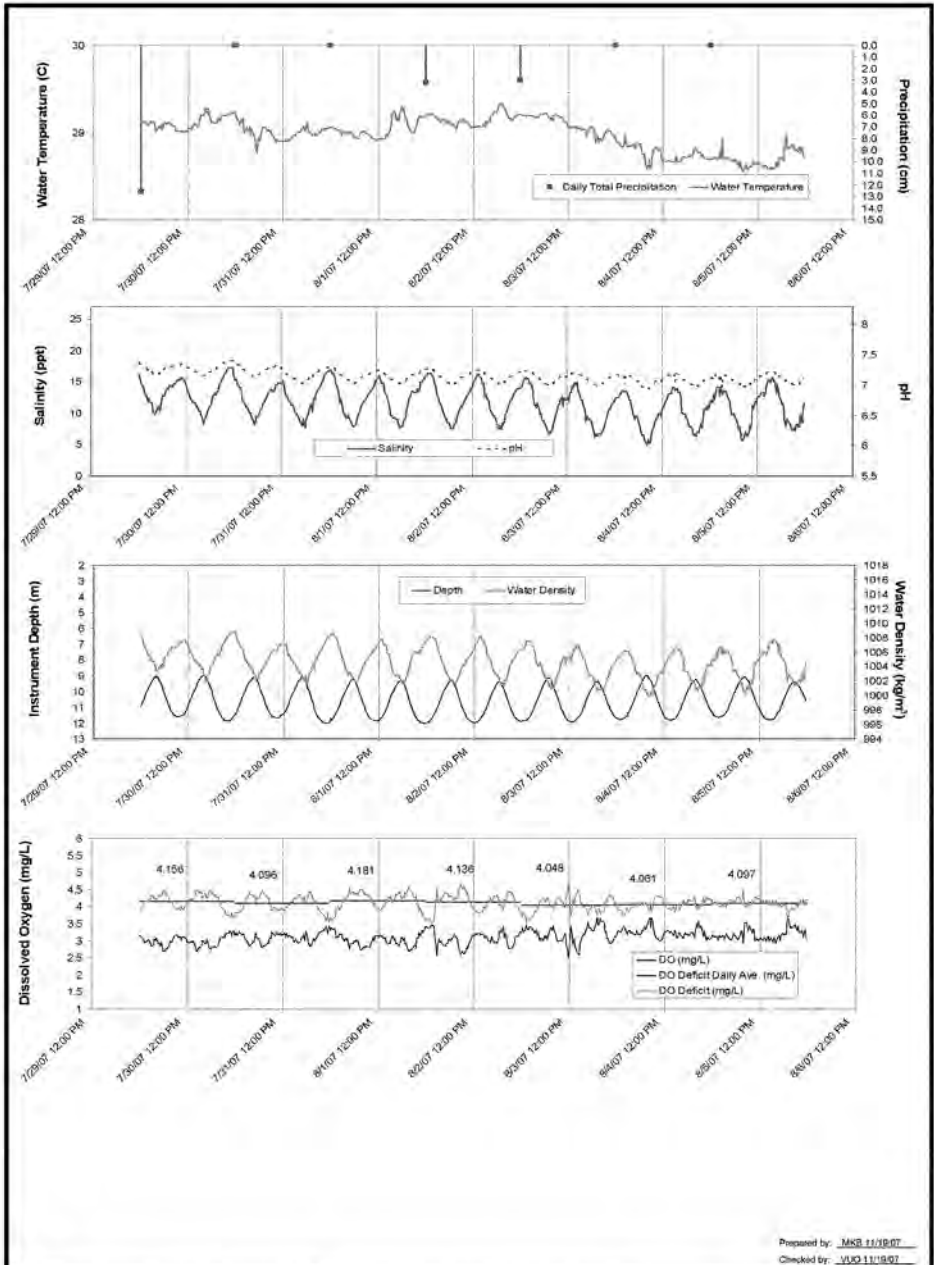
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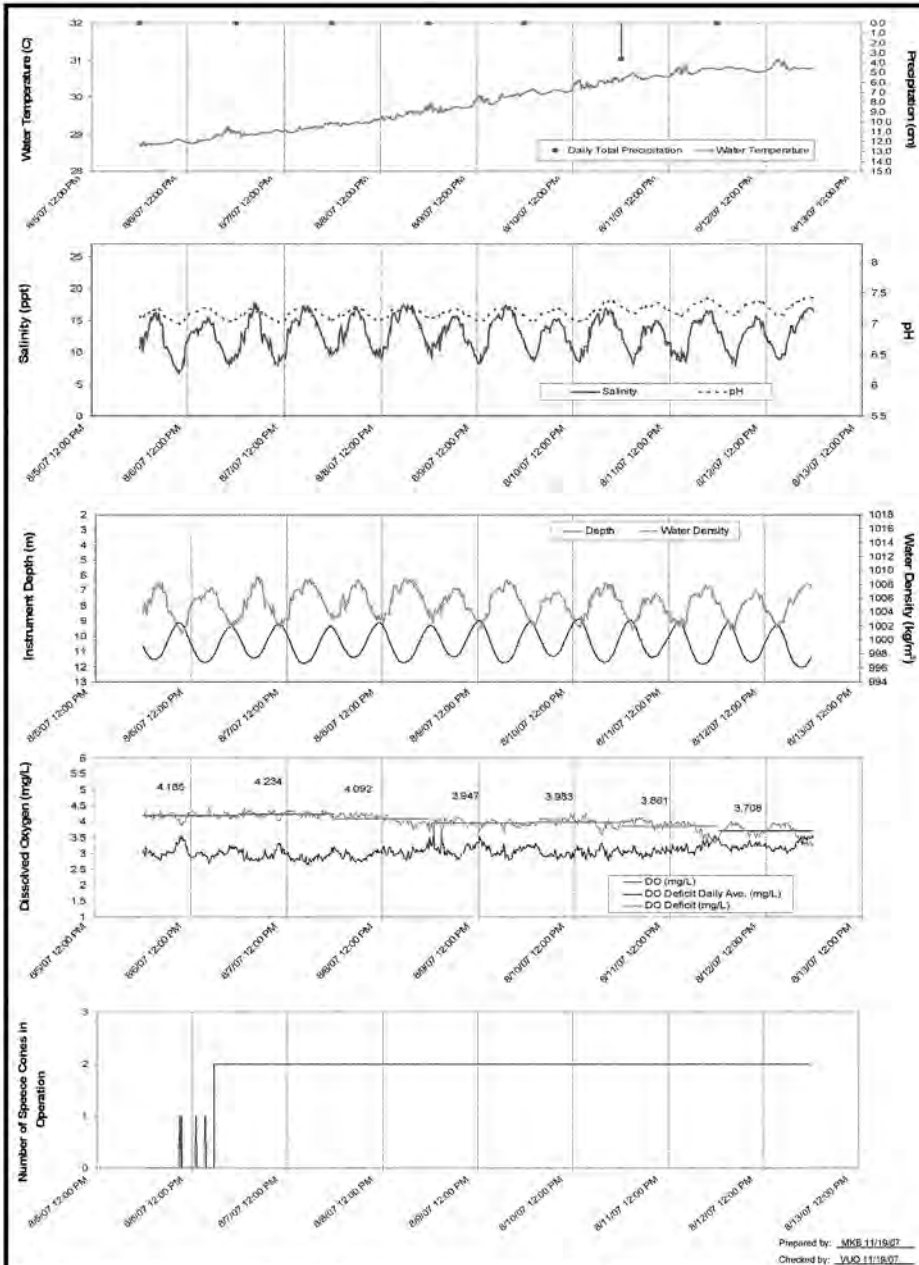
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Figure: 4-2.1



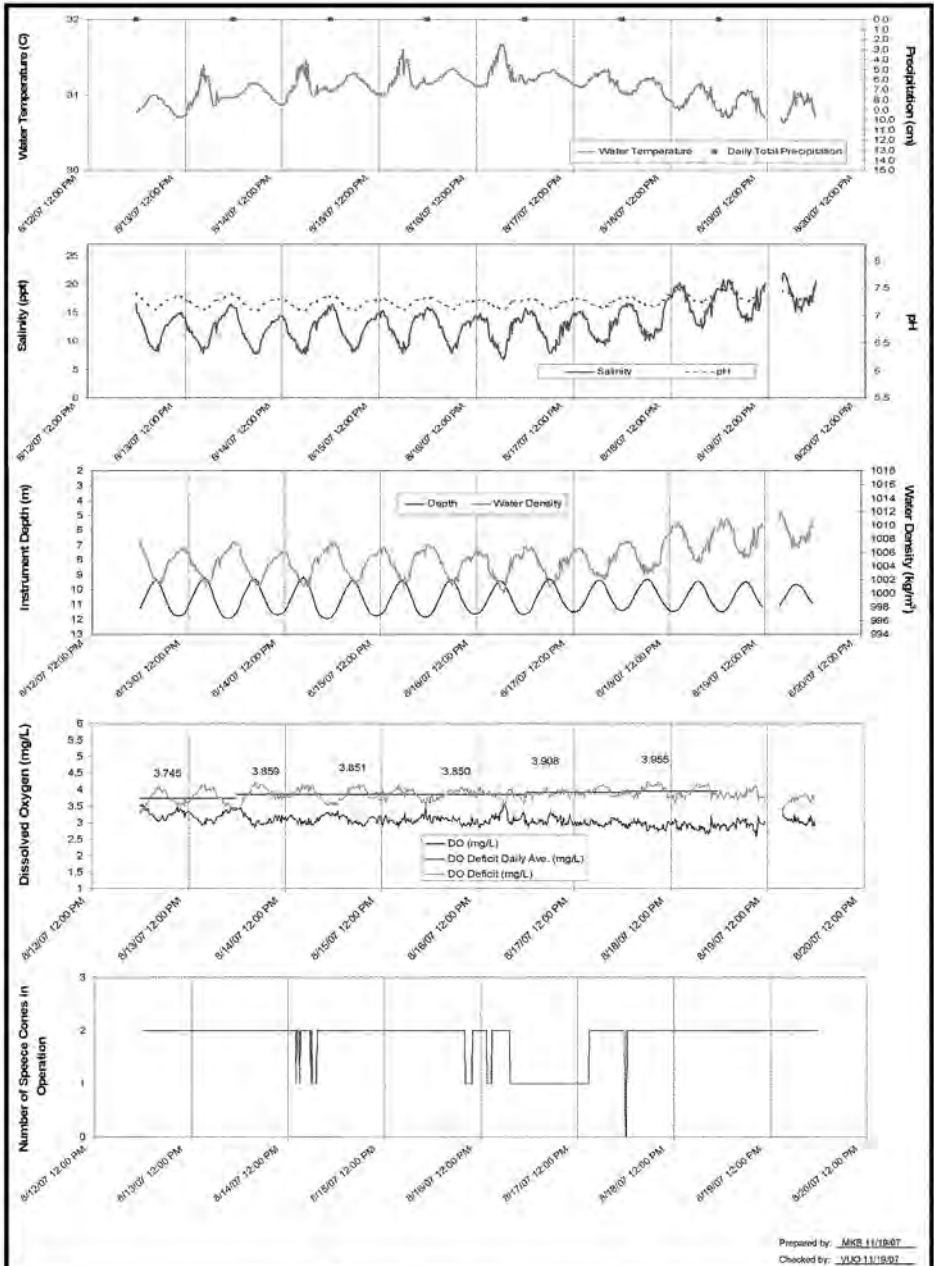
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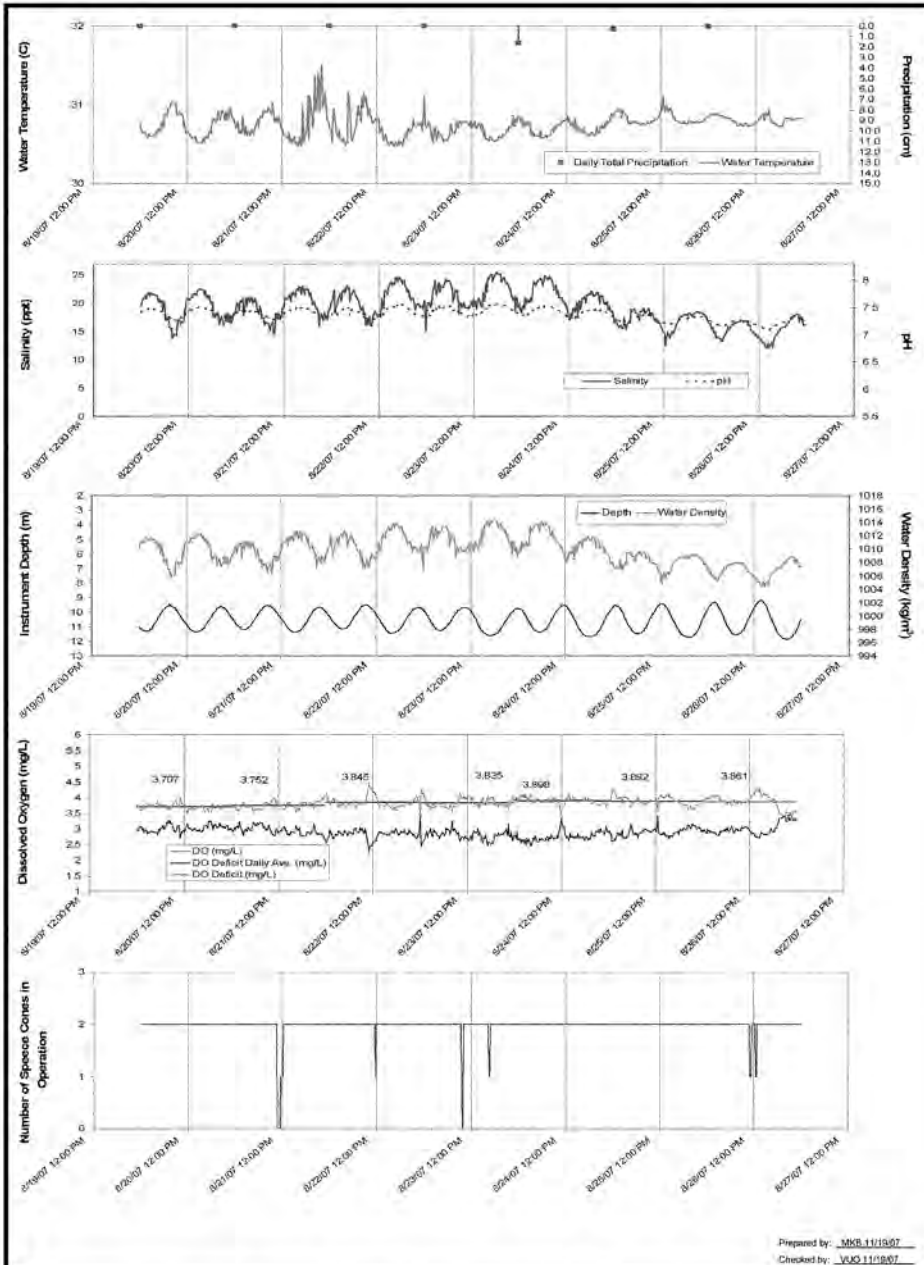
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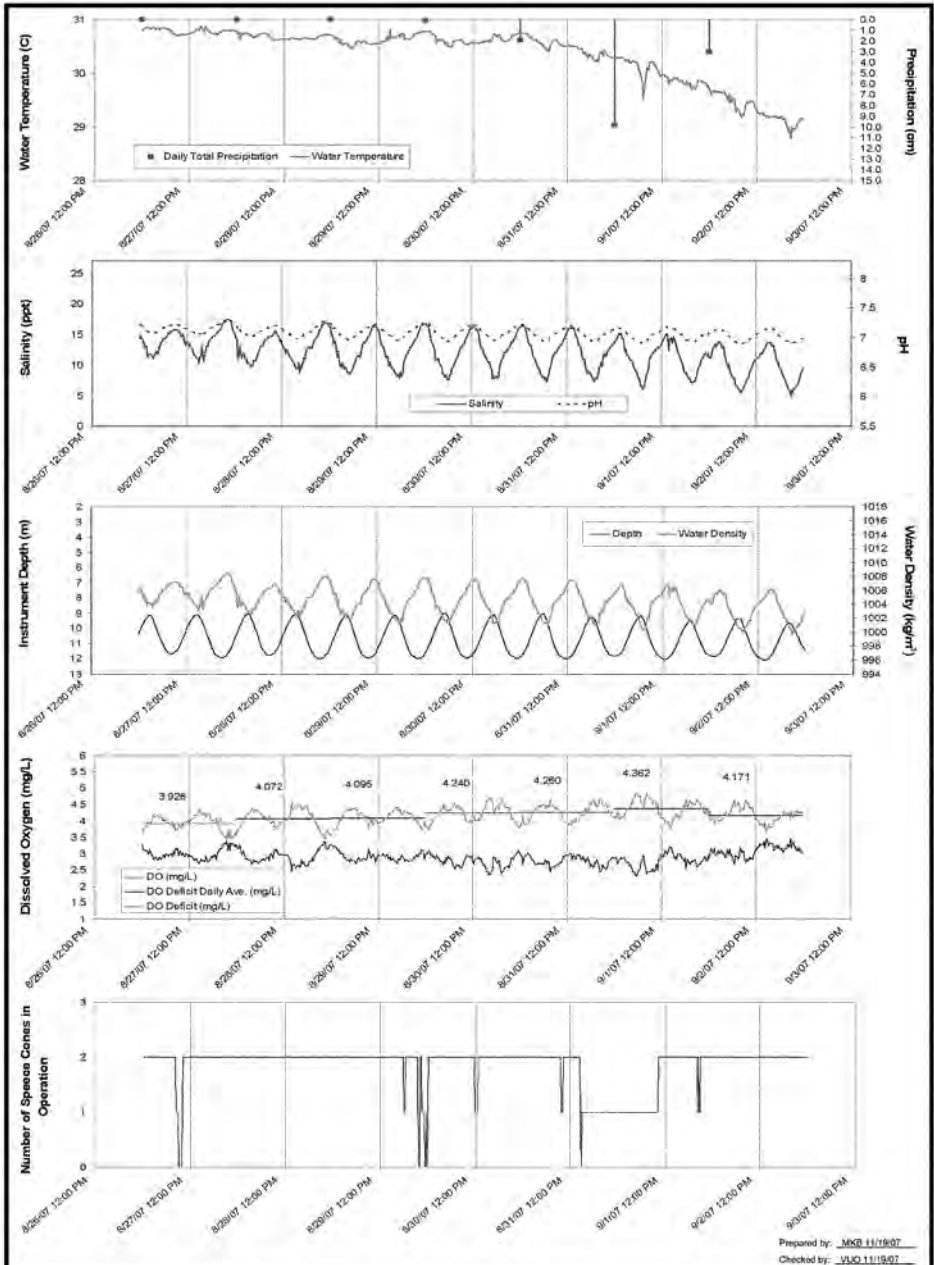
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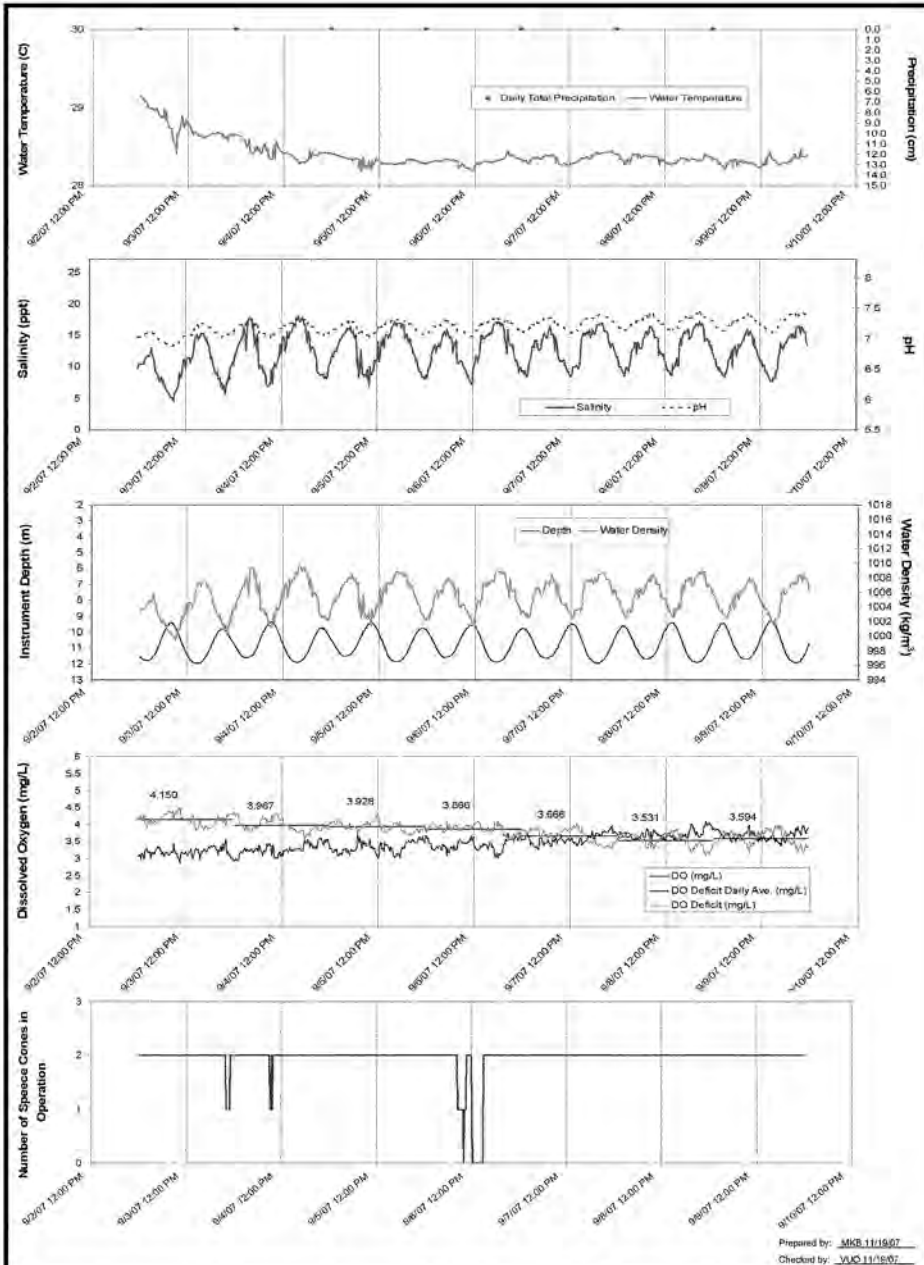
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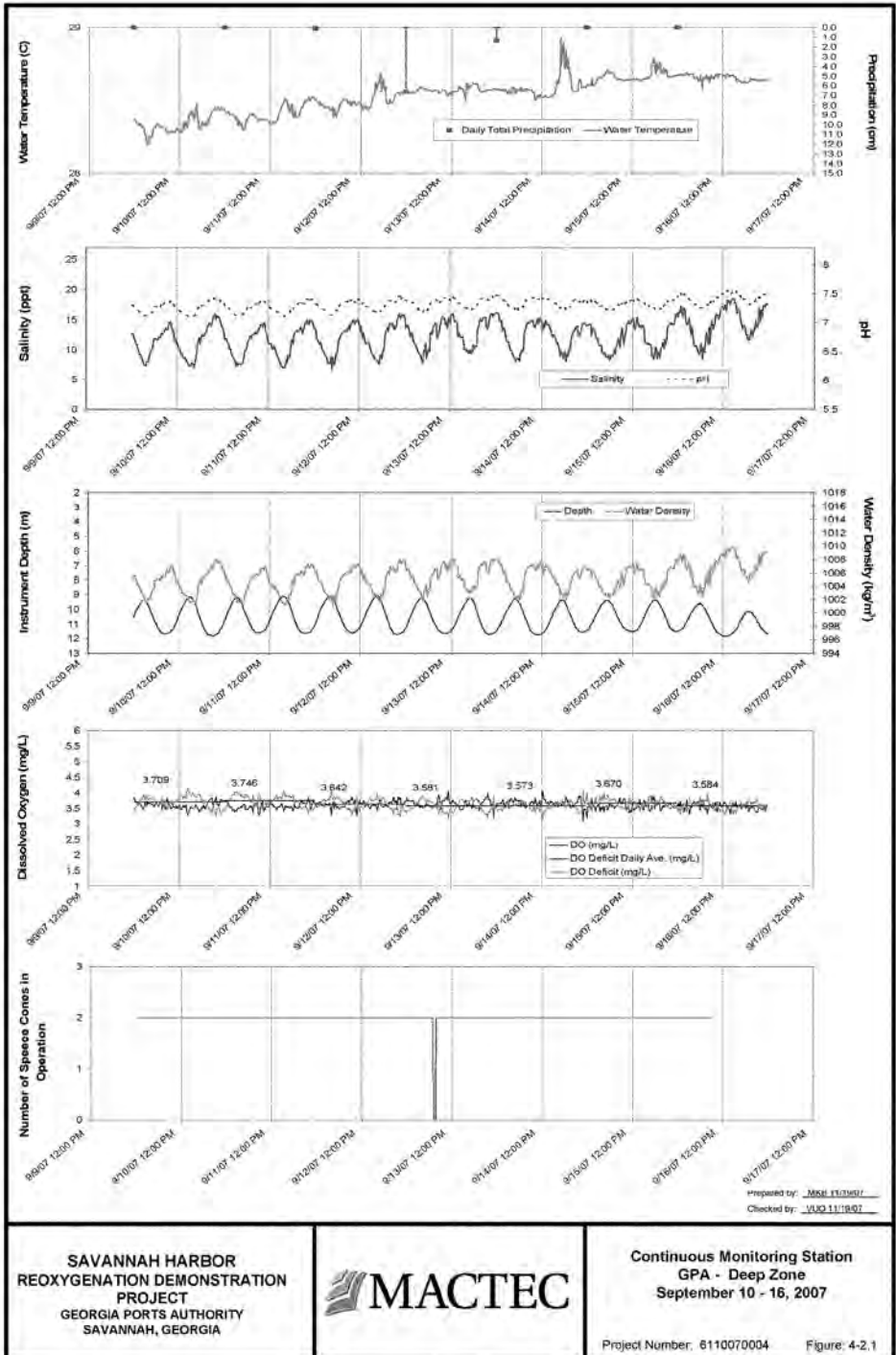
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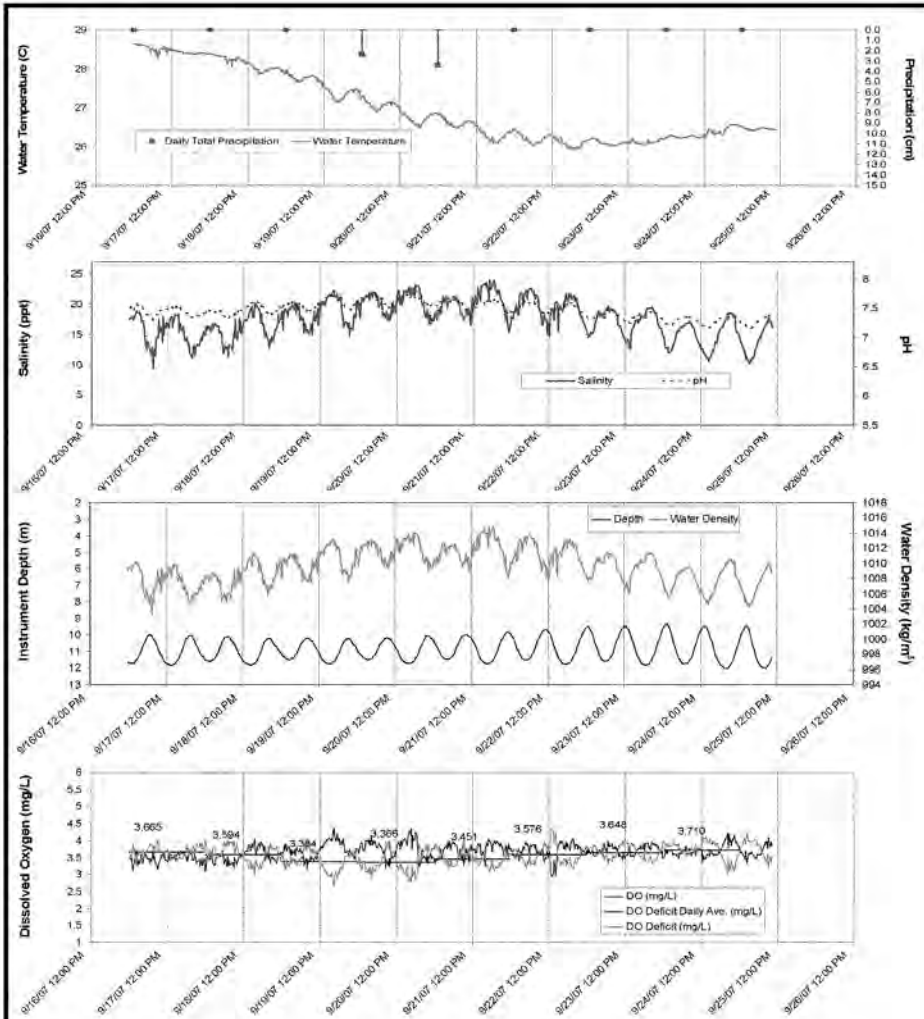
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Figure: 4-2.1





Prepared by: MDR 11/19/07
 Checked by: VJD 11/19/07

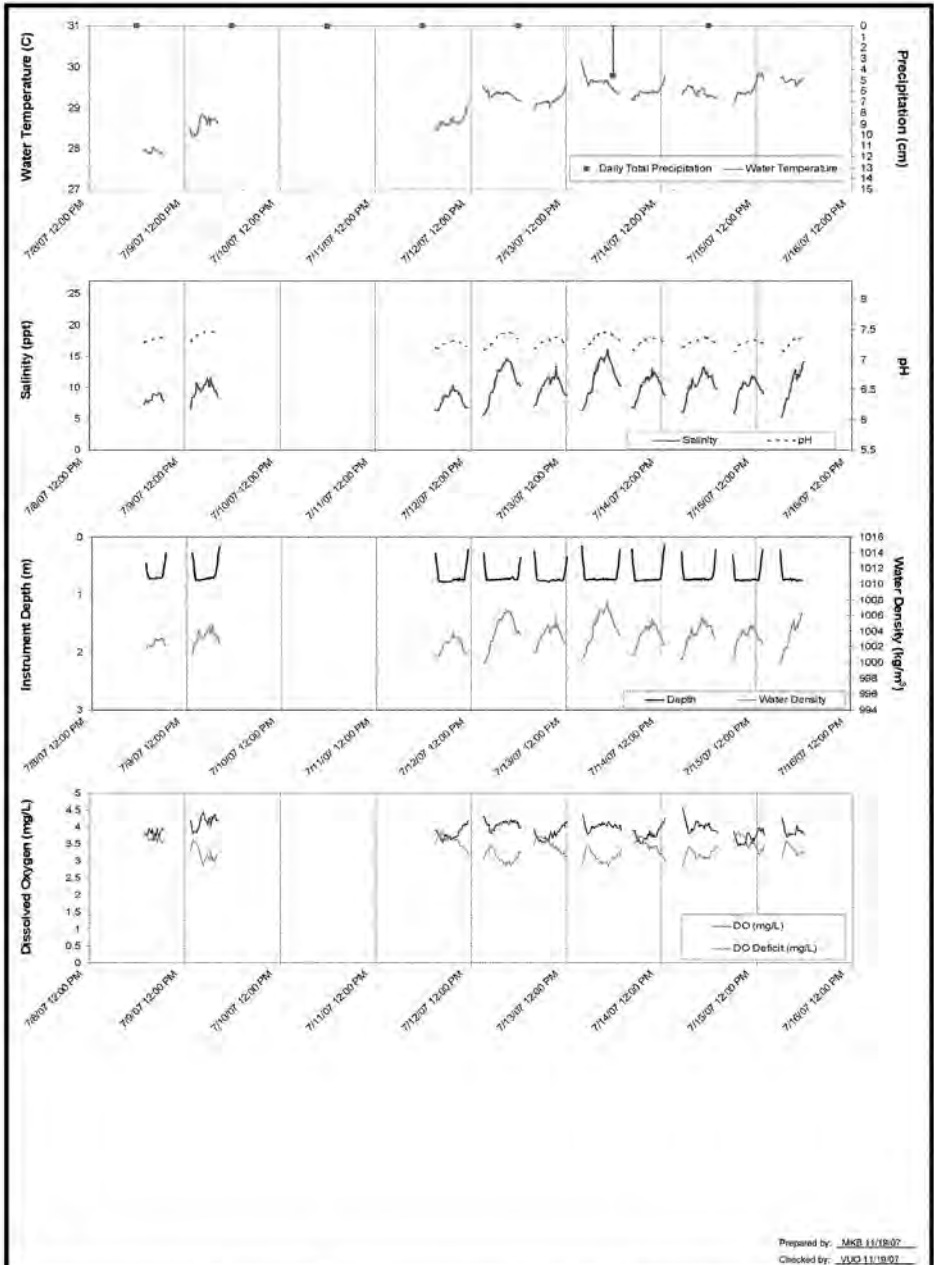
SAVANNAH HARBOR
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 SAVANNAH, GEORGIA



Continuous Monitoring Station
 GPA - Deep Zone
 September 17 - 25, 2007

Project Number: 6110070004

Figure: 4-2.1



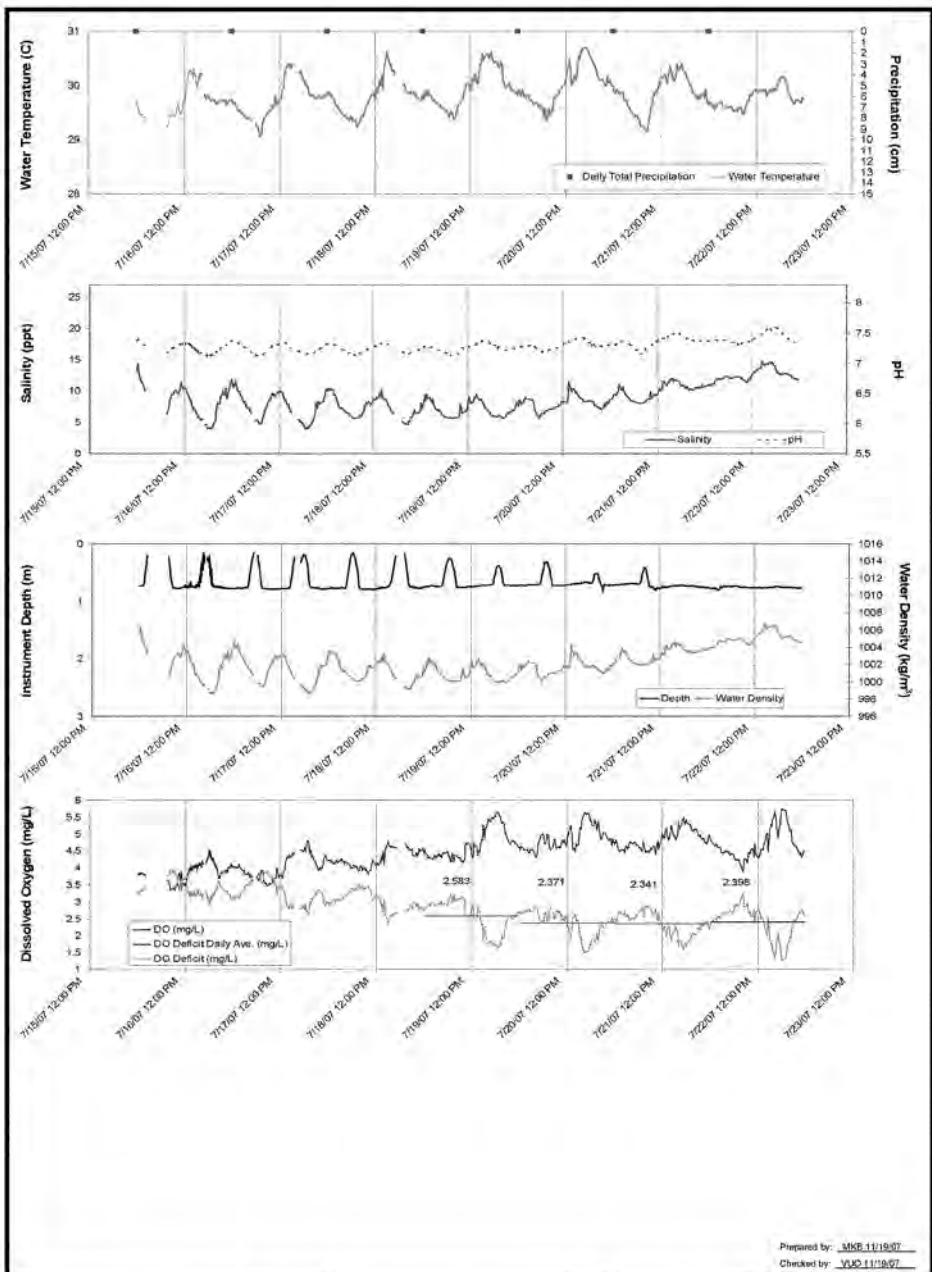
SAVANNAH HARBOR
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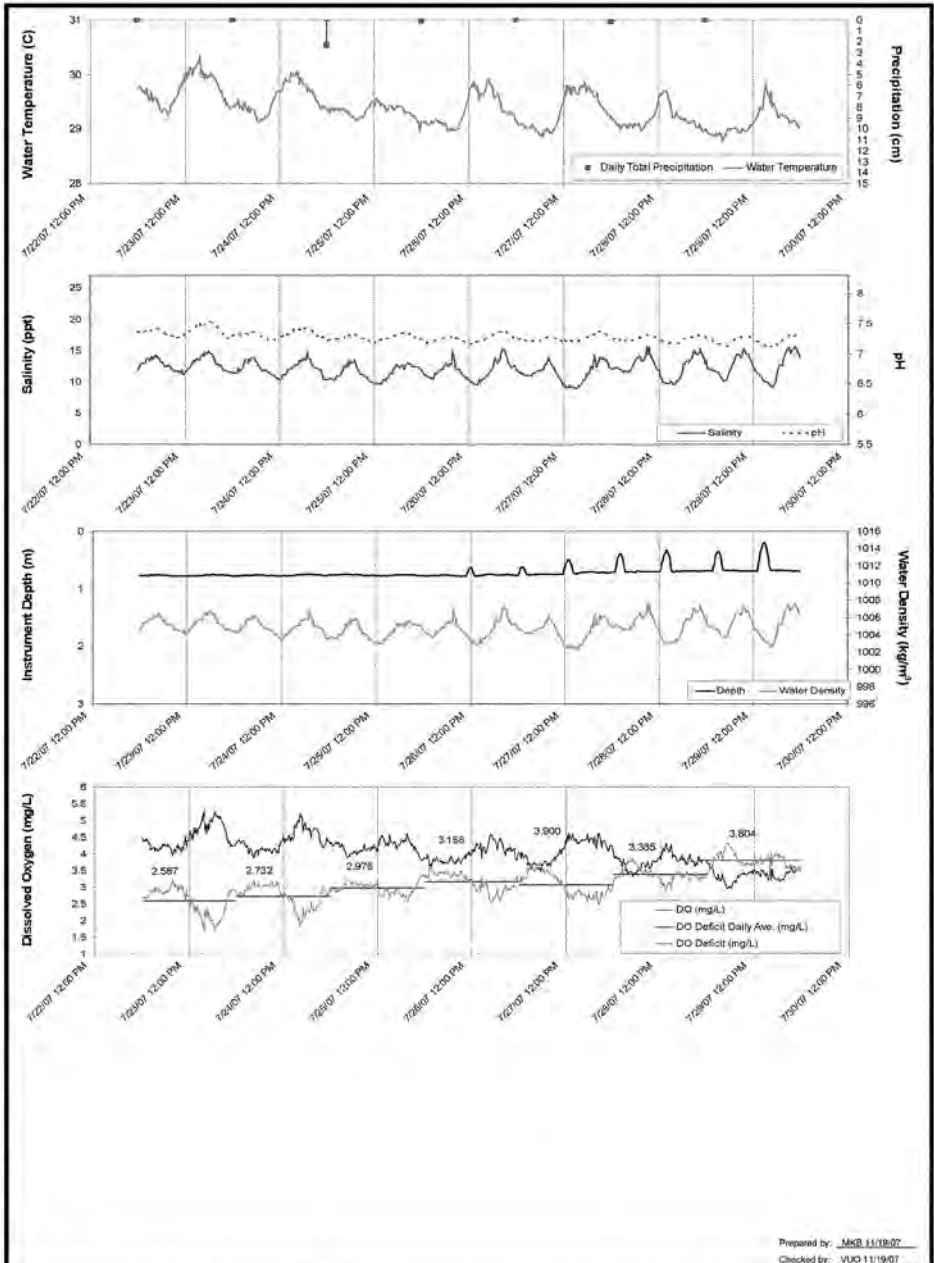
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Continuous Monitoring Station
 Near ReOx System
 TIC - Shallow Zone
 July 9 - 15, 2007

Project Number: 6110070004

Figure: 4-2.2A





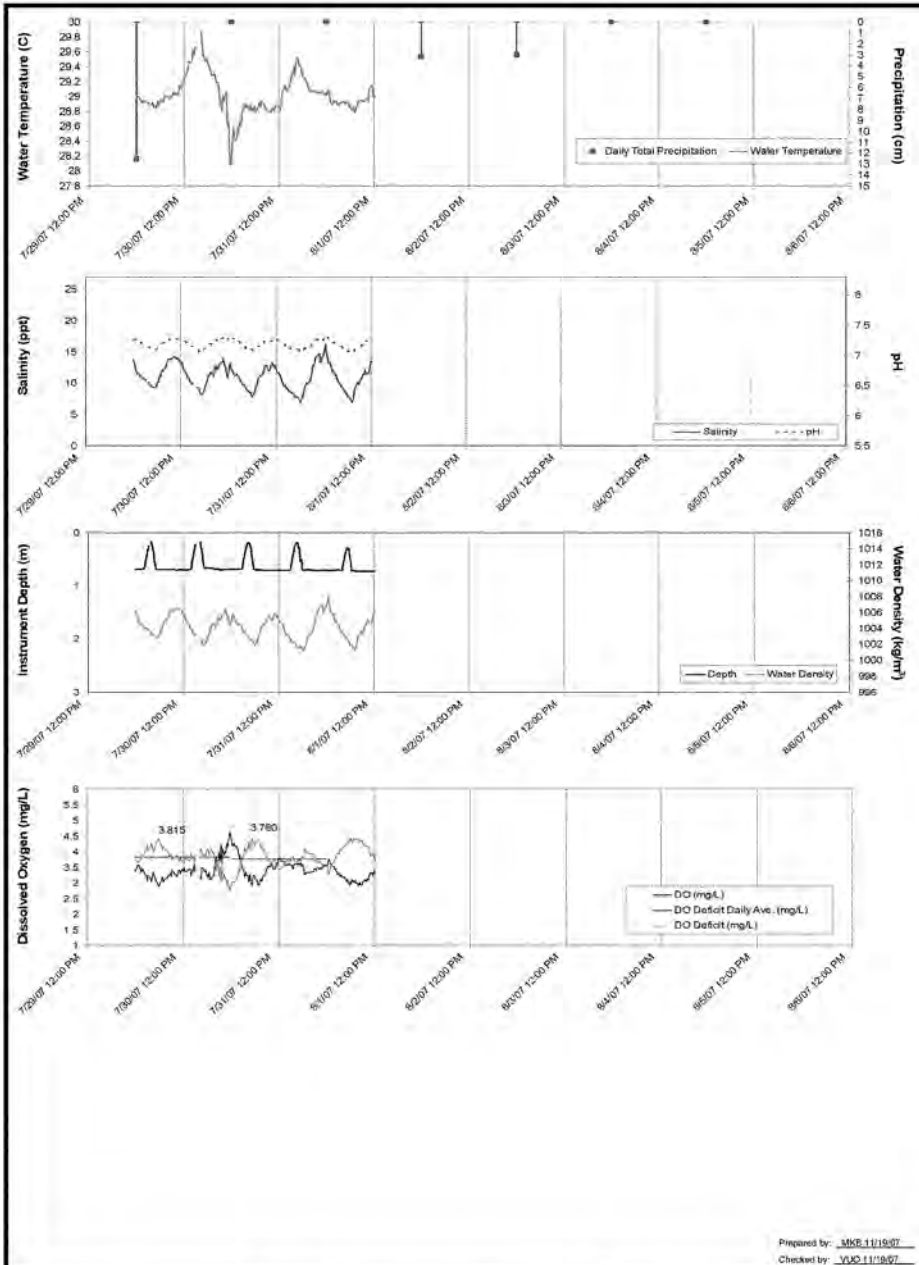
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 Near ReOx System
 TIC - Shallow Zone
 July 23 - 29, 2007

Project Number: 6110070004

Figure 4-2.2A



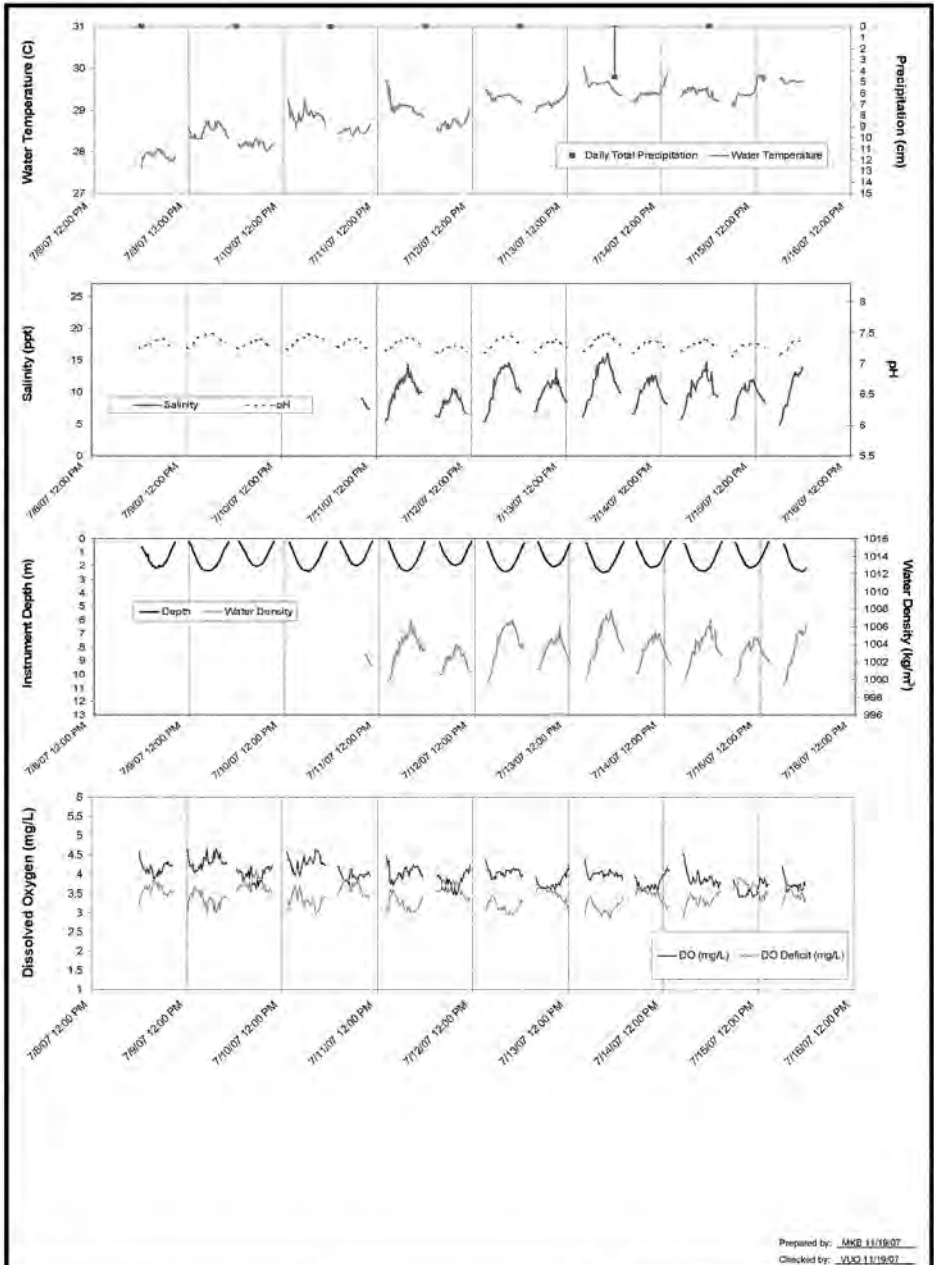
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Continuous Monitoring Station
 Near ReOx System
 TIC - Shallow Zone
 July 30 - Aug 5, 2007

Project Number: 6110070004

Figure: 4-2.2A



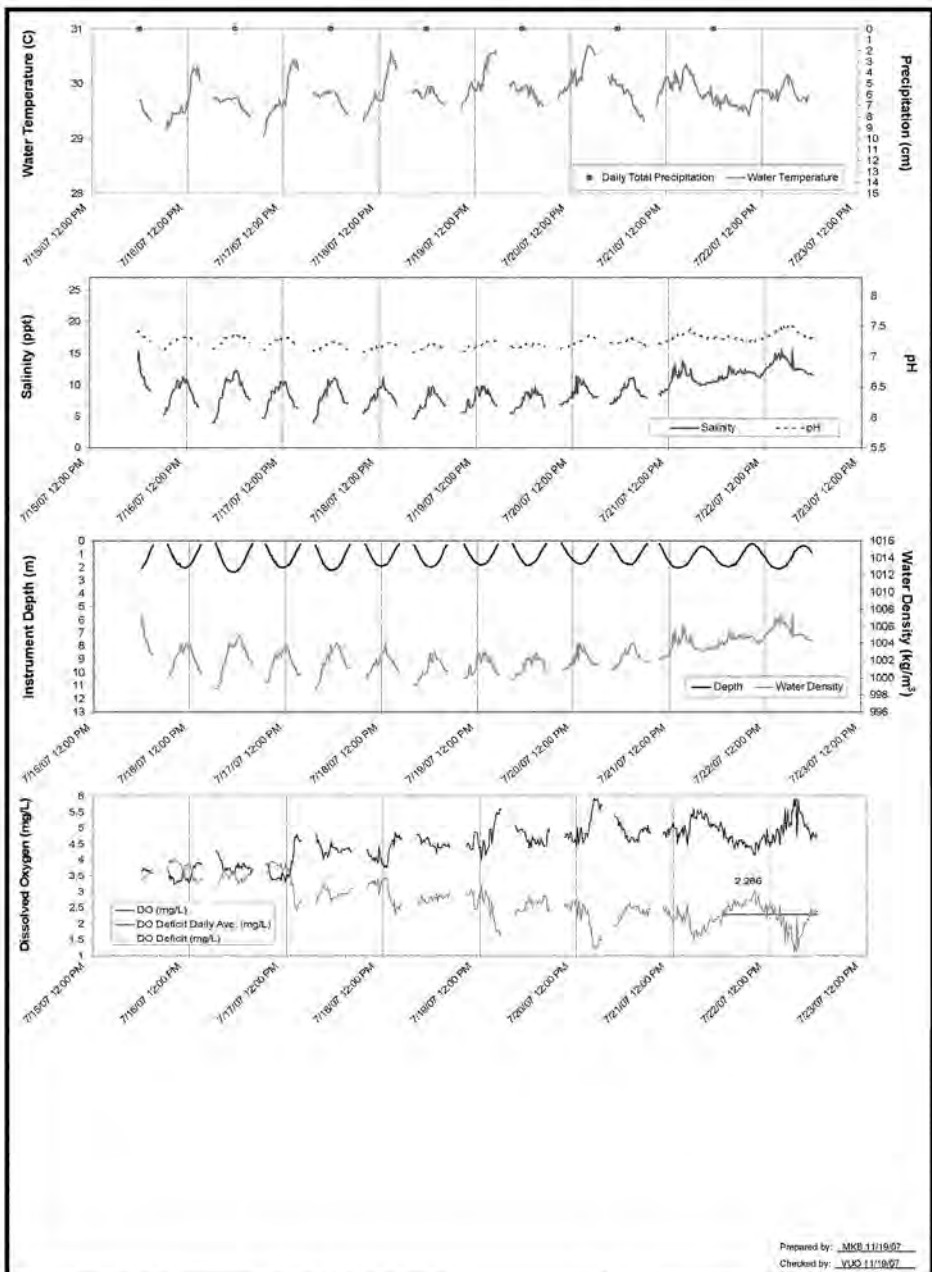
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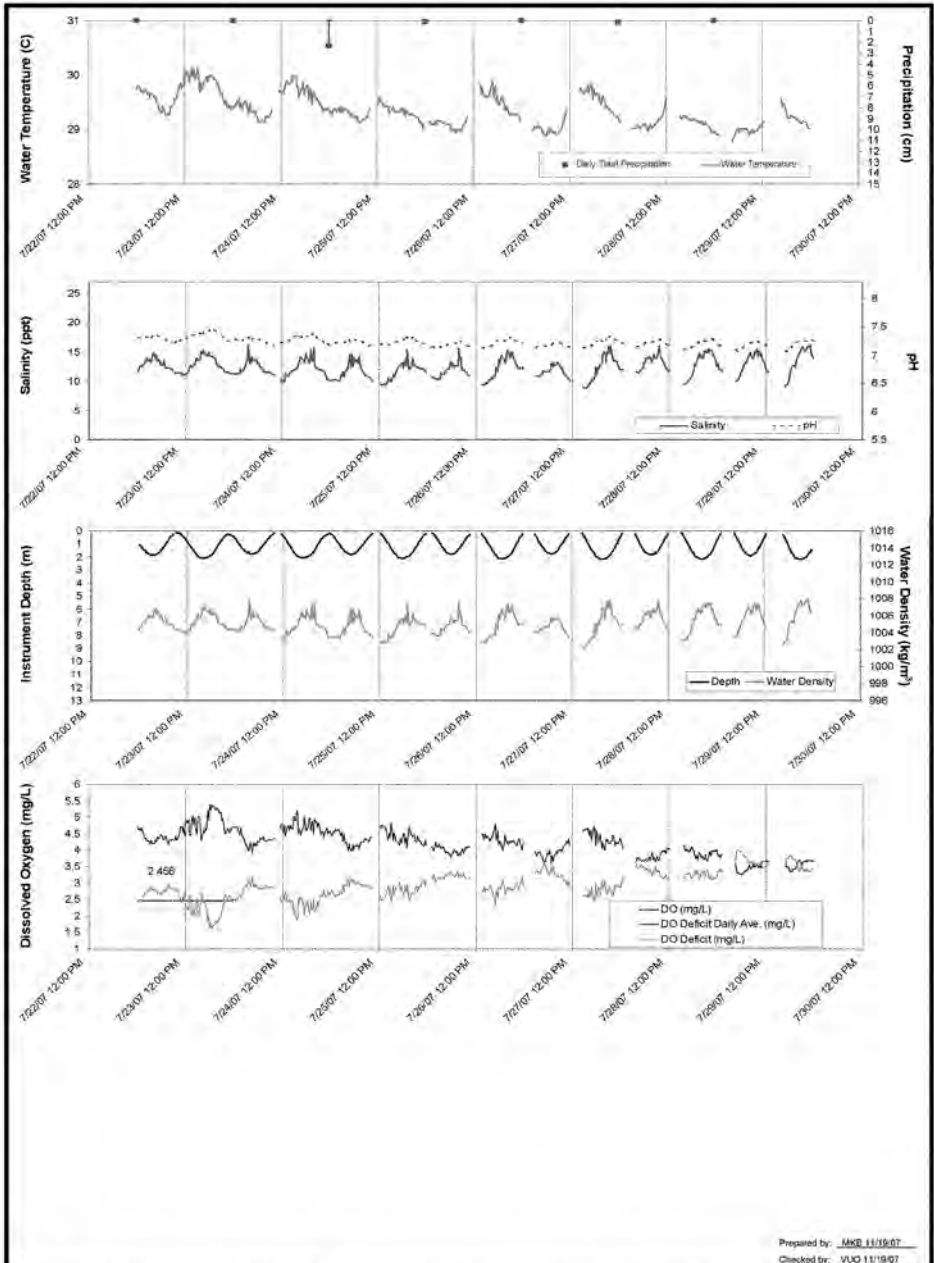
Continuous Monitoring Station
 Near ReOx System
 TIC - Deep Zone
 July 9 - 15, 2007

Project Number: 6110070004

Figure 4-2.2A



Prepared by: MCR 11/19/07
Checked by: VJS 11/19/07



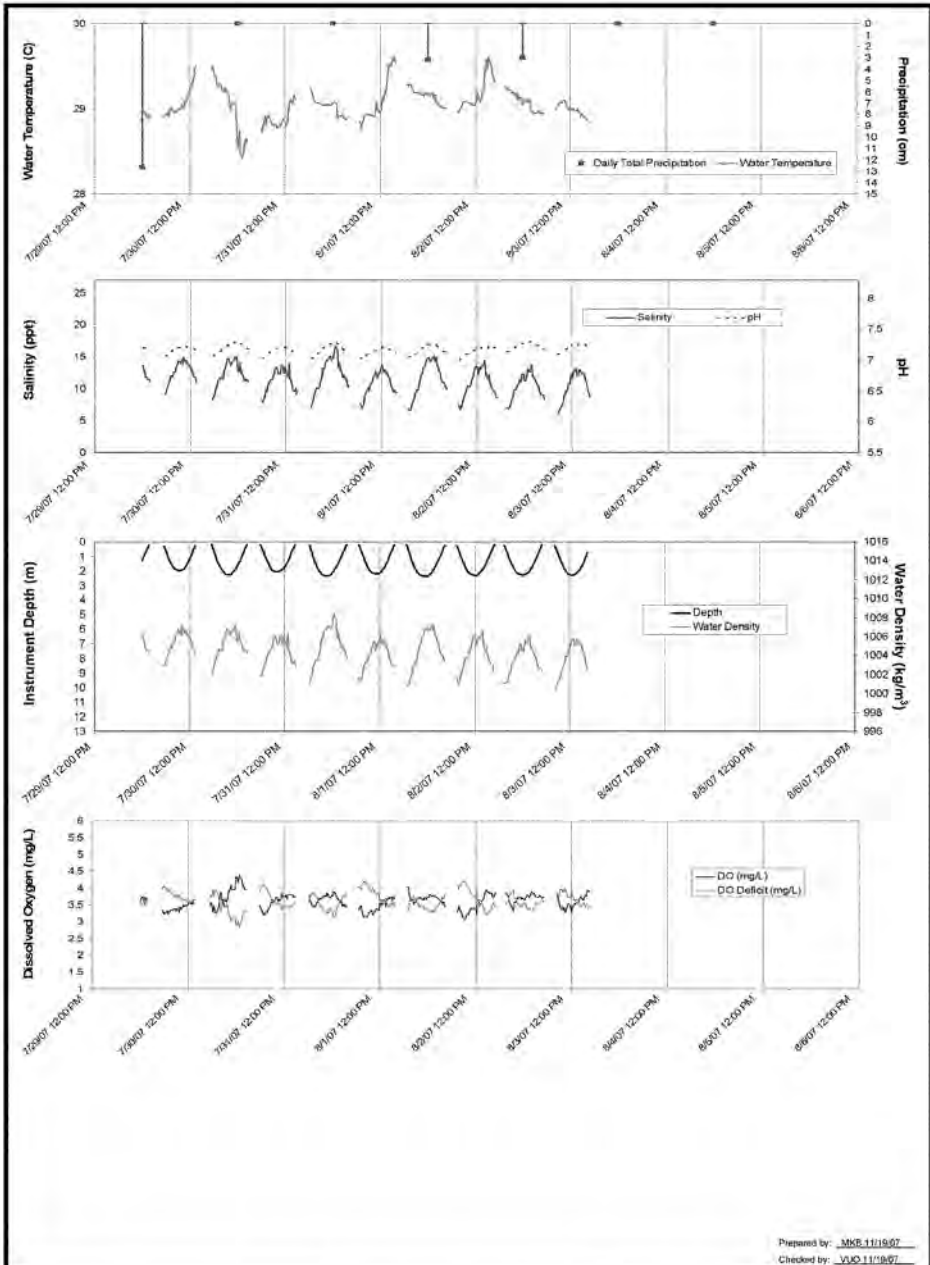
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 Near ReOx System
 TIC - Deep Zone
 July 23 - 29, 2007

Project Number: 6110070004

Figure: 4-2.2A



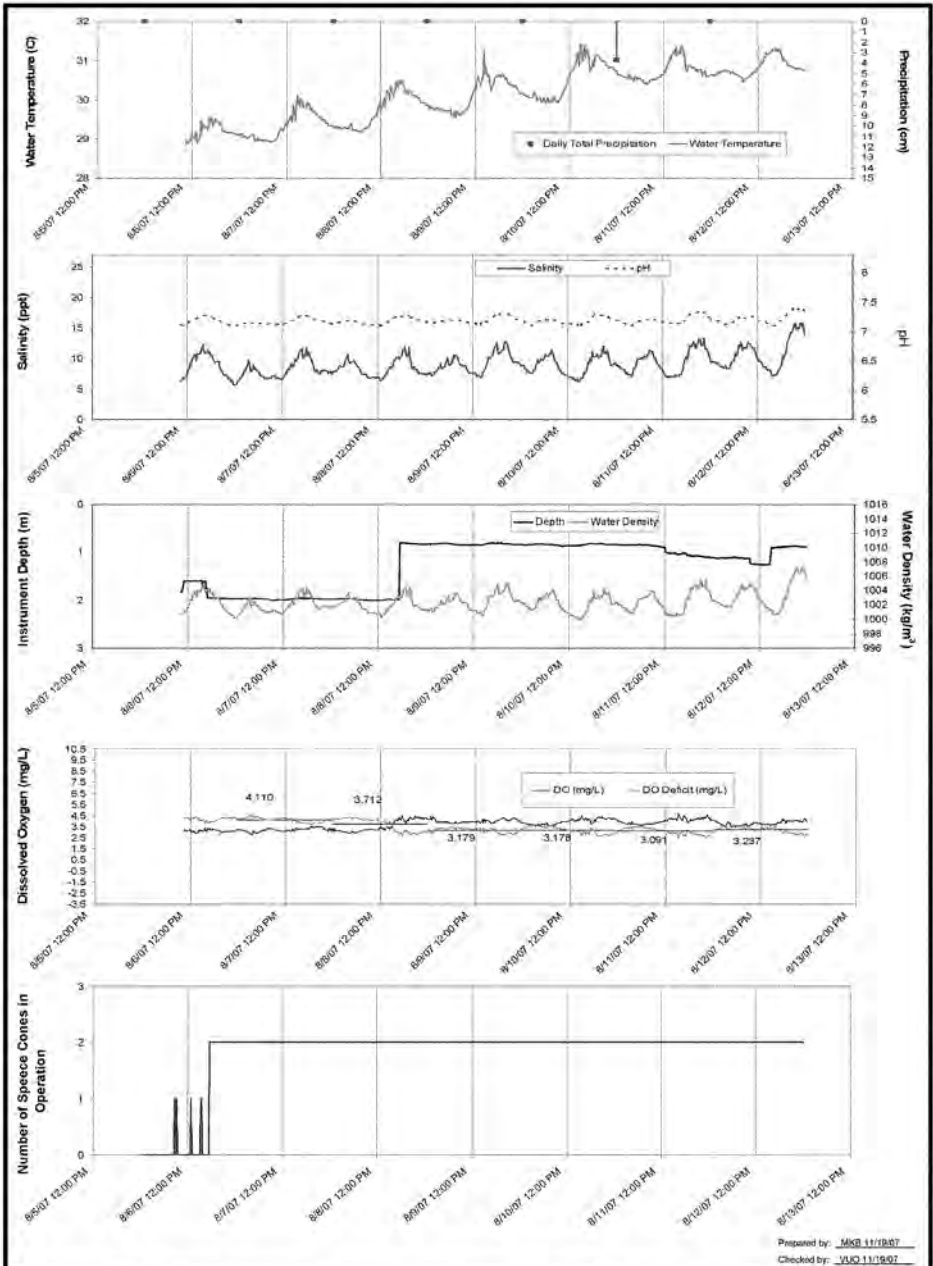
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Continuous Monitoring Station
 Near ReOx System
 TIC - Deep Zone
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Project Number: 8110070004

Figure: 4-2.2A



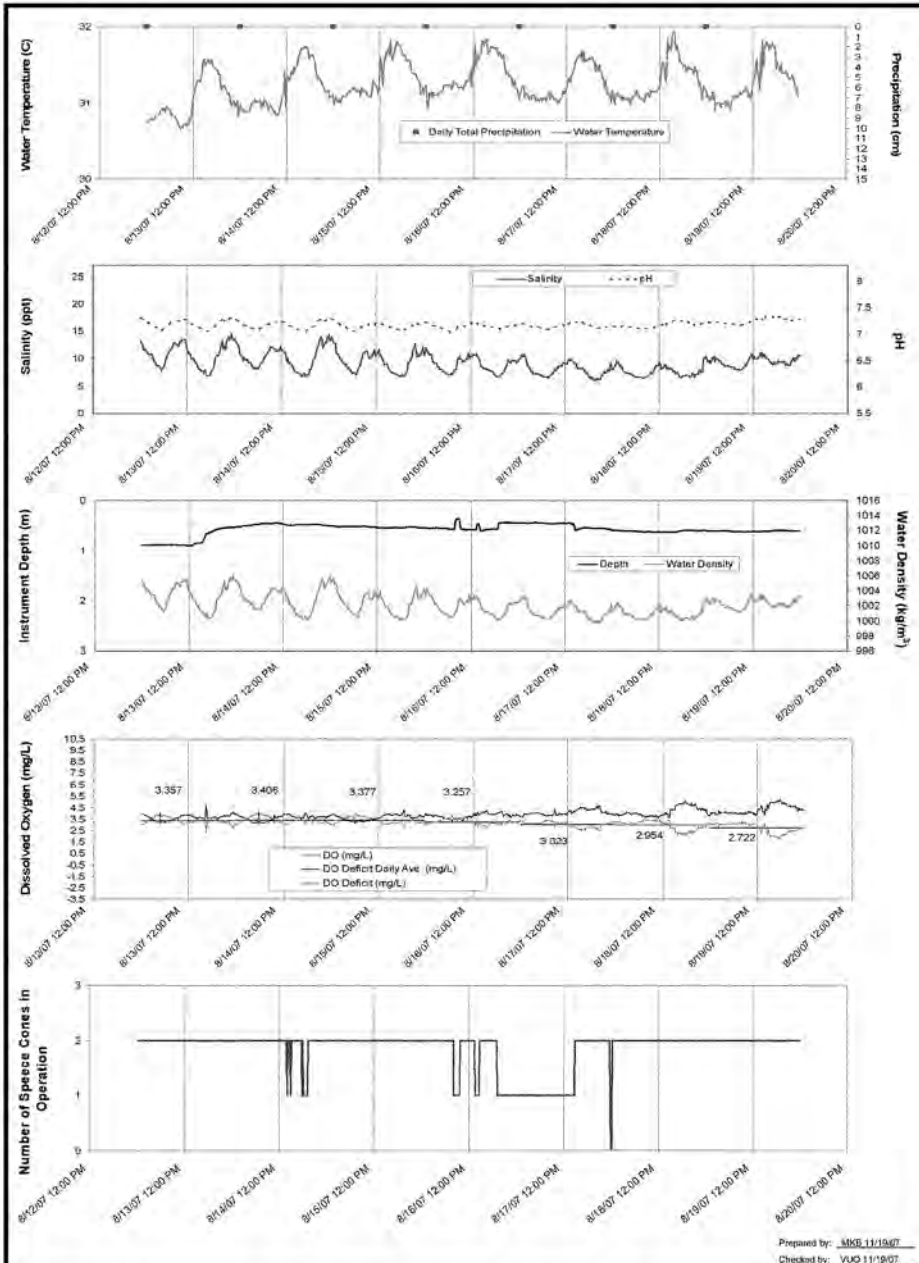
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Near ReOx System
Barge - Shallow Zone
Aug 6 - 12, 2007

Project Number: 6110070004

Figure 4-2.2B



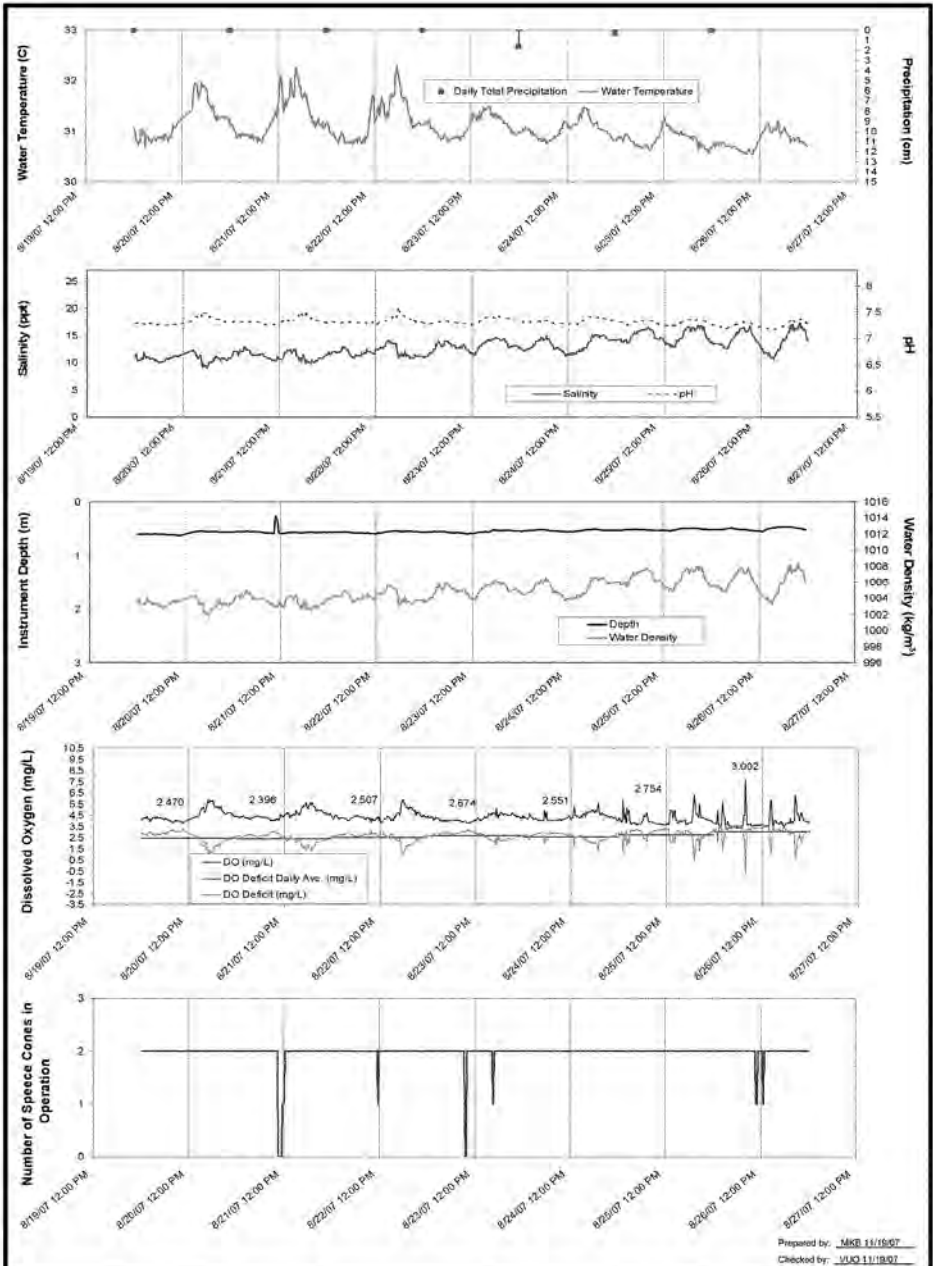
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Continuous Monitoring Station
 Near ReOx System
 Barge - Shallow Zone
 Aug 13 - 19, 2007

Project Number: 6110070004

Figure 4-2.2B



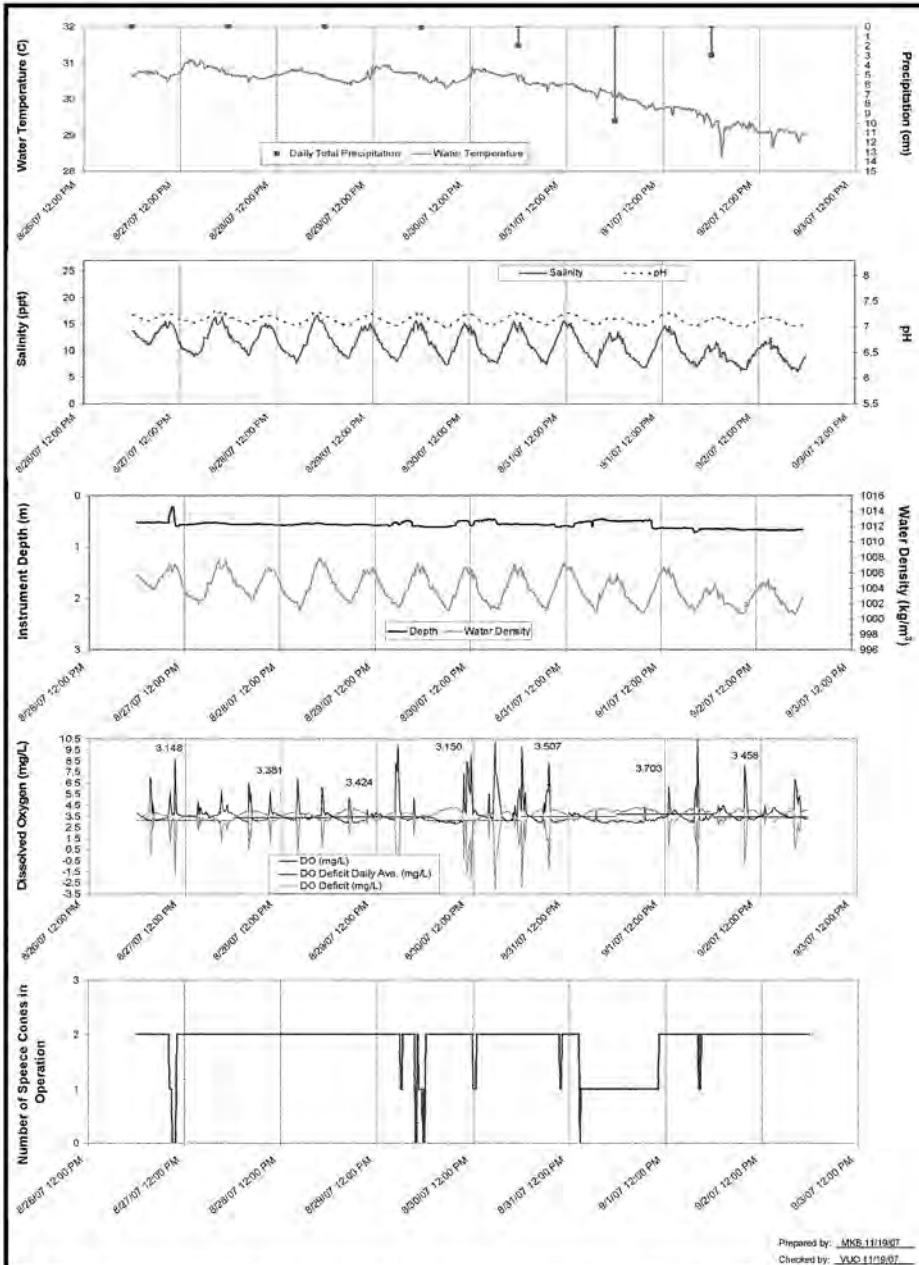
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Continuous Monitoring Station
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 Barge - Shallow Zone
 Aug 20 - 26, 2007

Project Number: 6110070004

Figure 4-2.2B



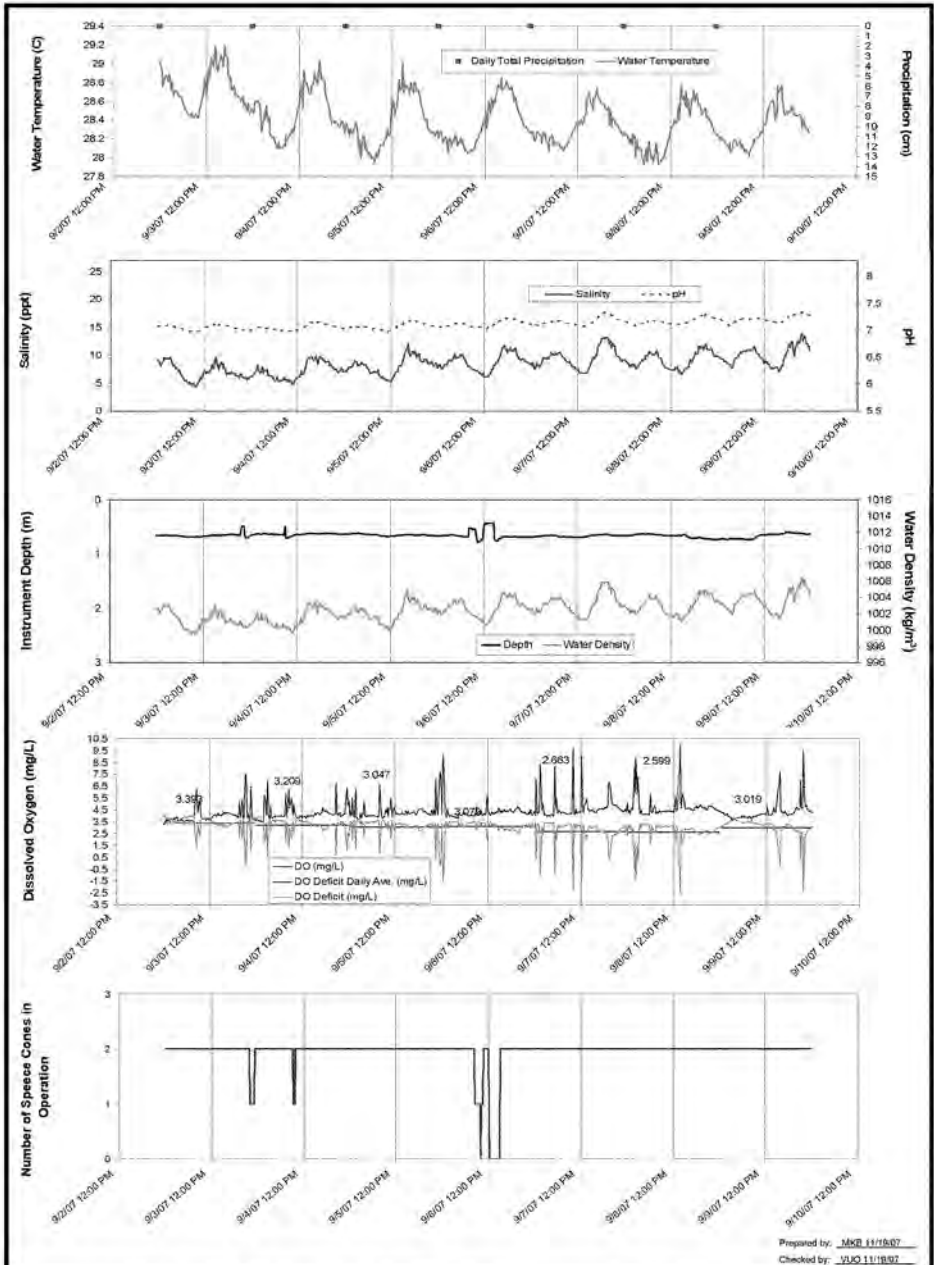
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Figure 4-2.2B



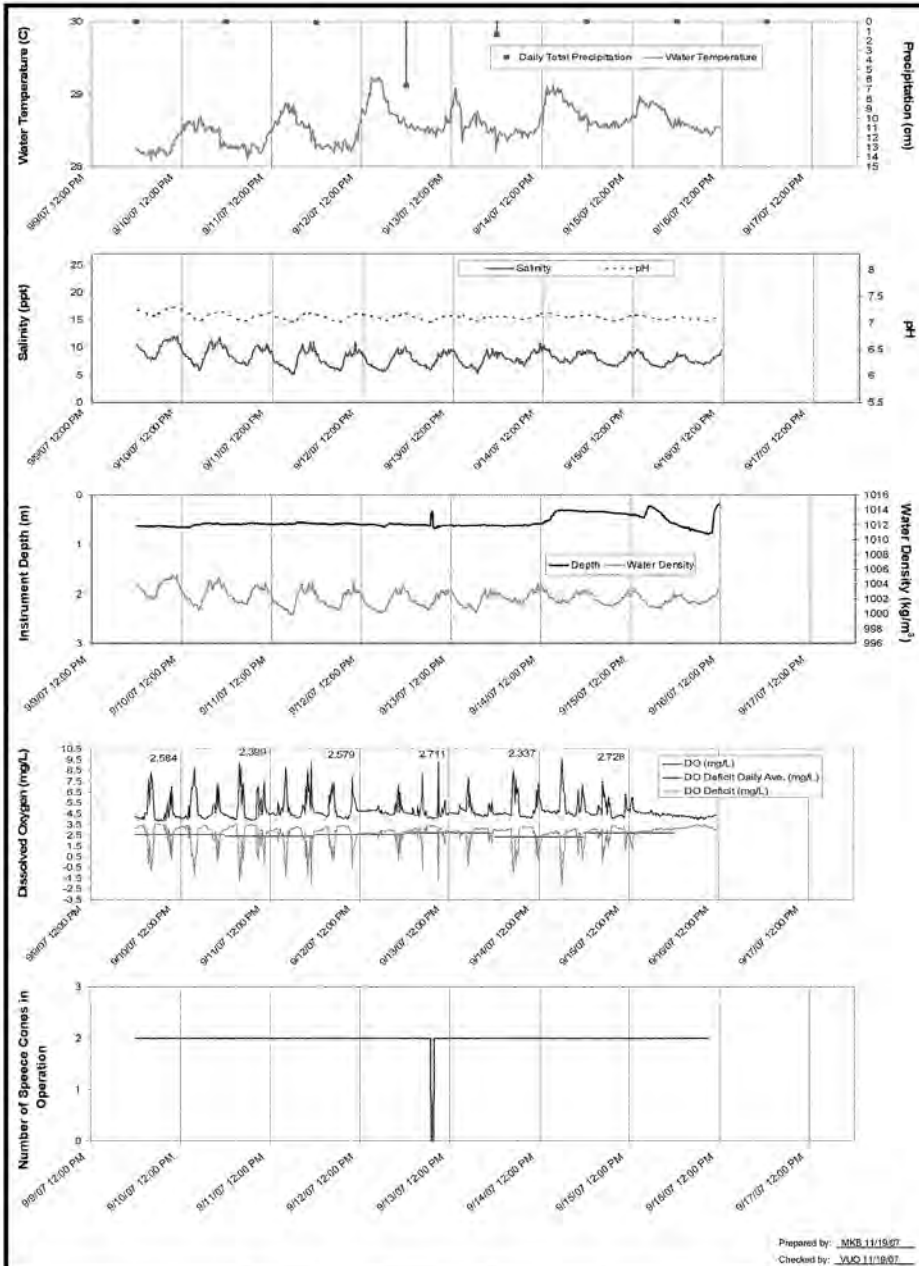
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Barge - Shallow Zone
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Figure 4-2.2B



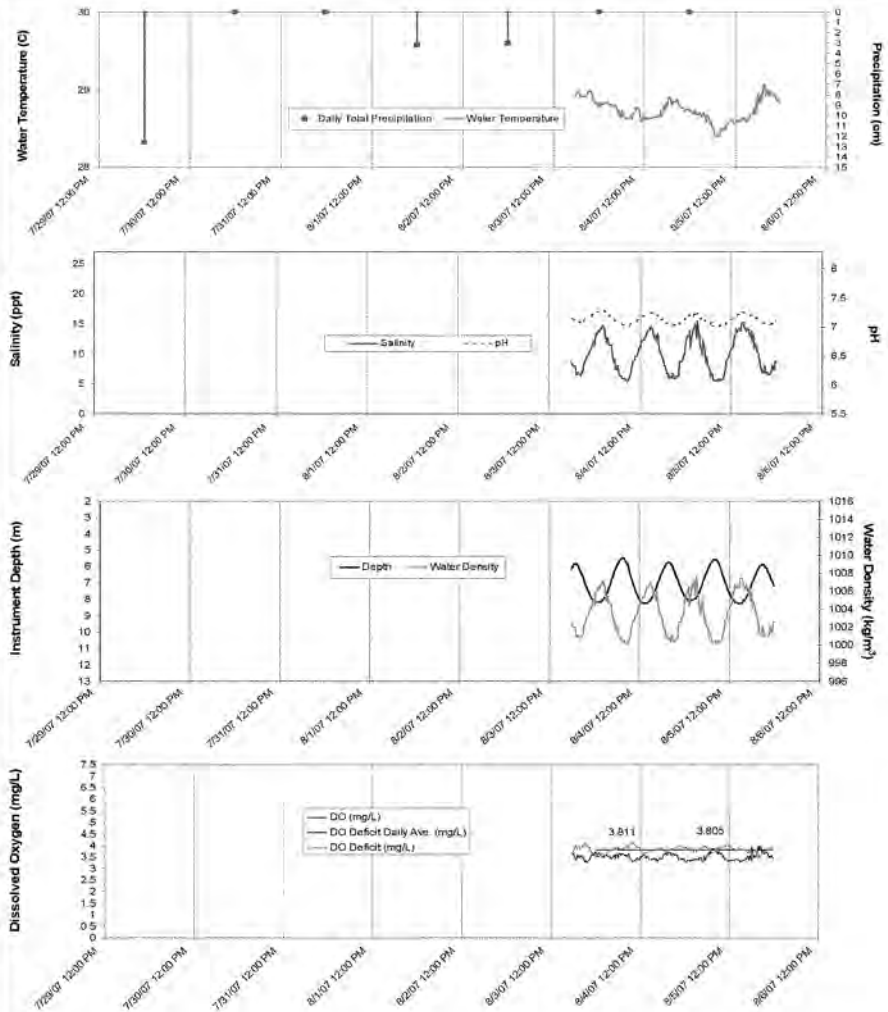
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 Barge - Shallow Zone
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Figure 4-2.2B



Prepared by: MKB 11/18/07
 Checked by: VJO 11/19/07

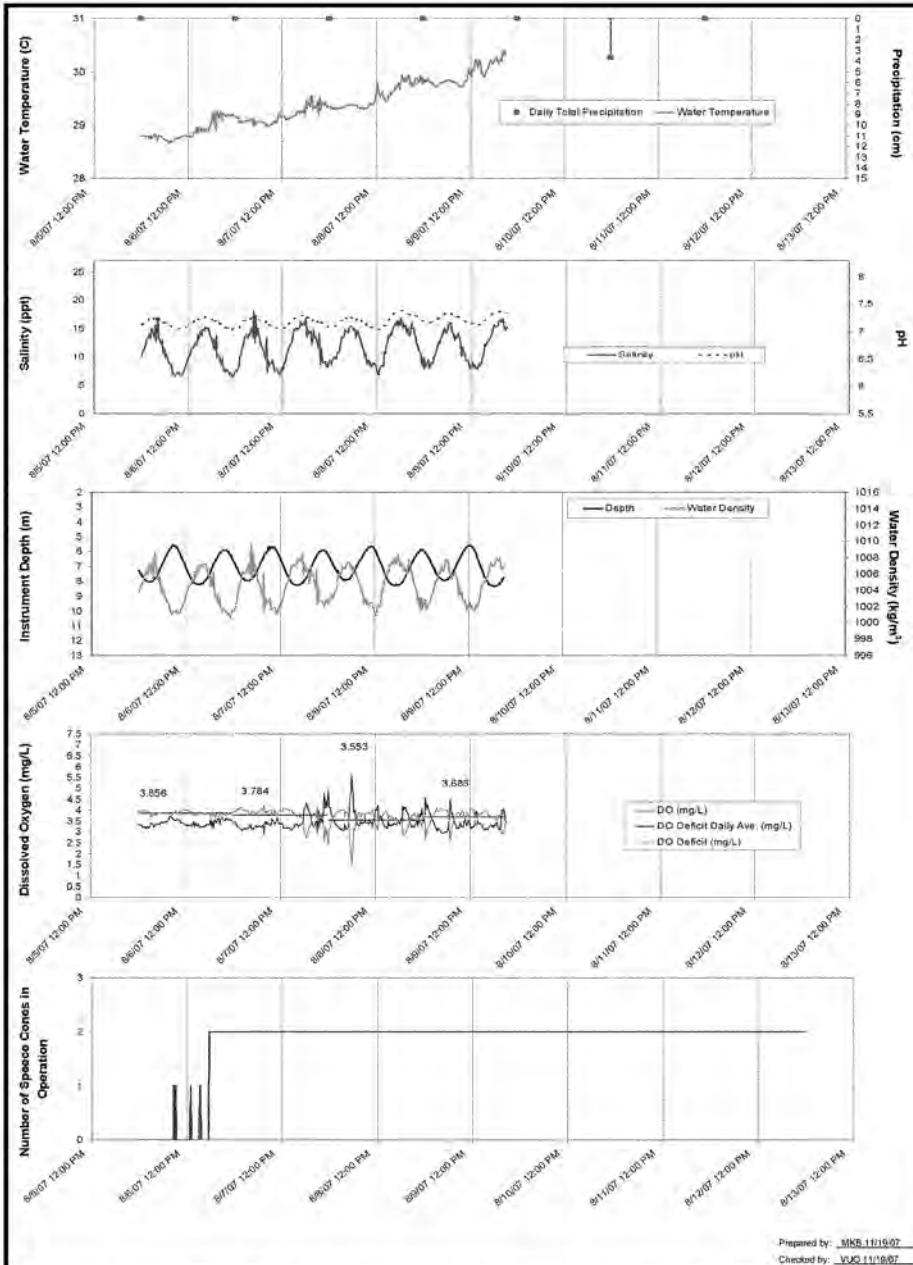
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 Barge - Mid Zone
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Project Number: 6110070004

Figure 4-2.2B



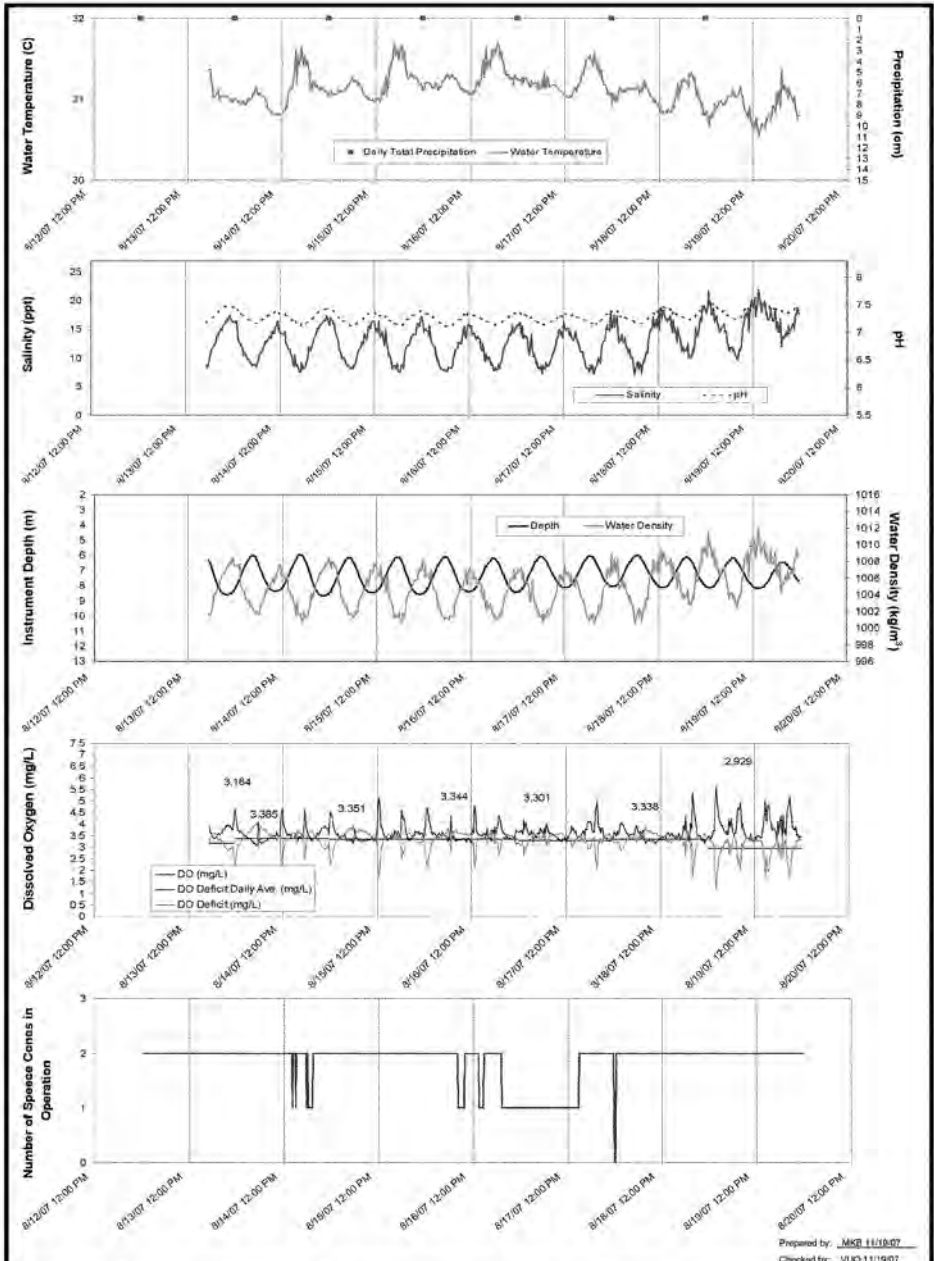
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 Barge - Mid Zone
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Figure 4-2.2B



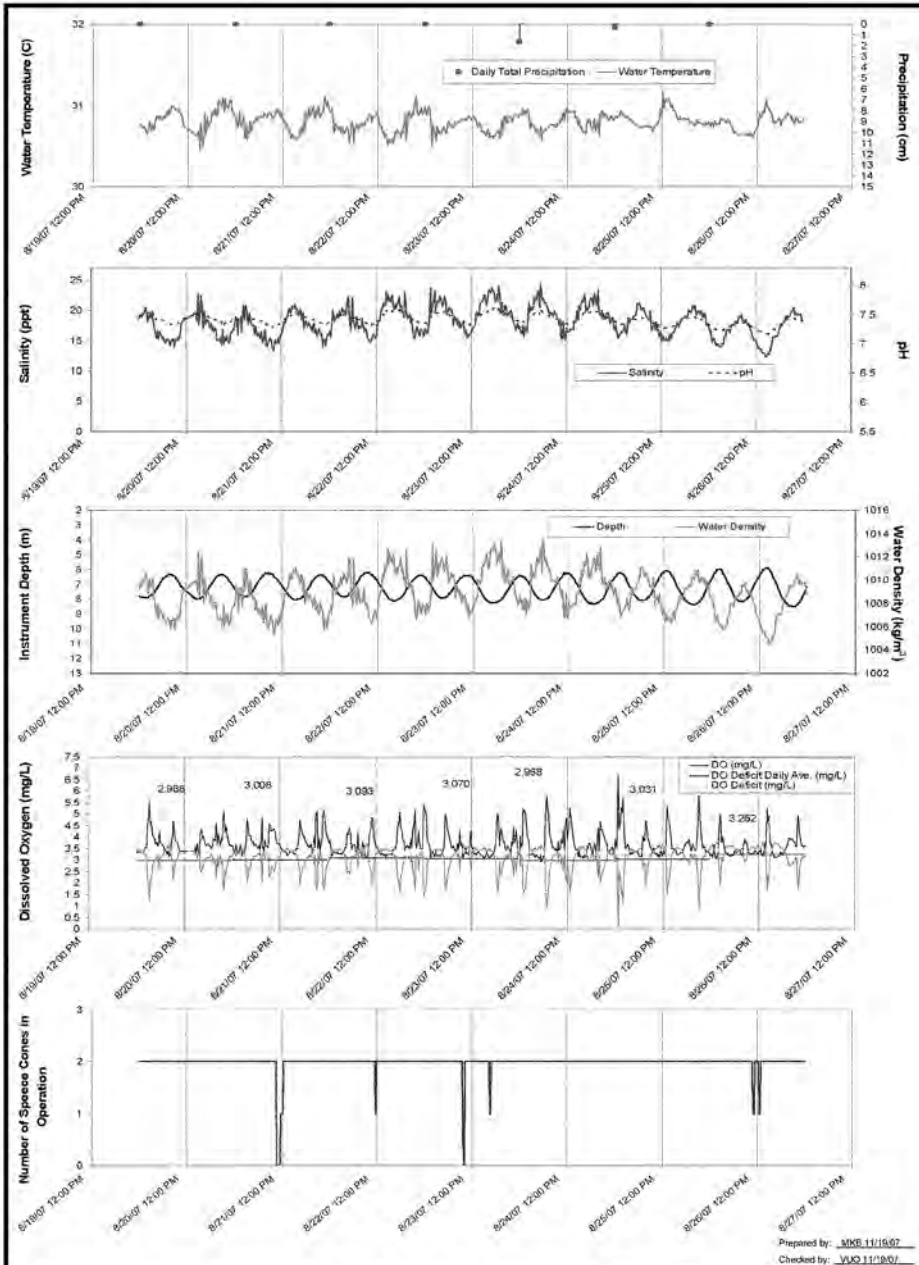
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Figure 4-2.2B



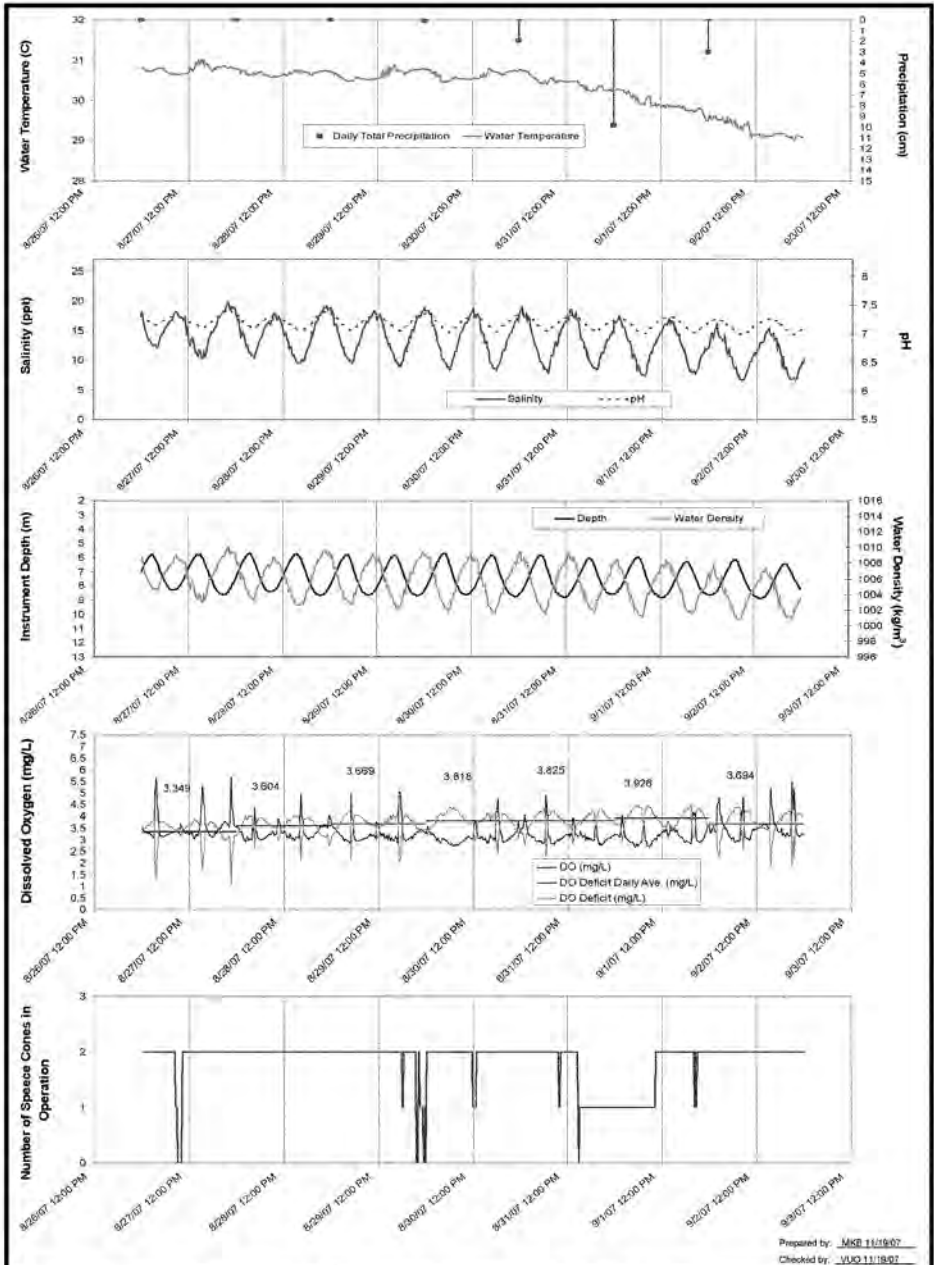
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Figure 4-2.2B



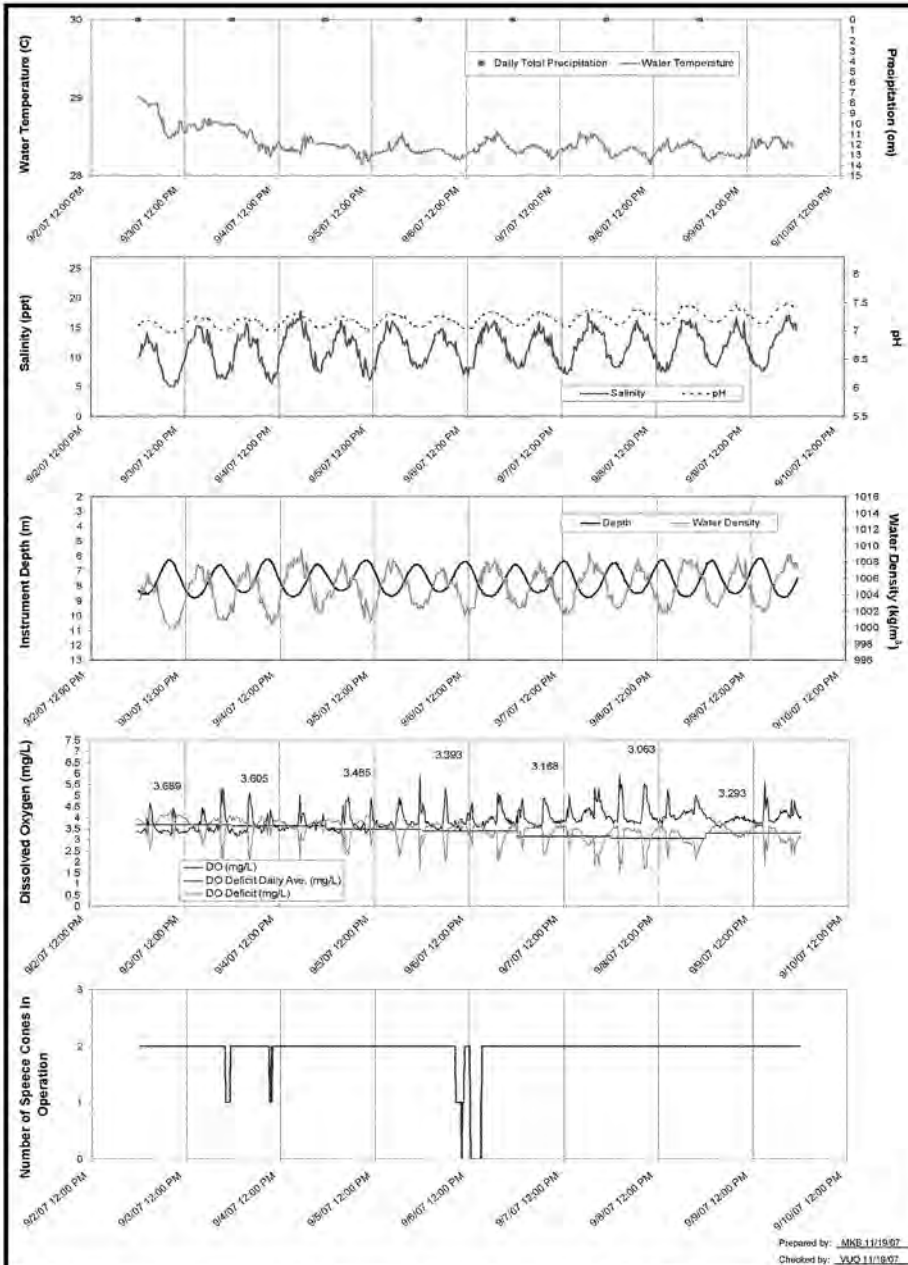
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Figure 4-2.2B



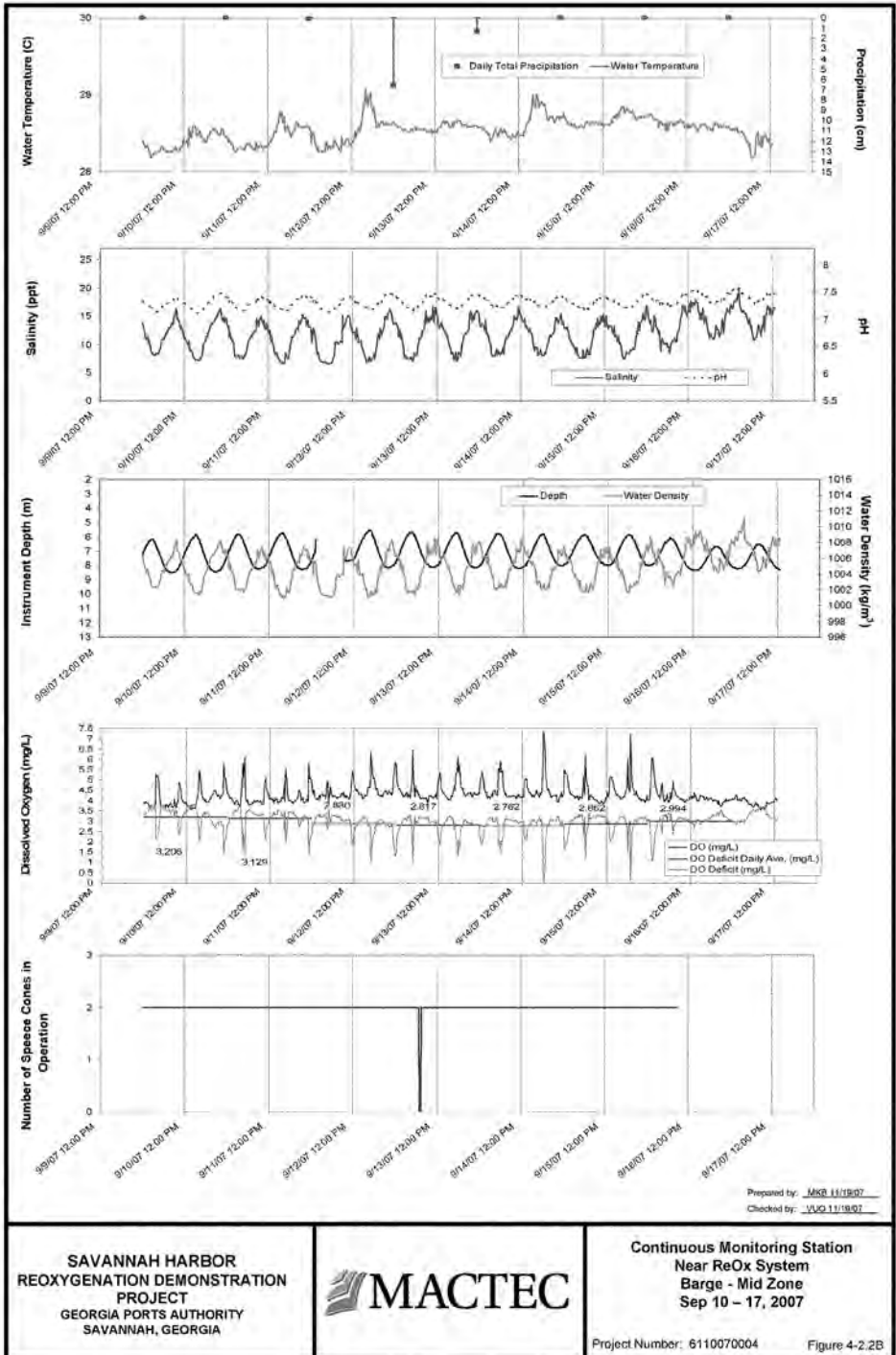
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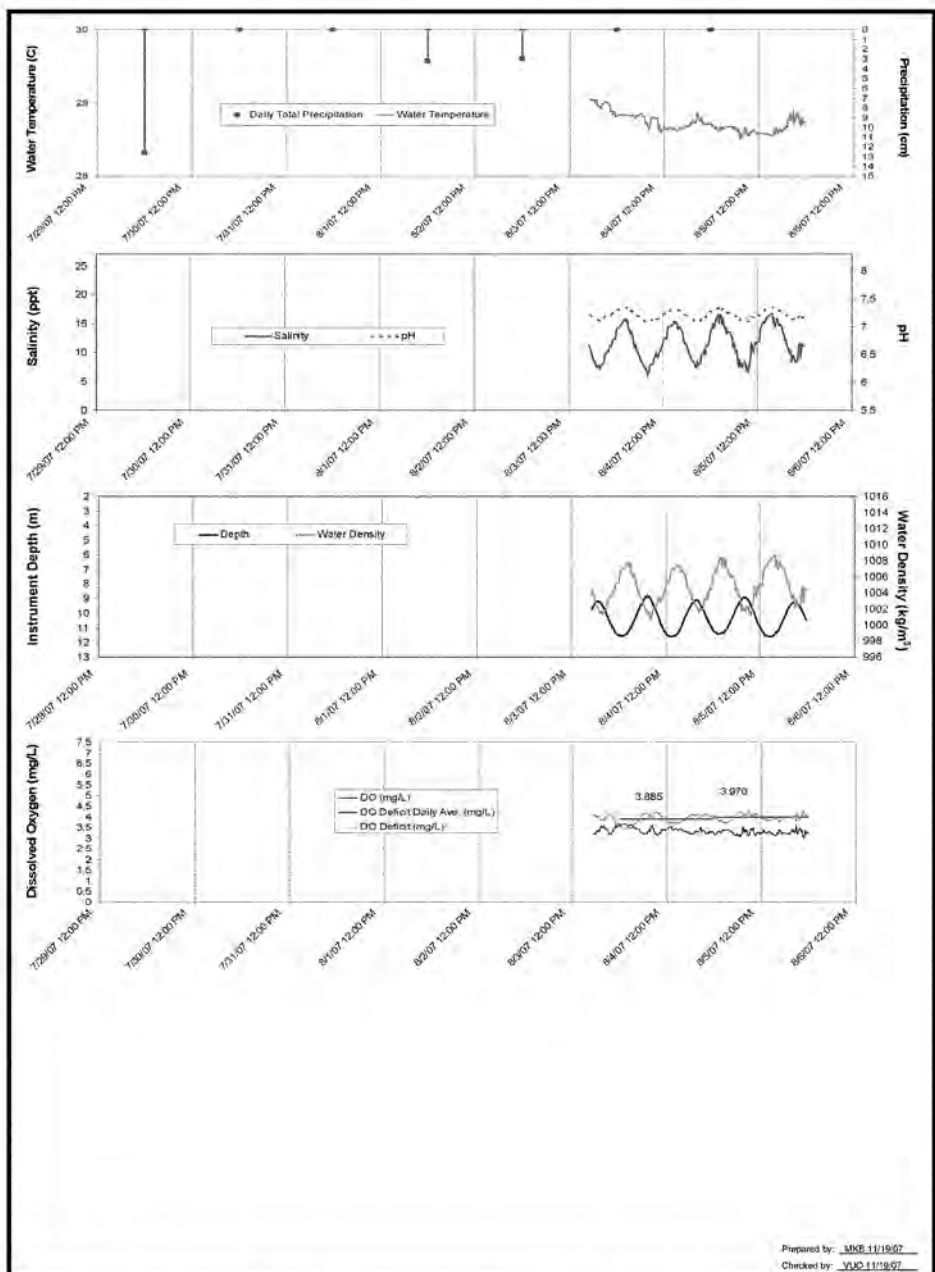
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Project Number: 6110070004

Figure 4-2.2B





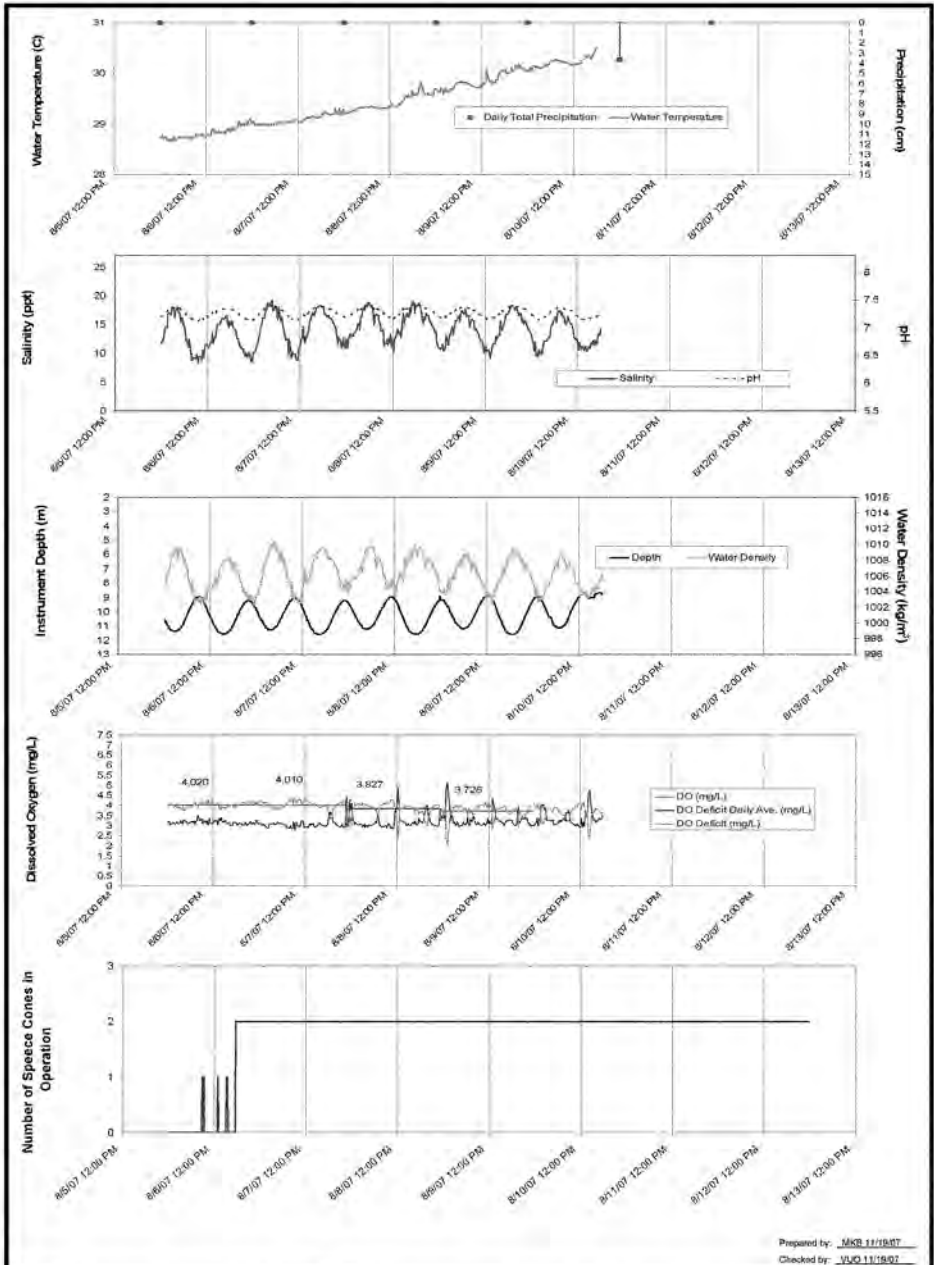
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Figure 4-2.2B



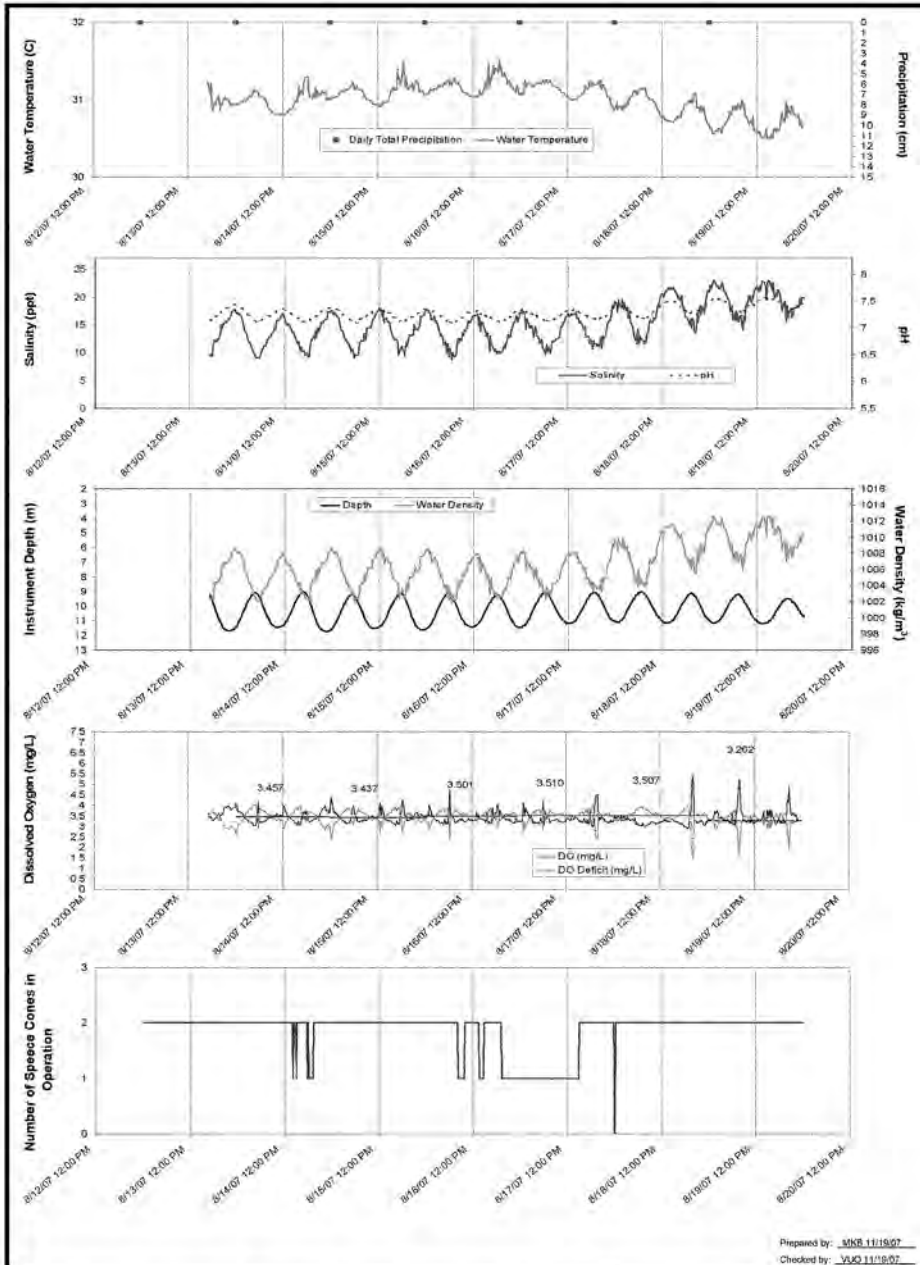
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4-2.2B



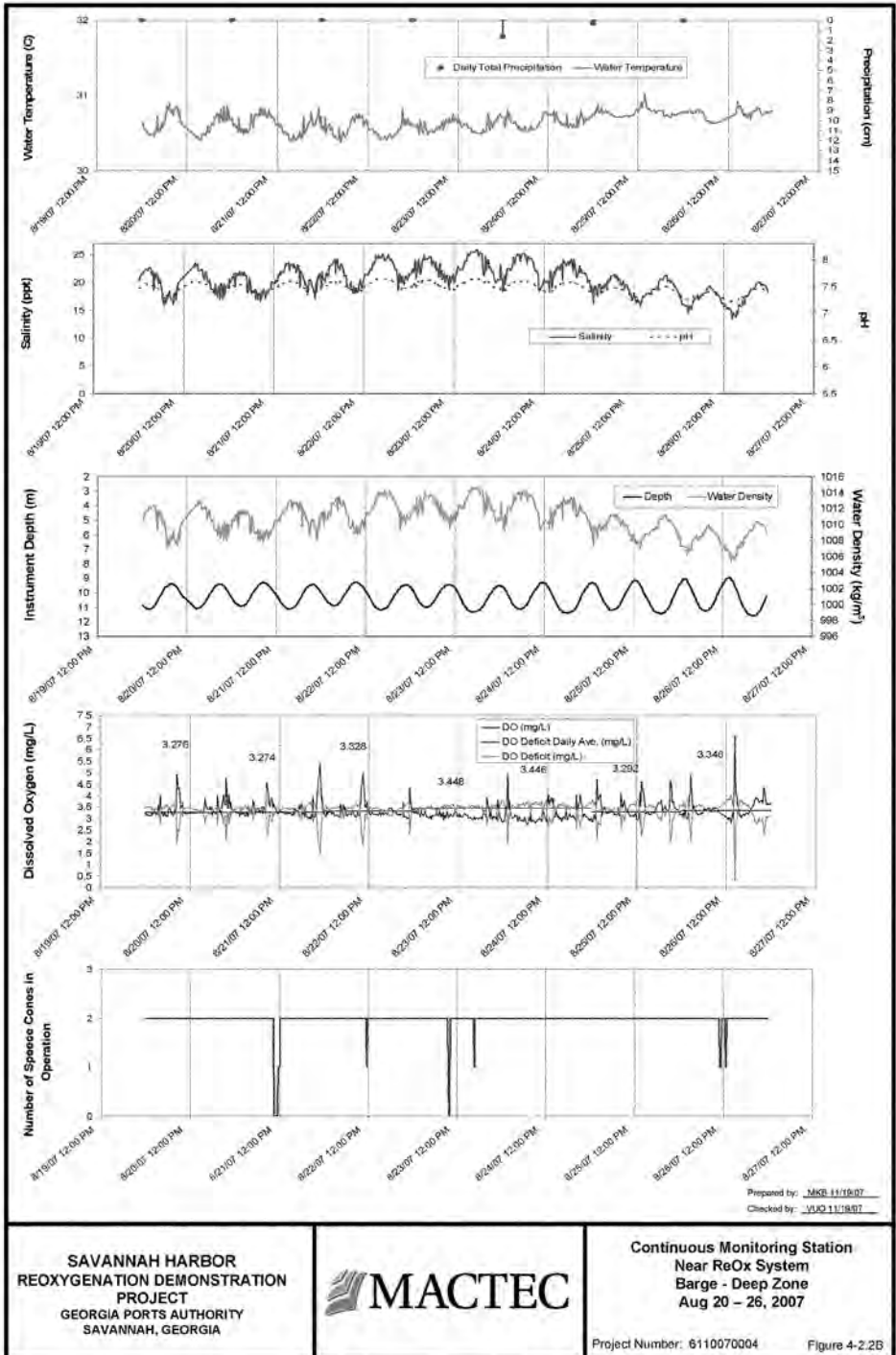
SAVANNAH HARBOR
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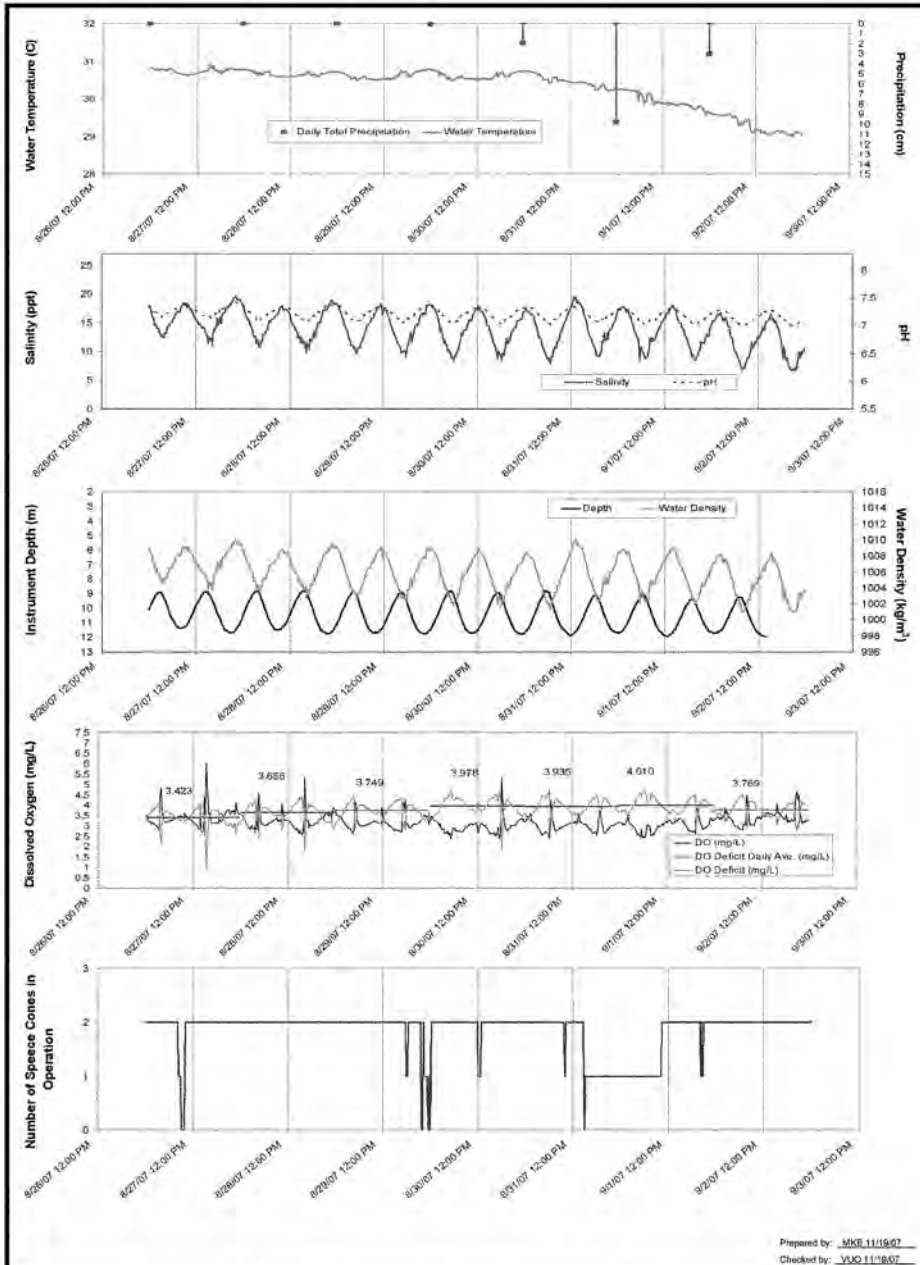


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Figure 4-2.2B





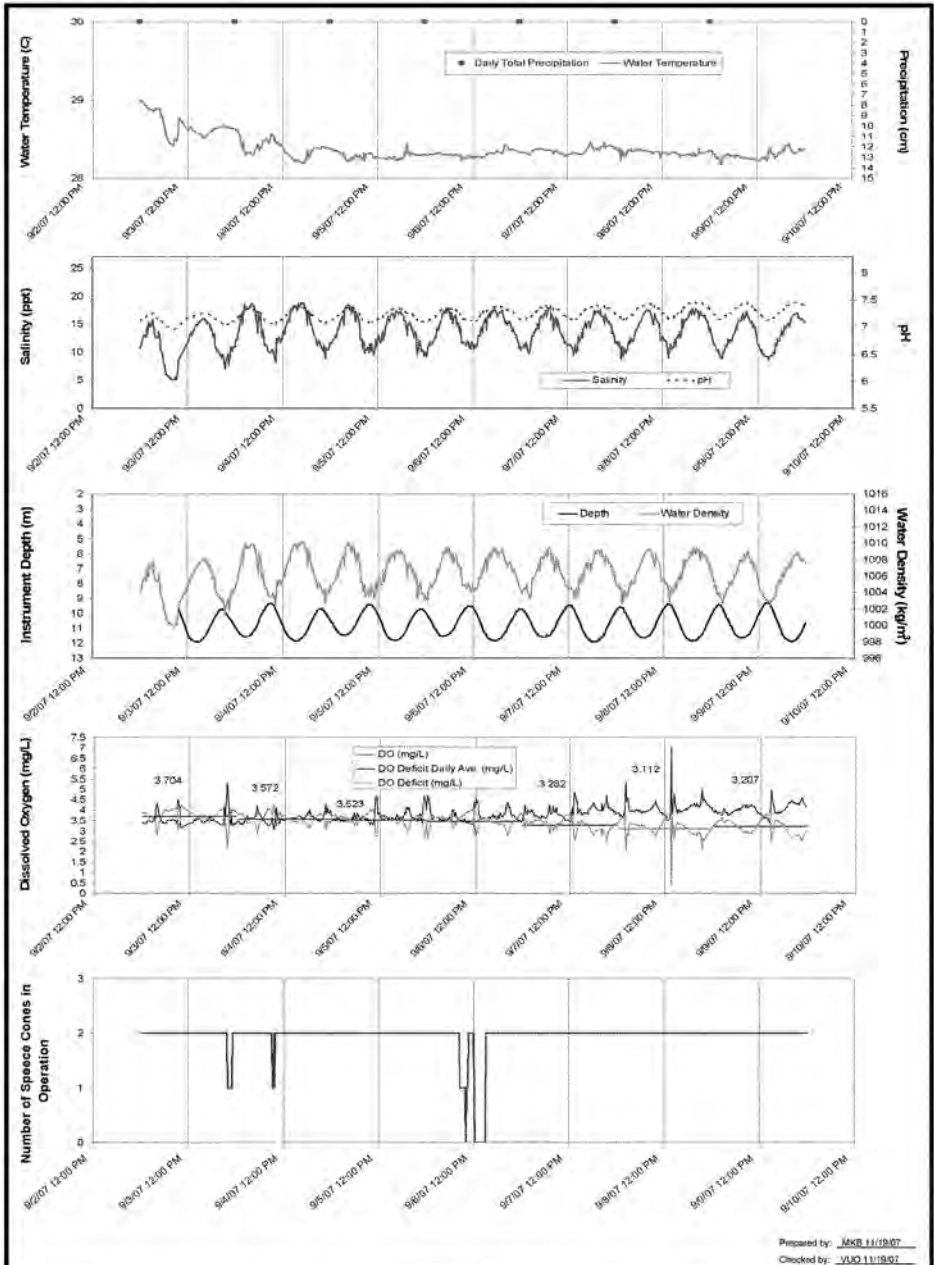
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Figure 4-2.2B



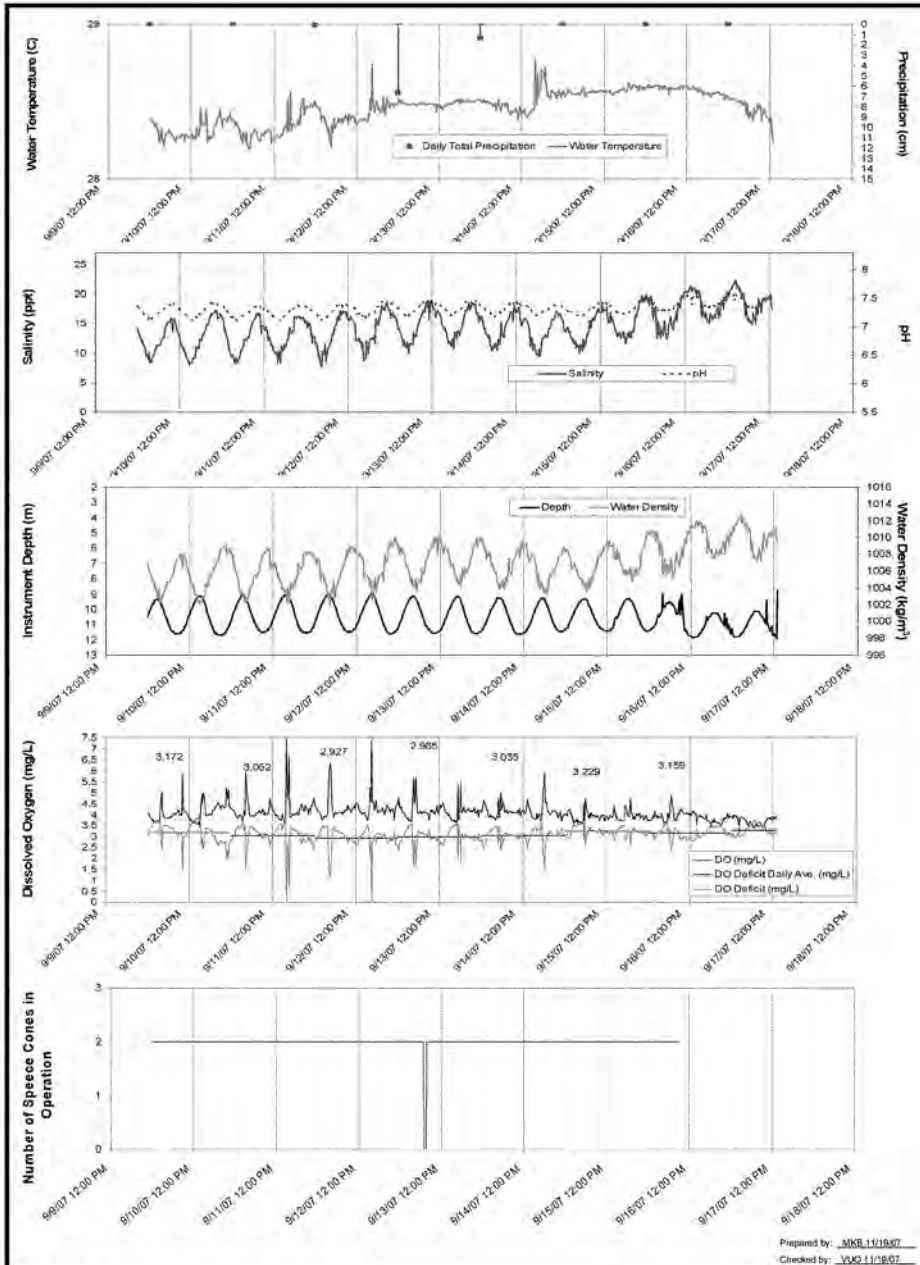
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Figure 4-2.2B



Prepared by: MSB.11/19/07
 Checked by: VJD.11/19/07

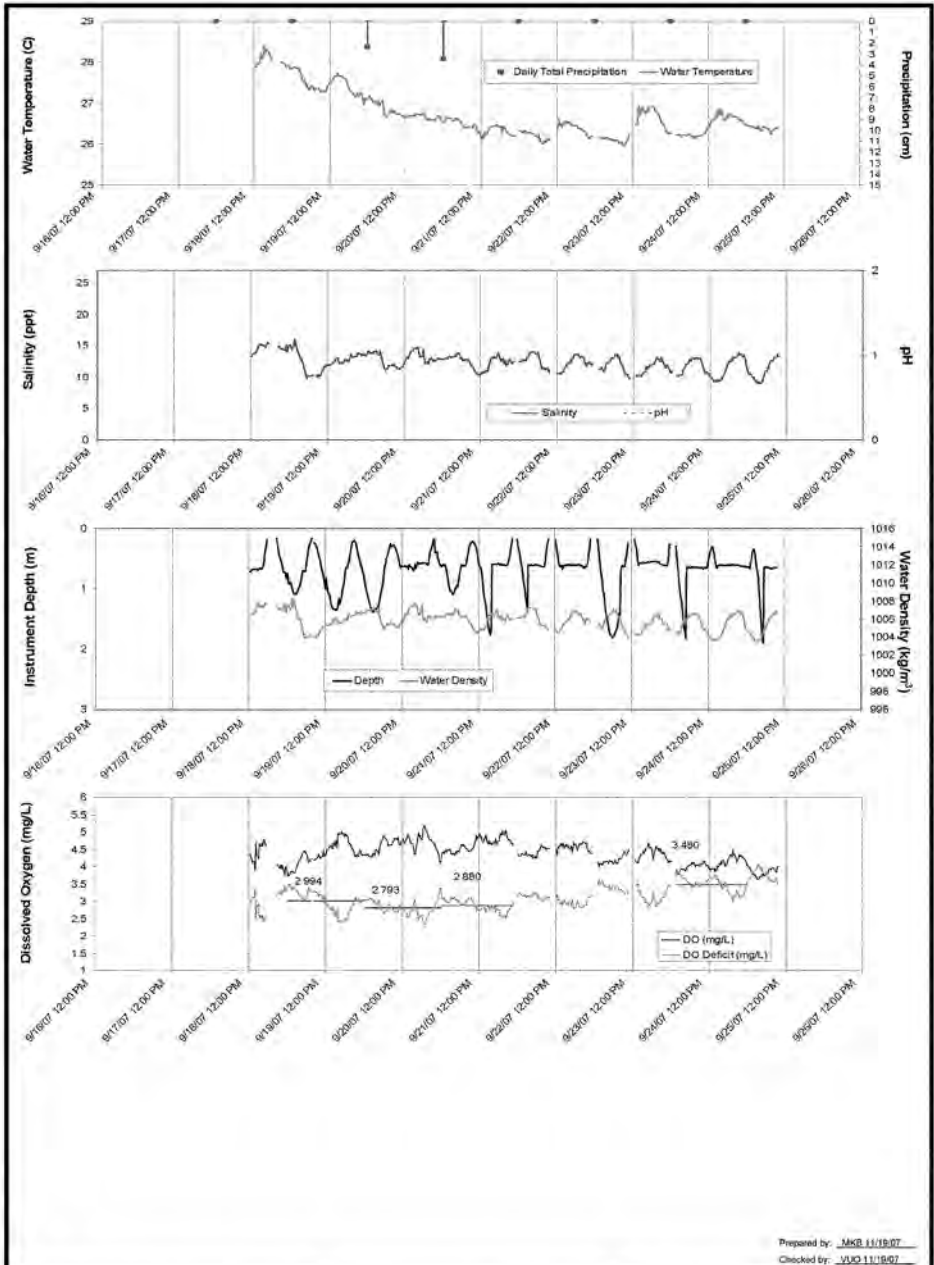
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Figure 4-2.2B



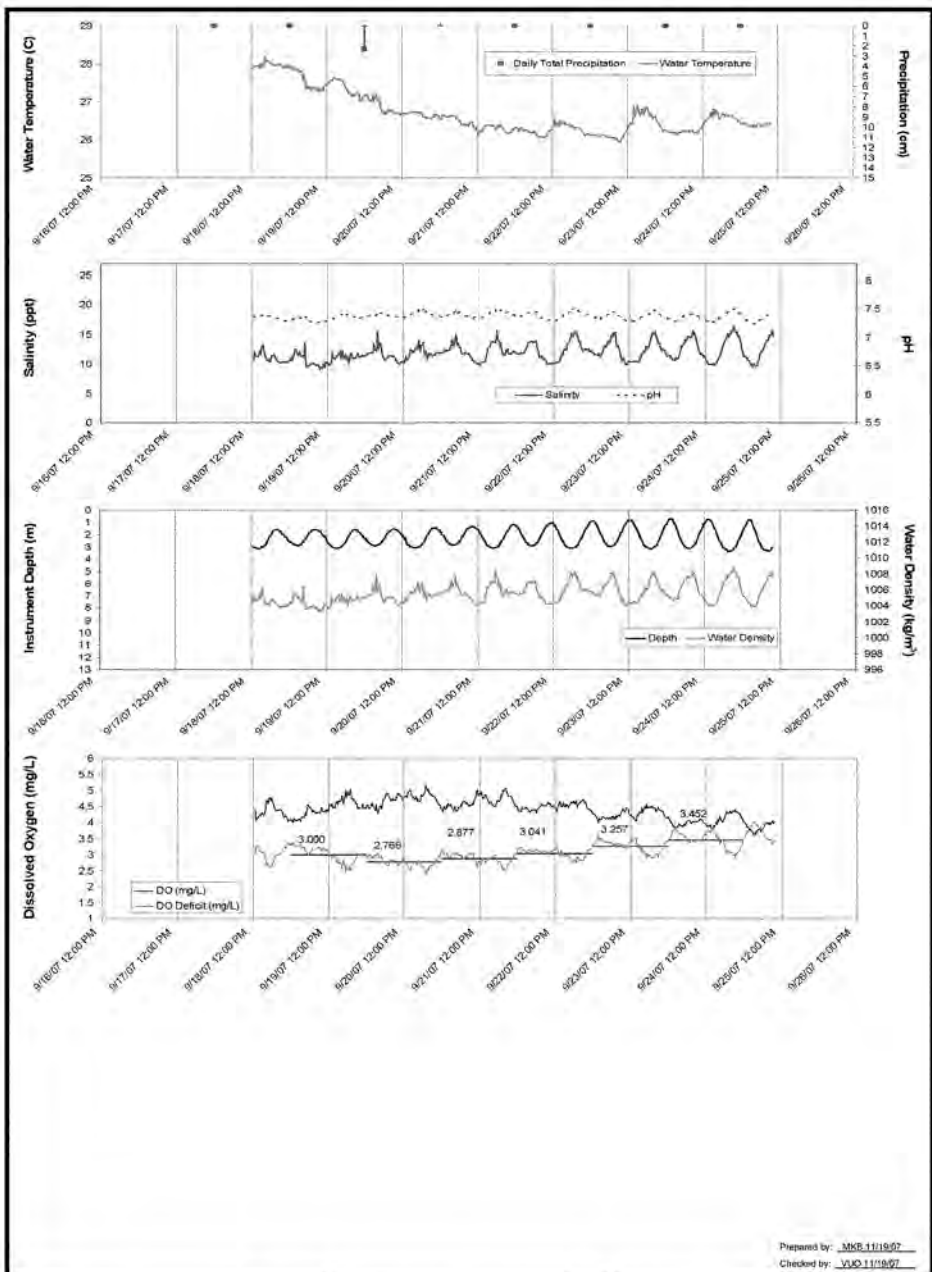
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Continuous Monitoring Station
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 Savannah Marine - Shallow Zone
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Project Number: 6110070004

Figure: 4-2.2C

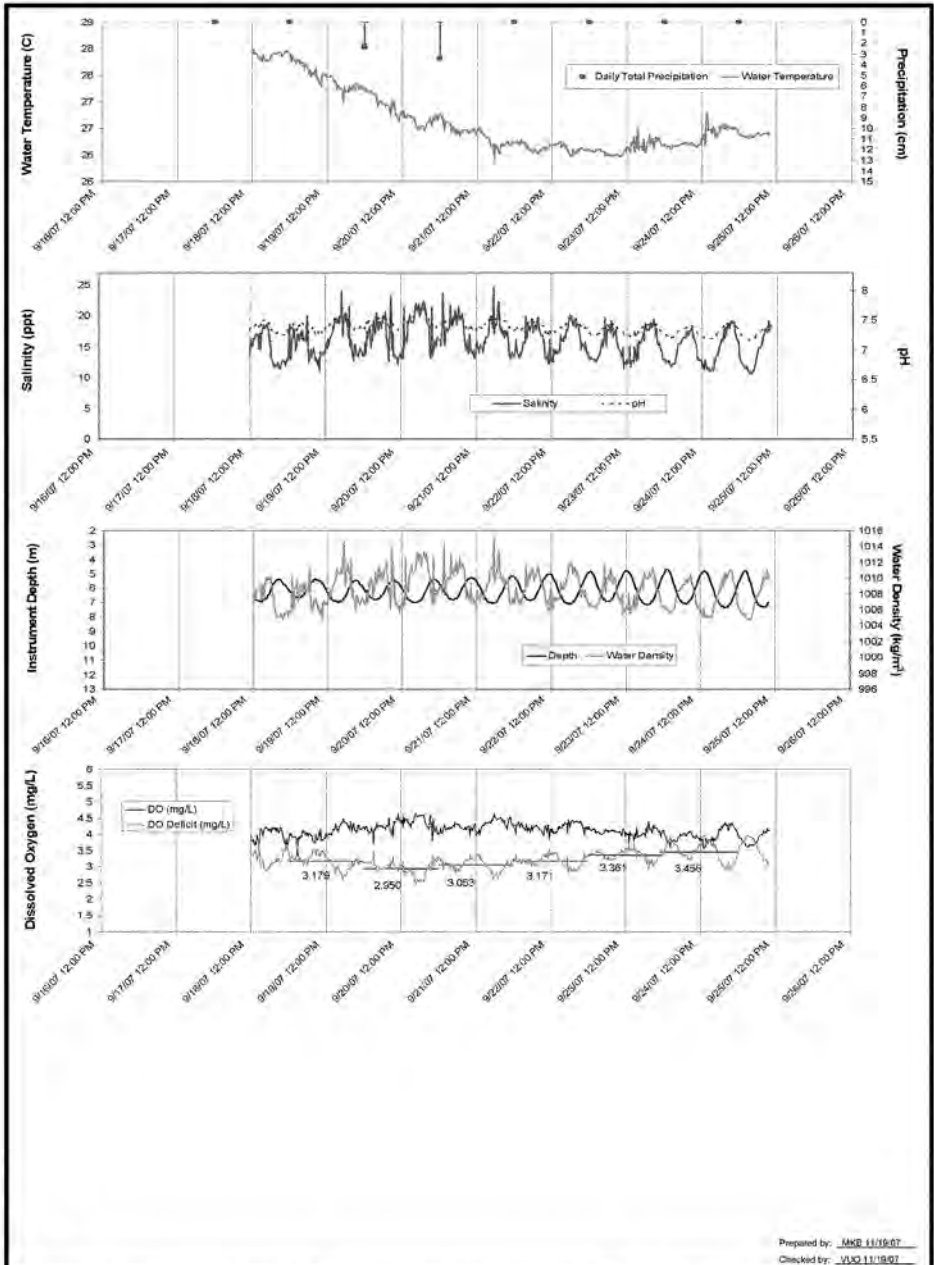


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Continuous Monitoring Station
Near ReOx System
Savannah Marine - Mid Zone
September 18 - 25, 2007

Project Number: 6110070004 Figure: 4-2.2C



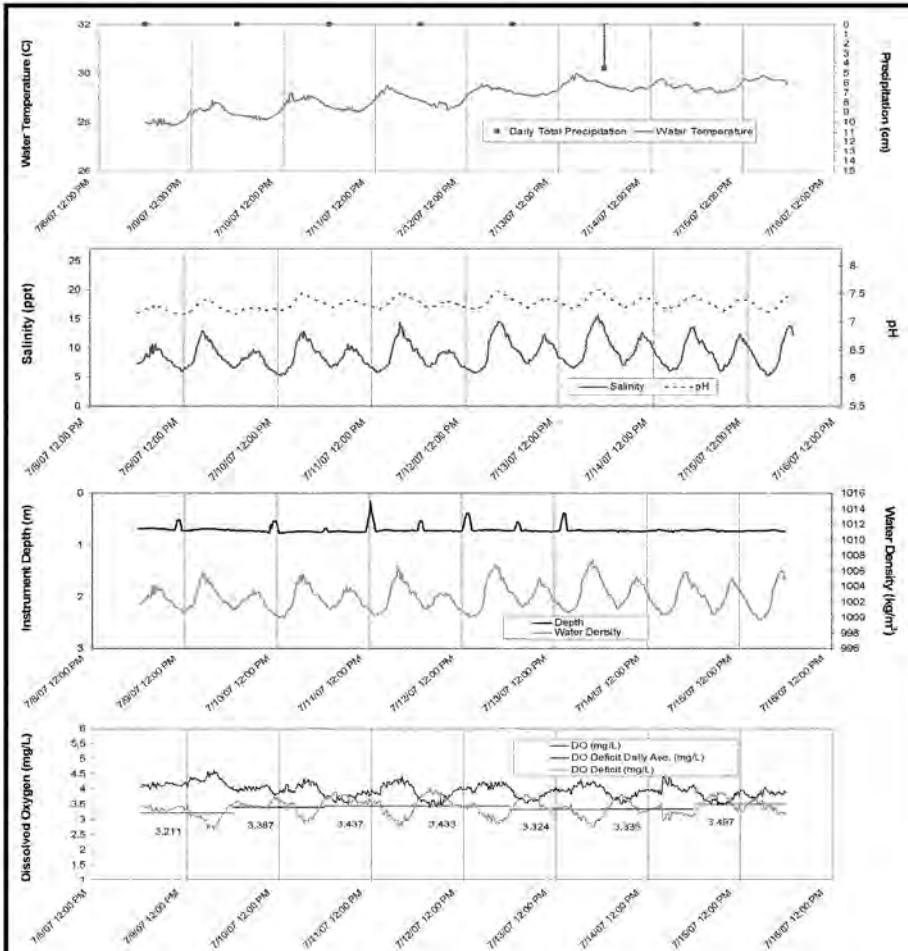
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Figure: 4-2.2C



Prepared by: MDR 11/19/07
 Checked by: VJS 11/19/07

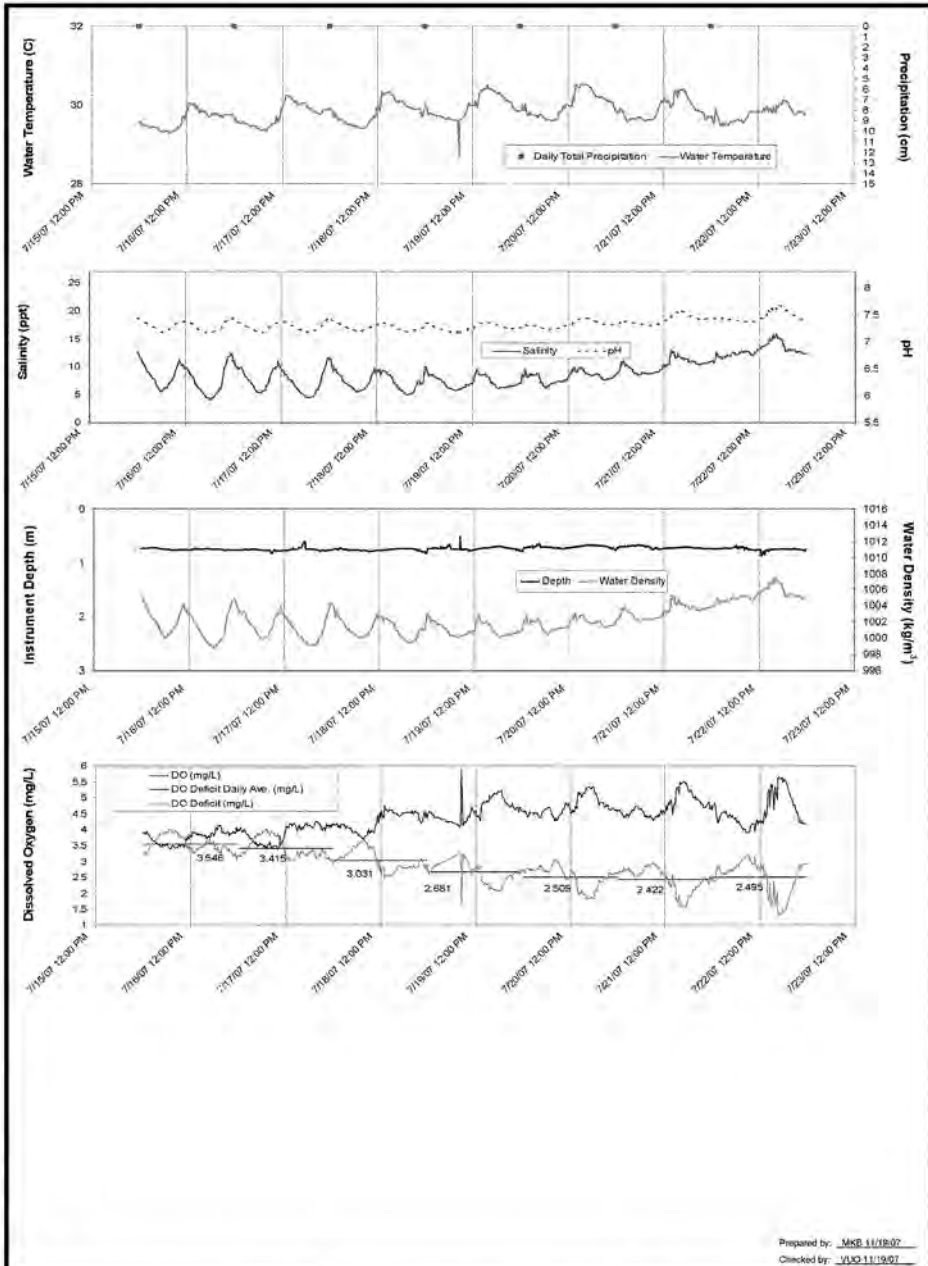
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Continuous Monitoring Station
 USACE Dock- Shallow Zone
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Project Number: 6110070004

Figure 4-2.3



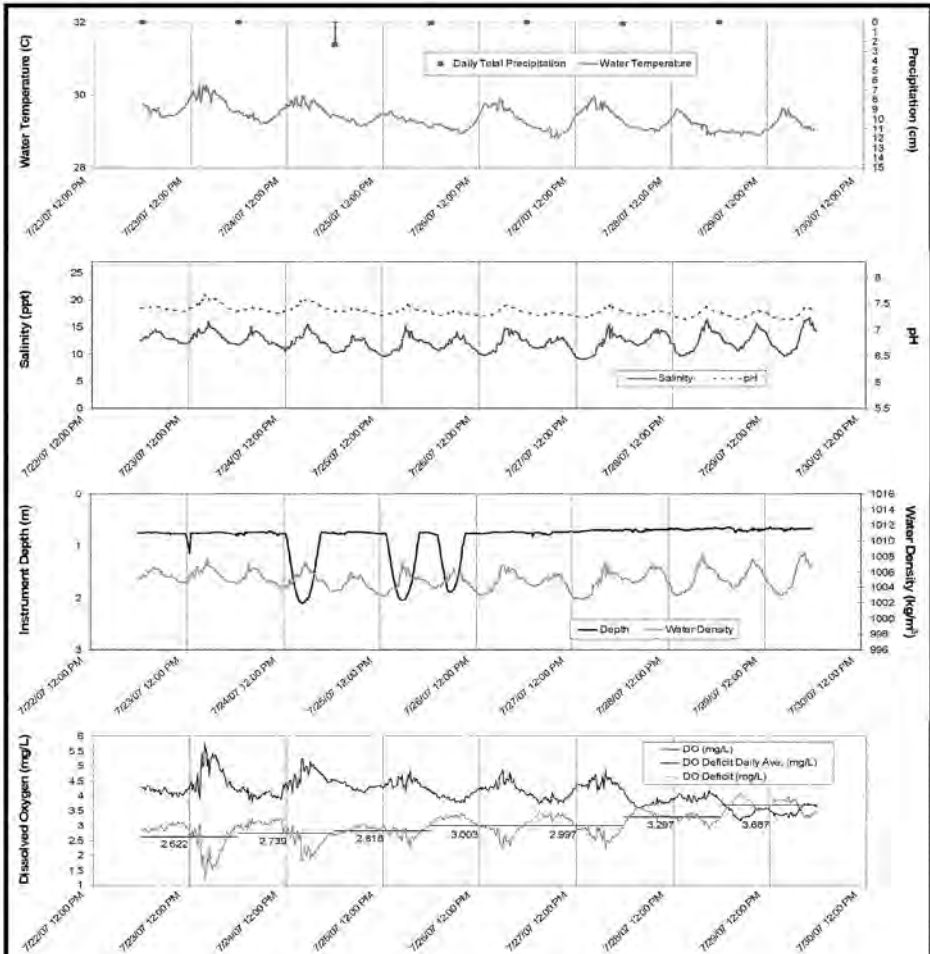
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Figure 4-2.3



Prepared by: MCR.11/19/07
 Checked by: VUD.11/19/07

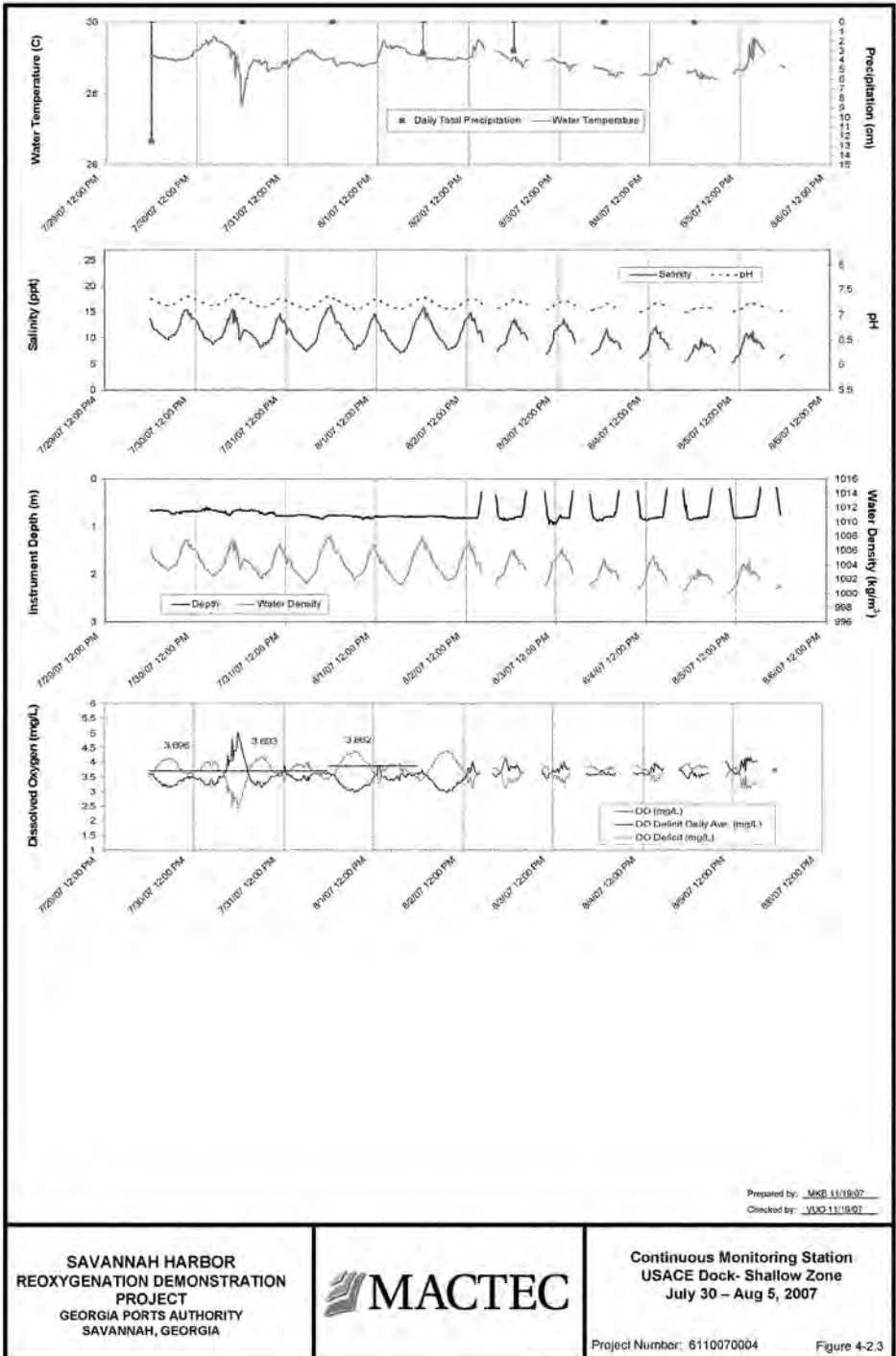
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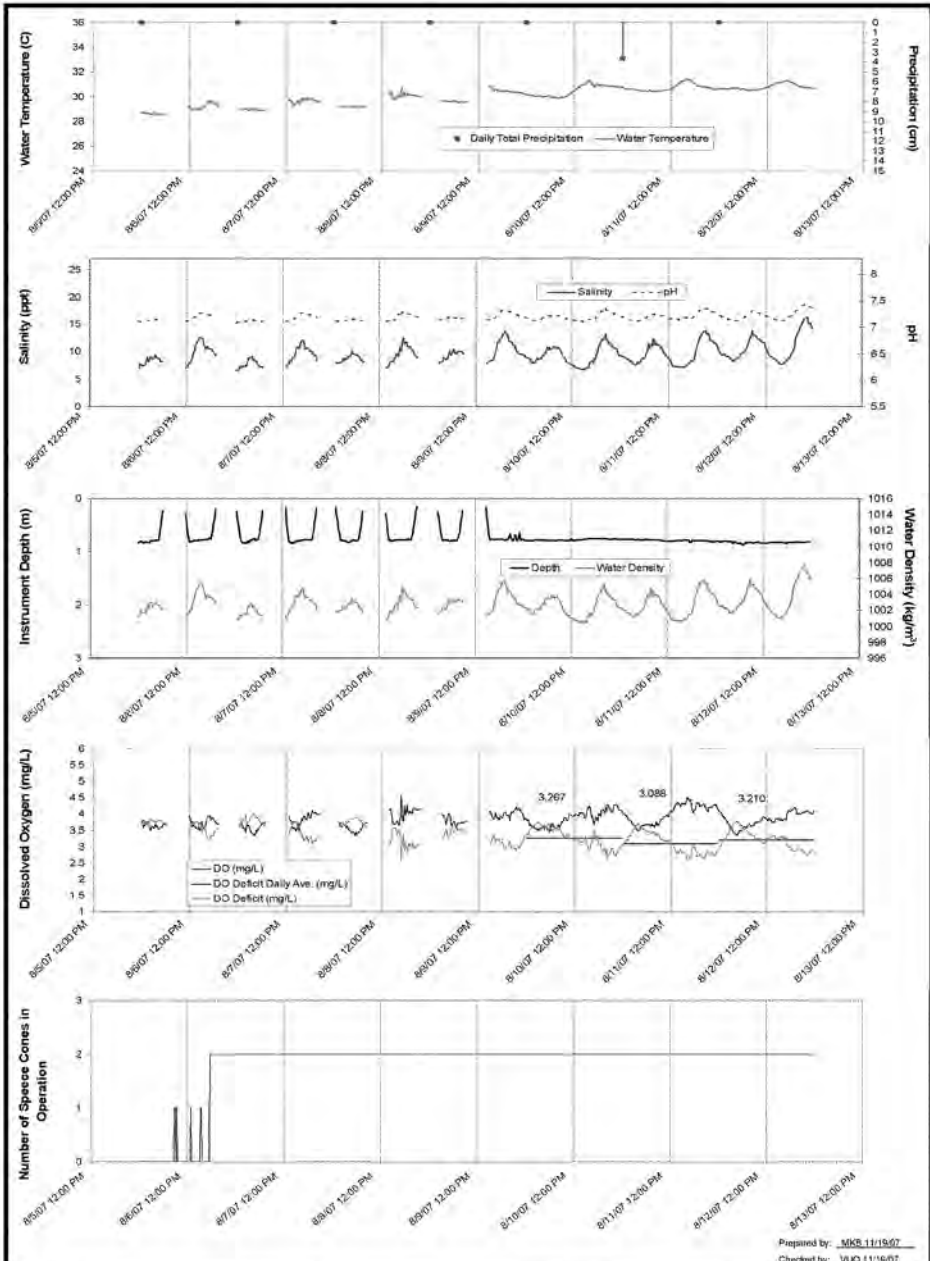


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Figure 4-2.3





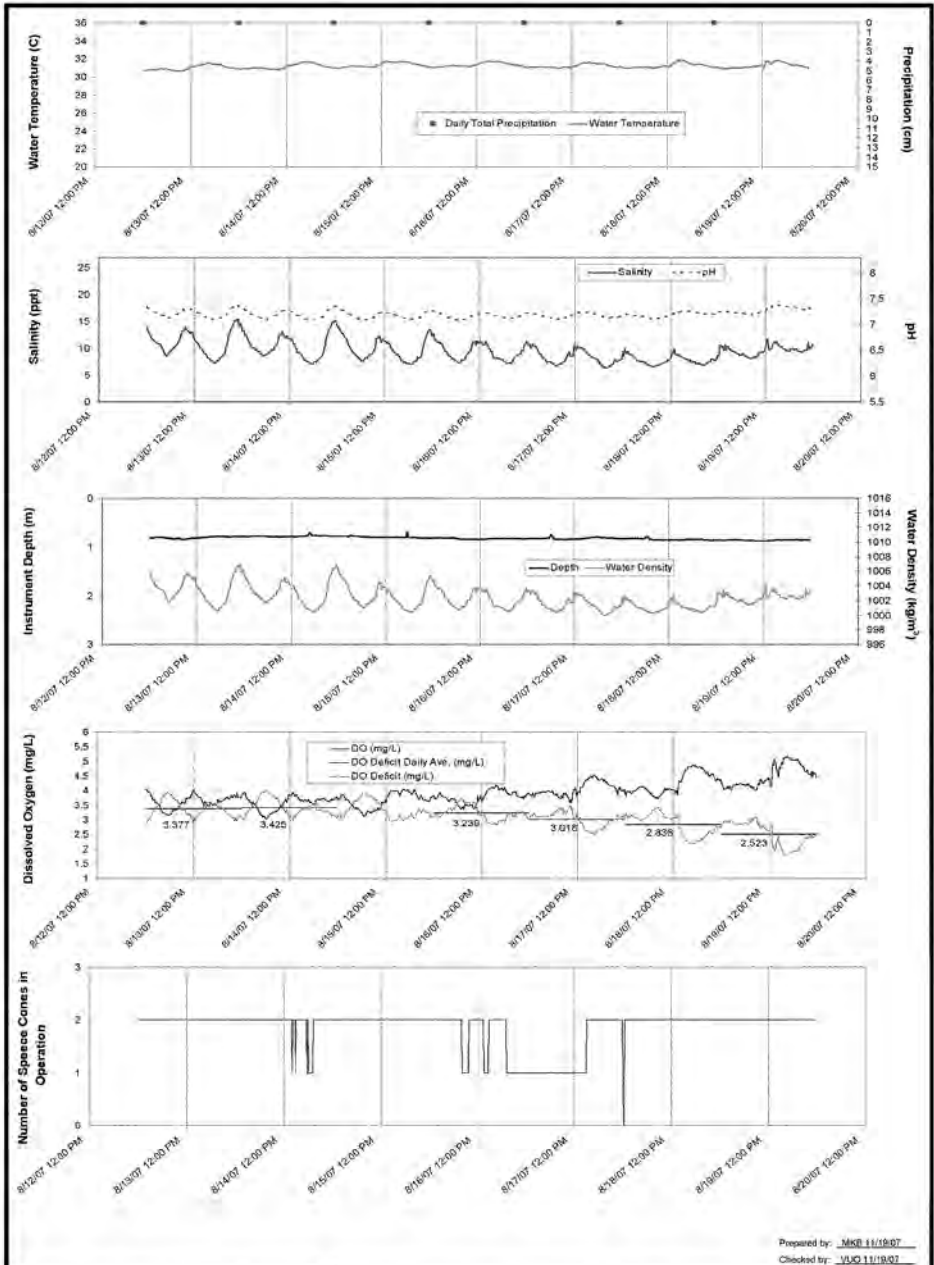
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Figure 4-2.3



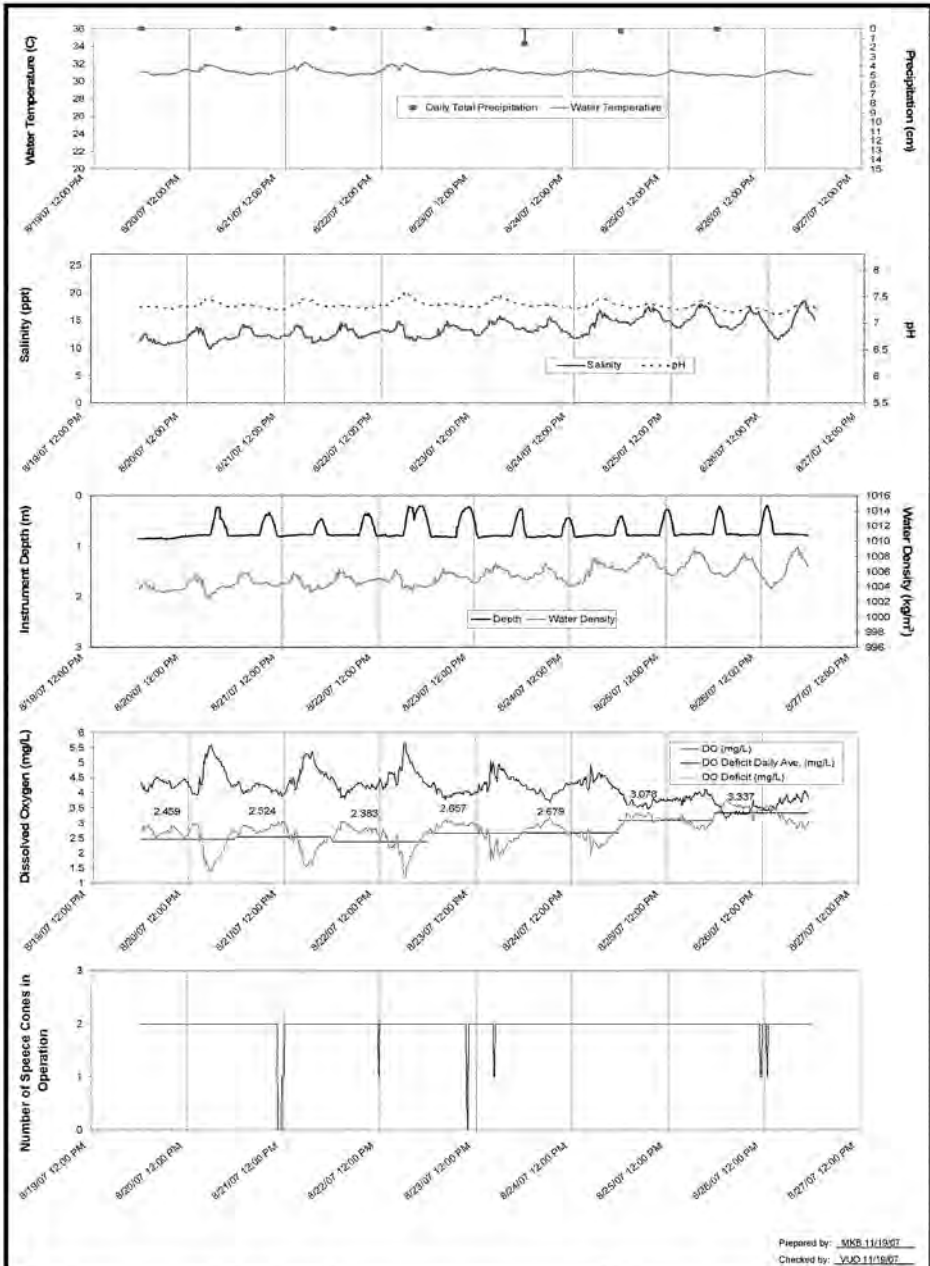
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Figure 4-2.3



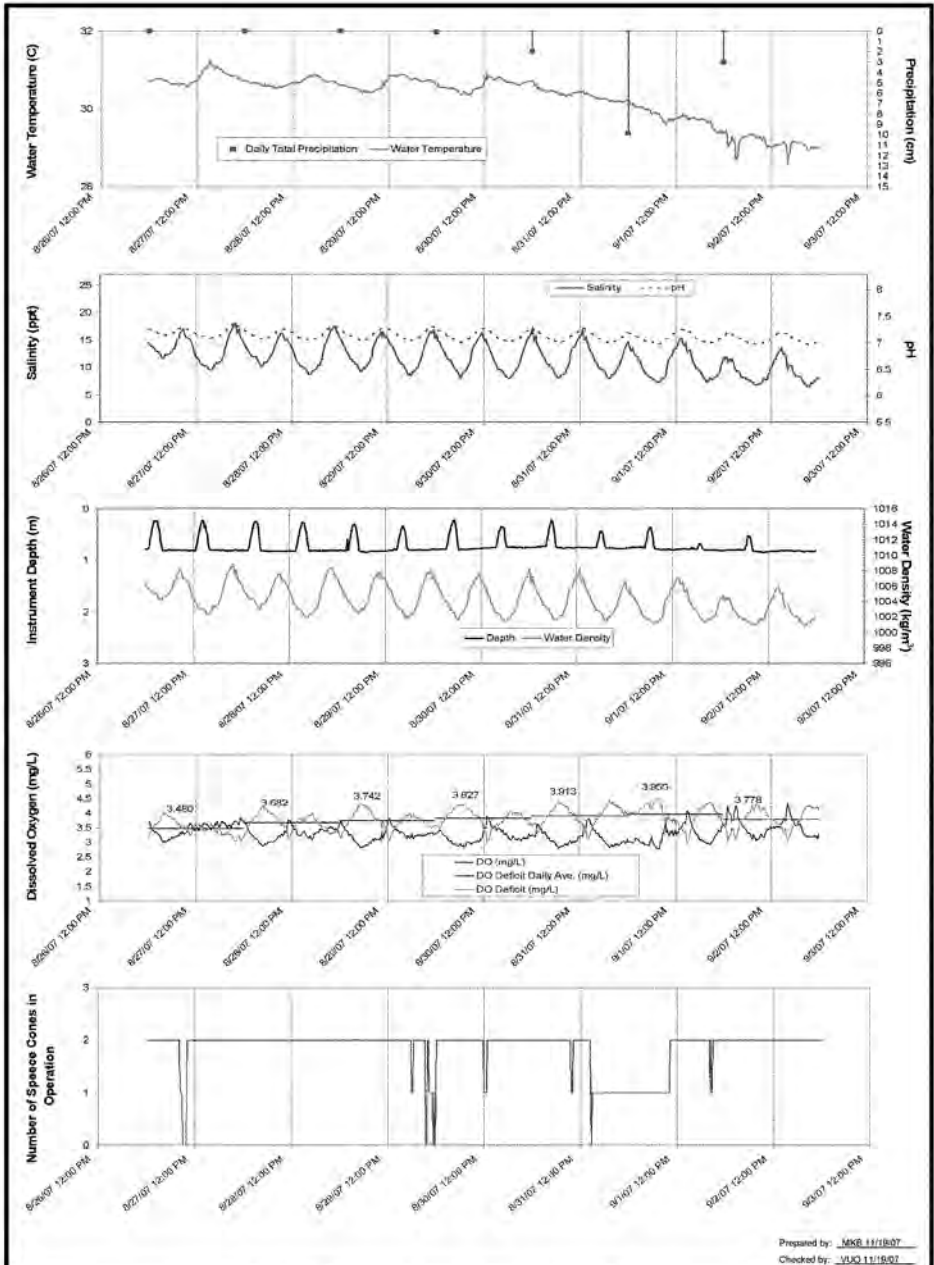
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Figure 4-2.3



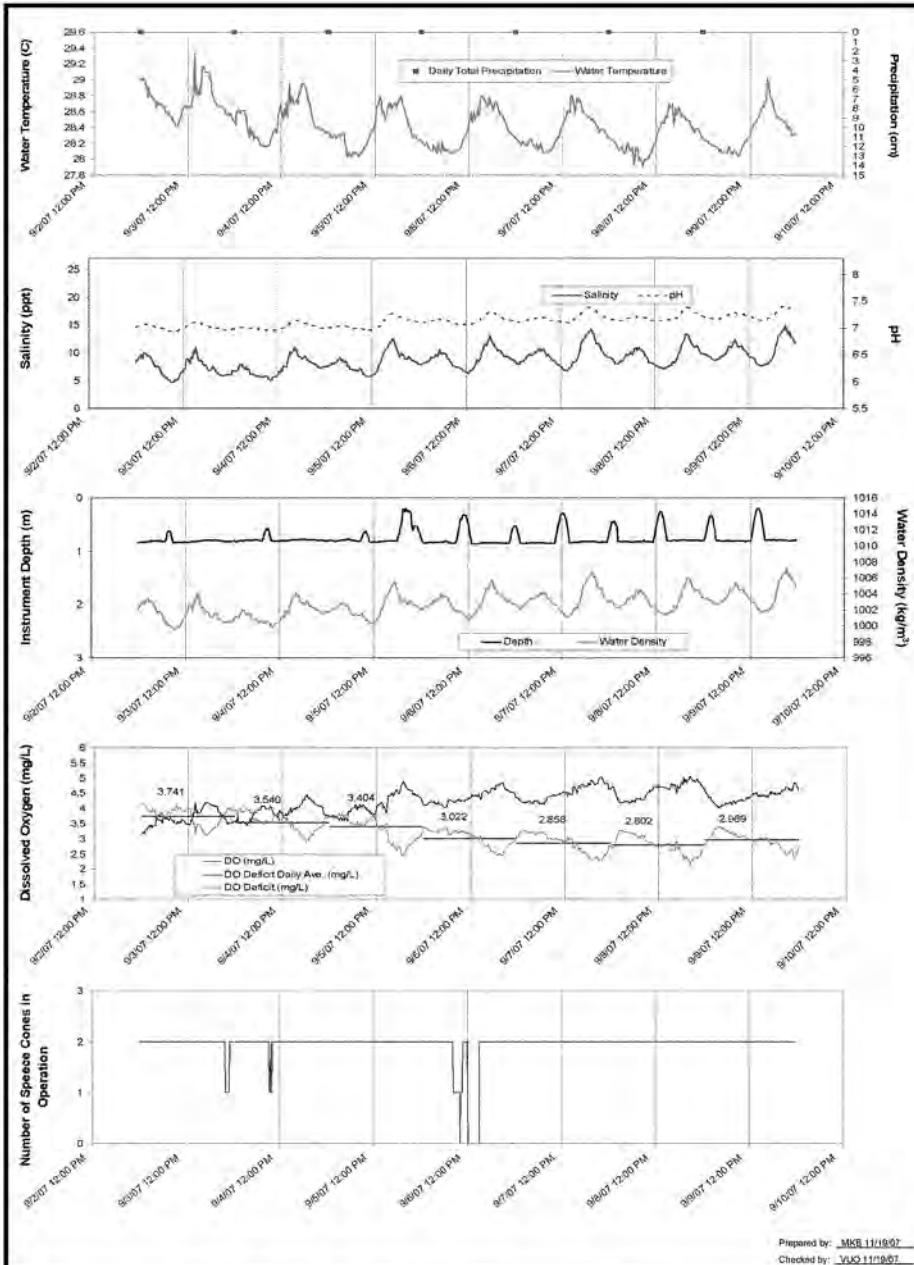
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Figure 4-2.3



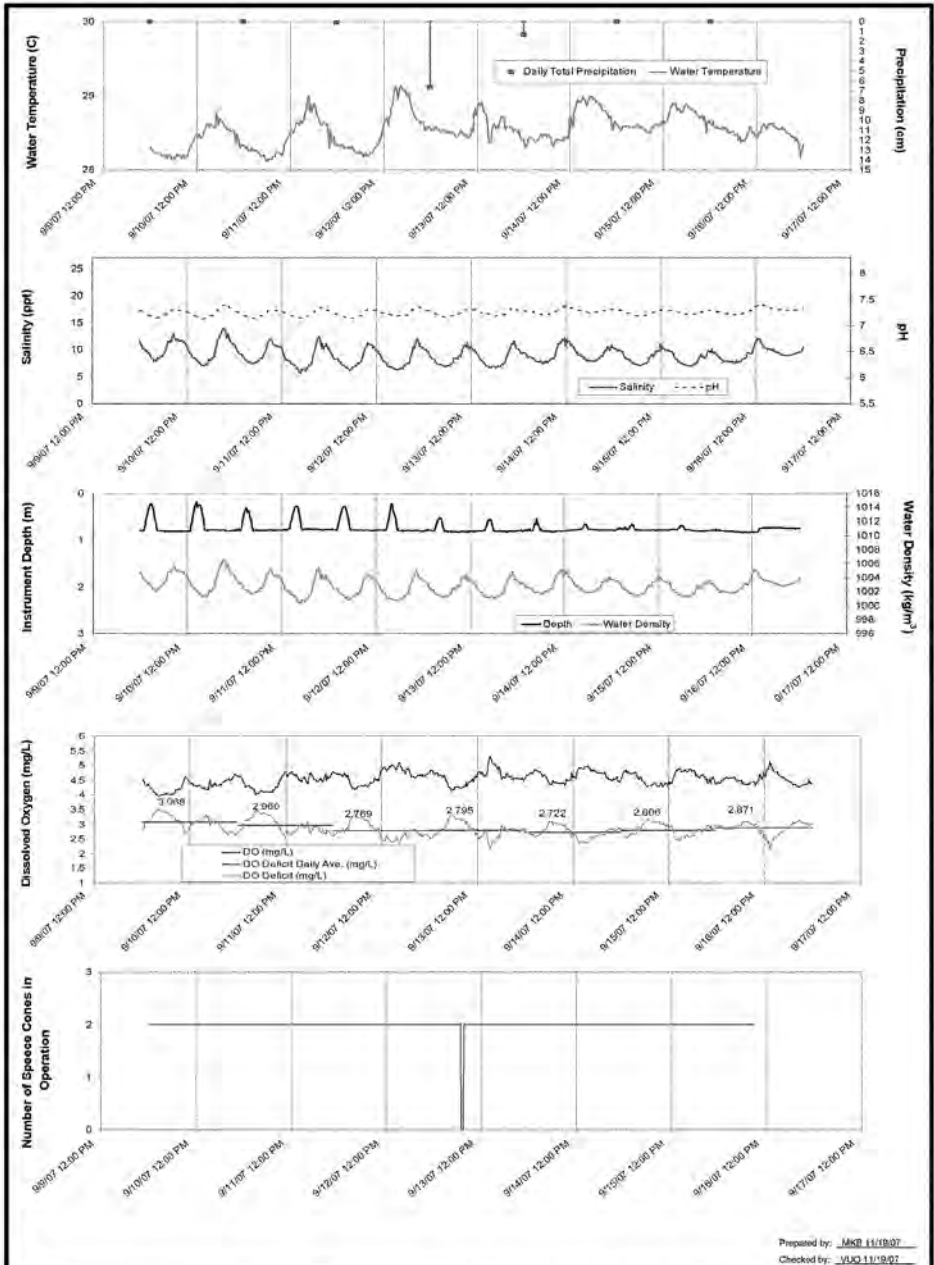
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Figure 4-2.3



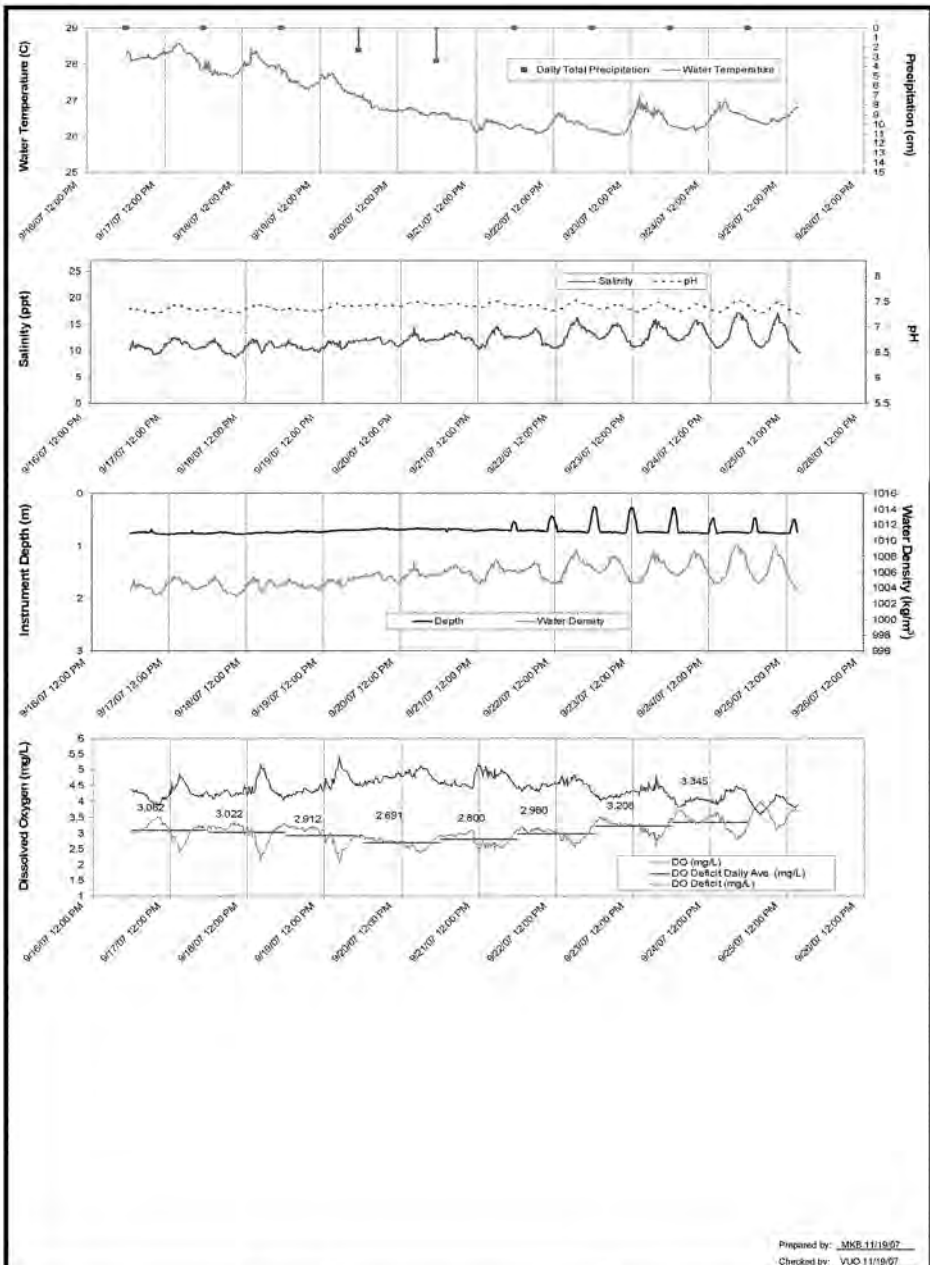
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Figure 4-2.3



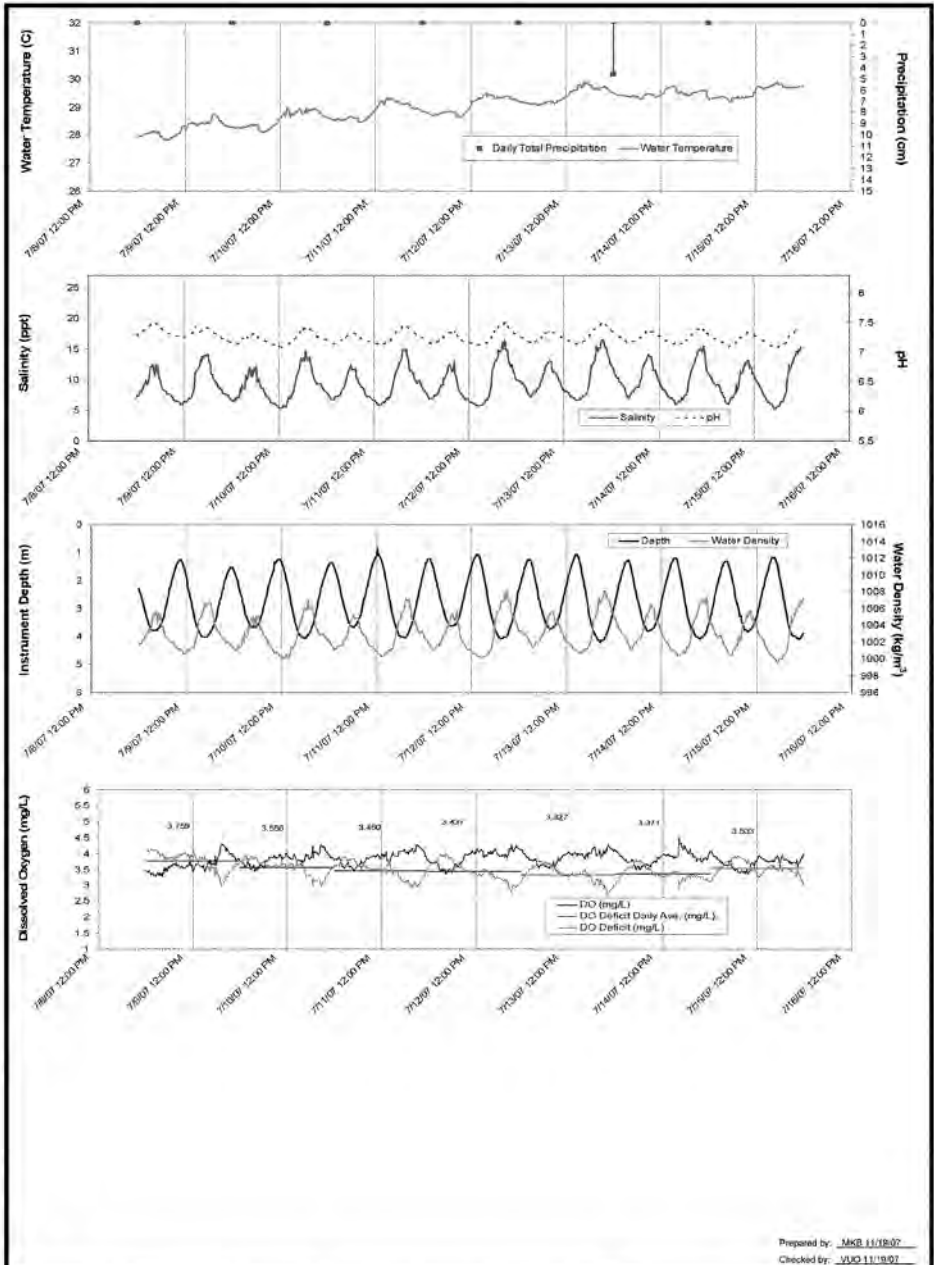
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Figure 4-2.3



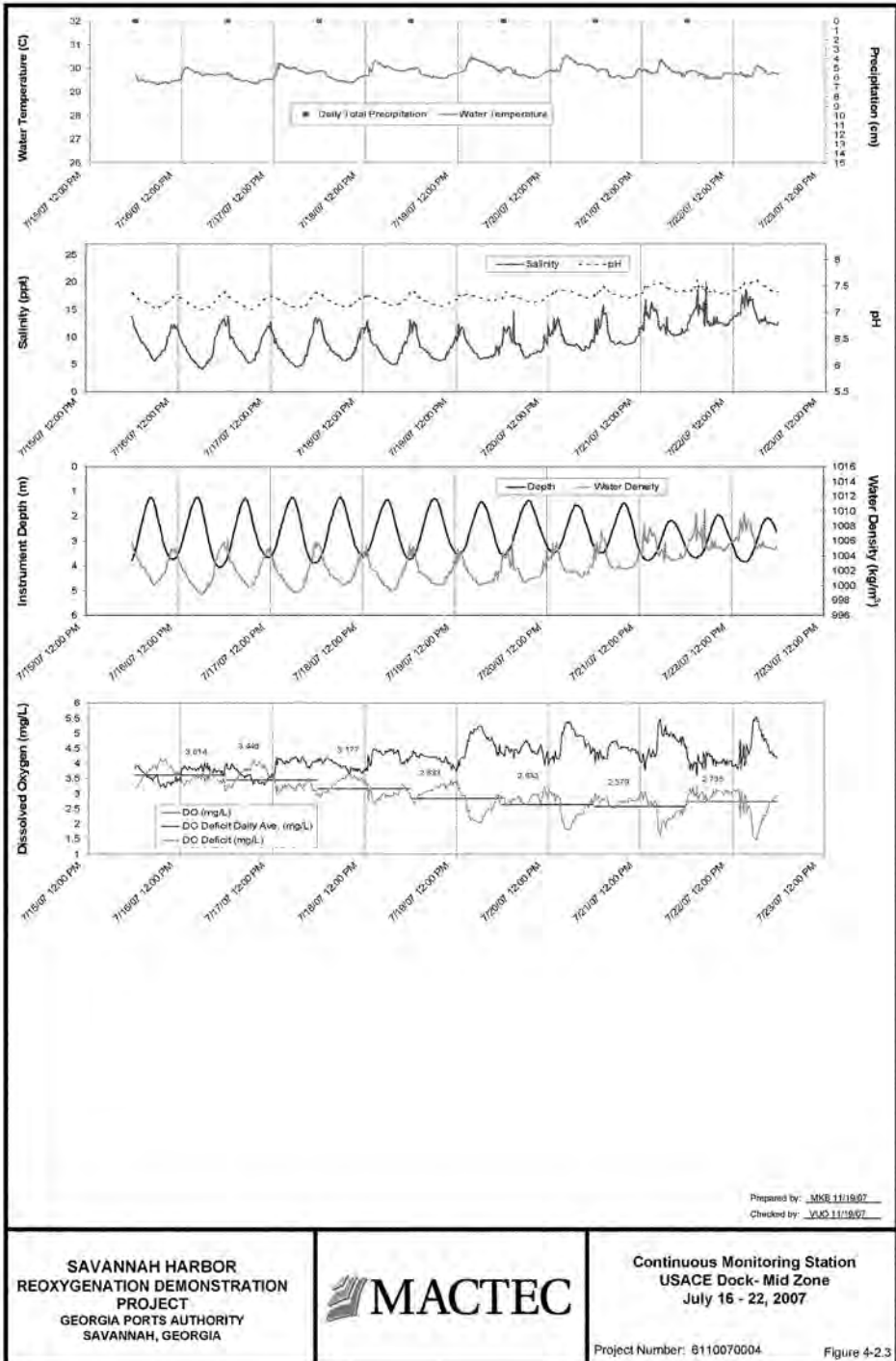
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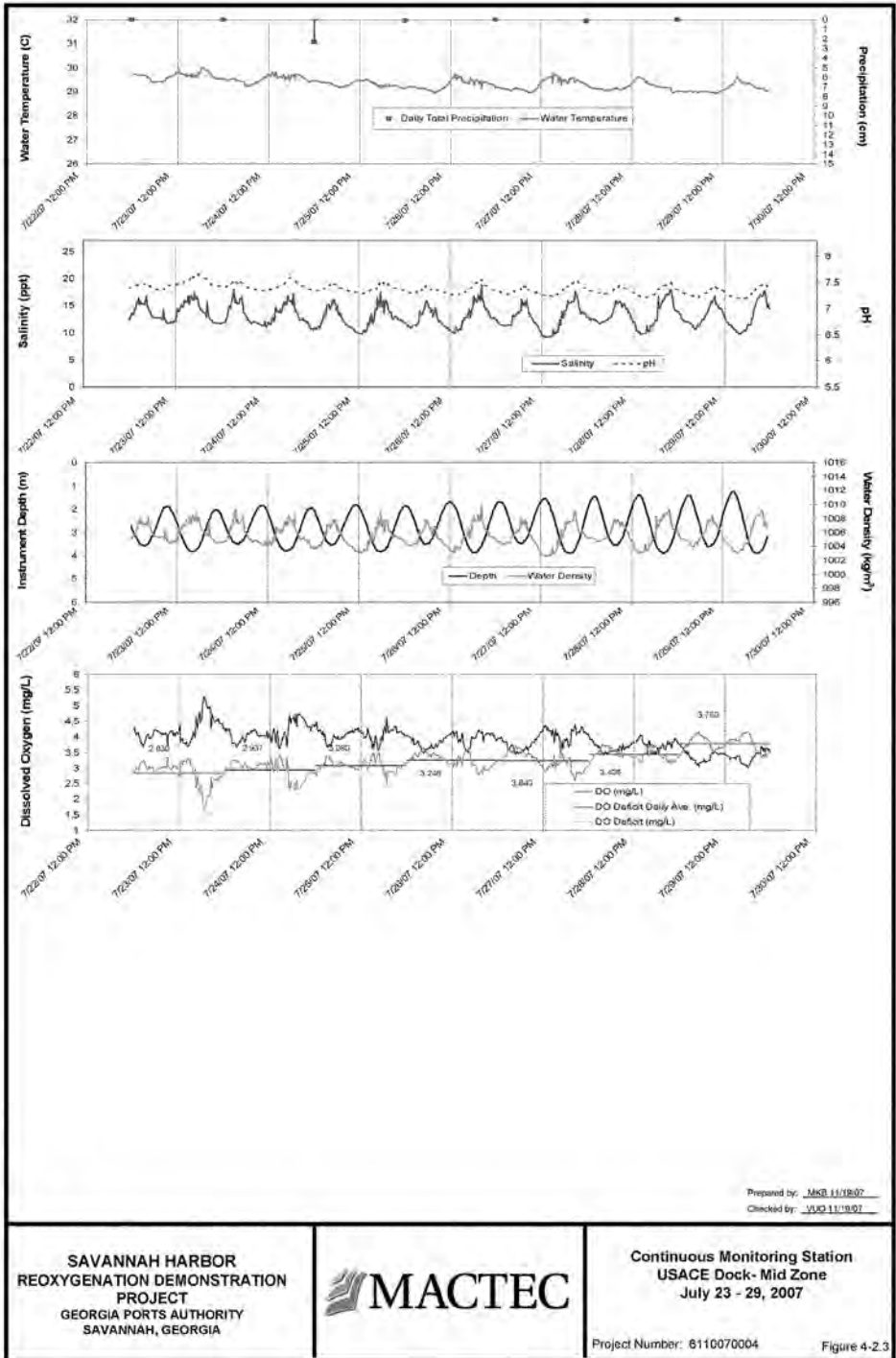
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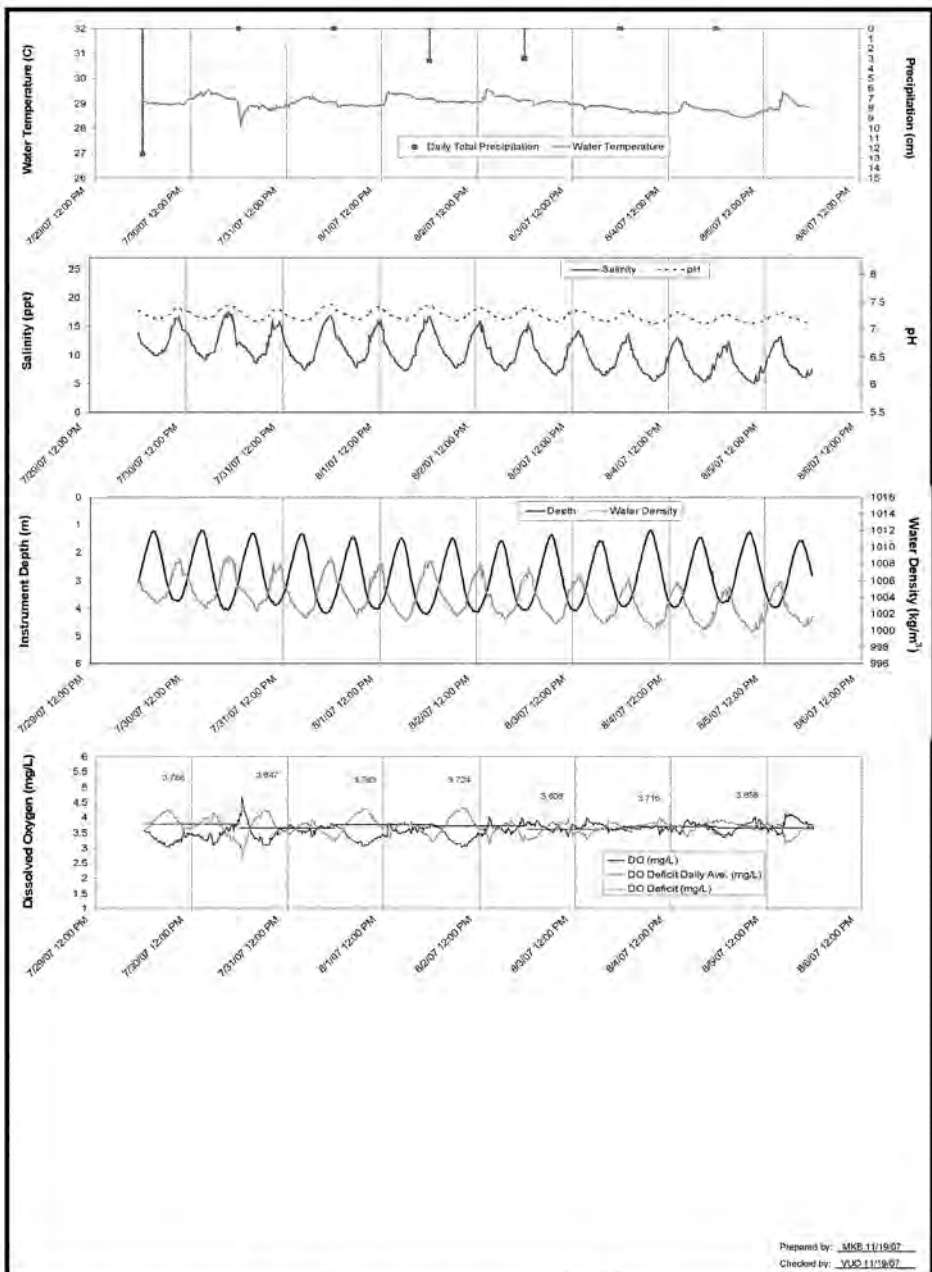
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Project Number: 6110070004

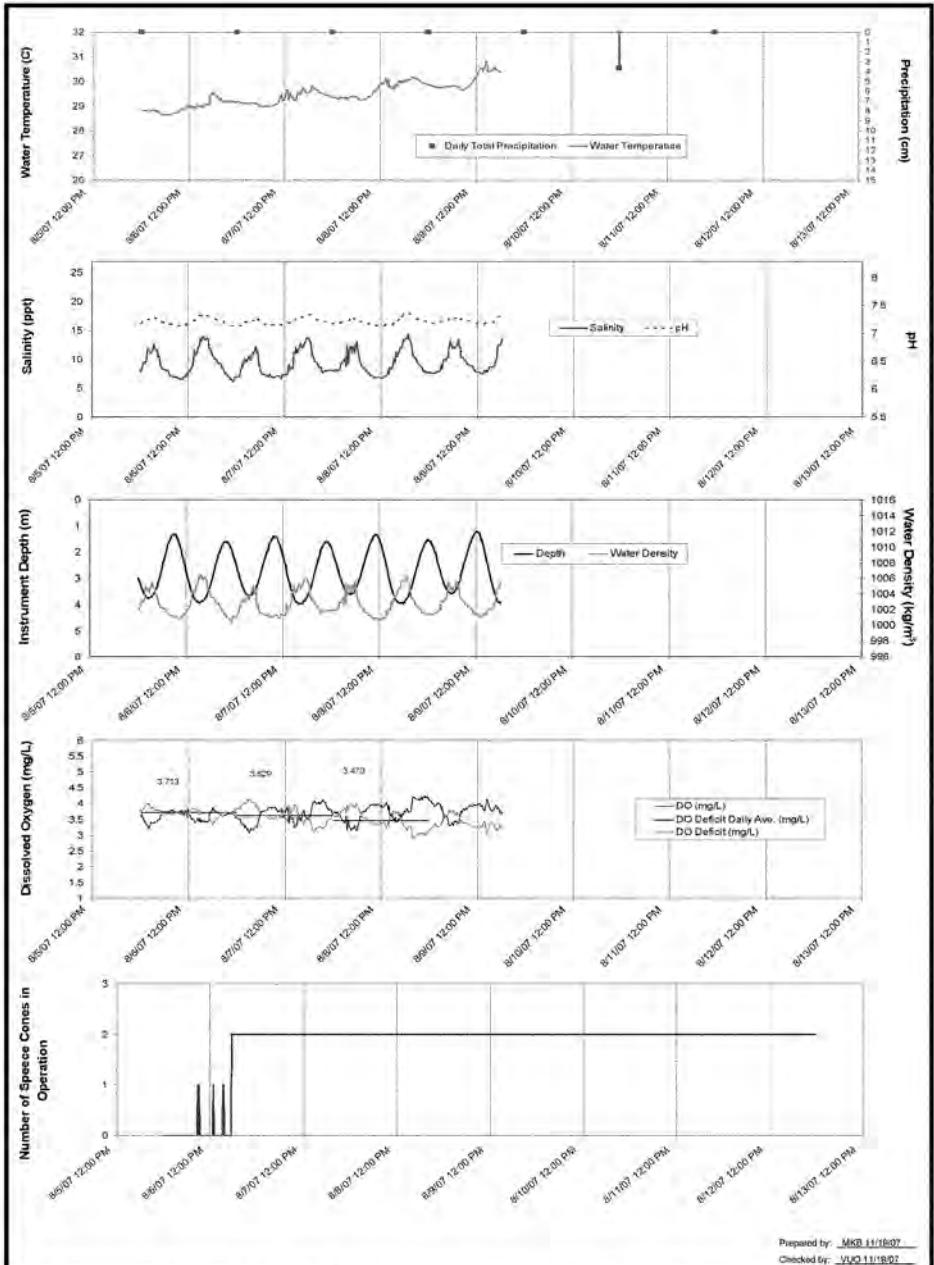
Figure 4-2.3







Prepared by: MKR.11/19/07
Checked by: YJD.11/19/07



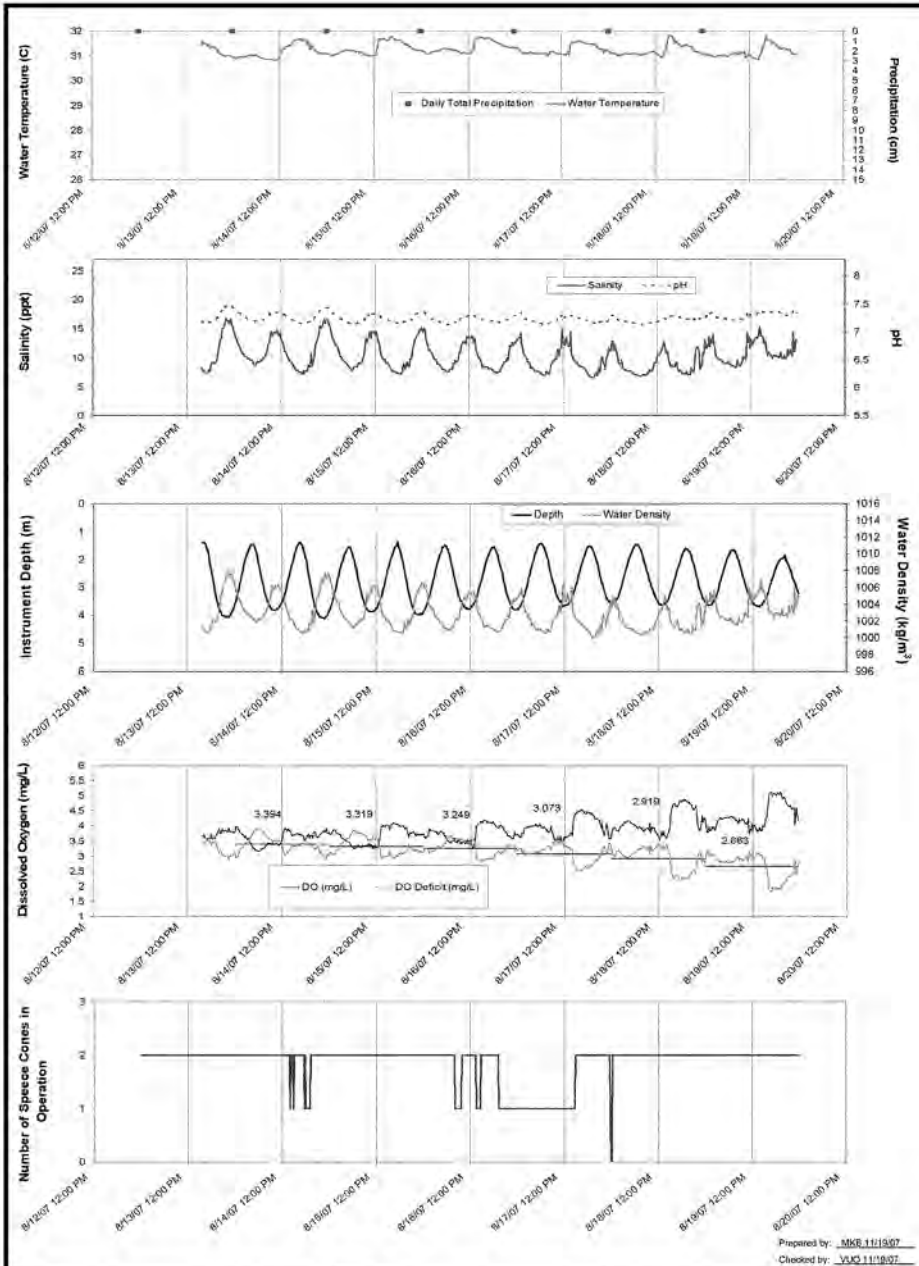
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Figure 4-2.3



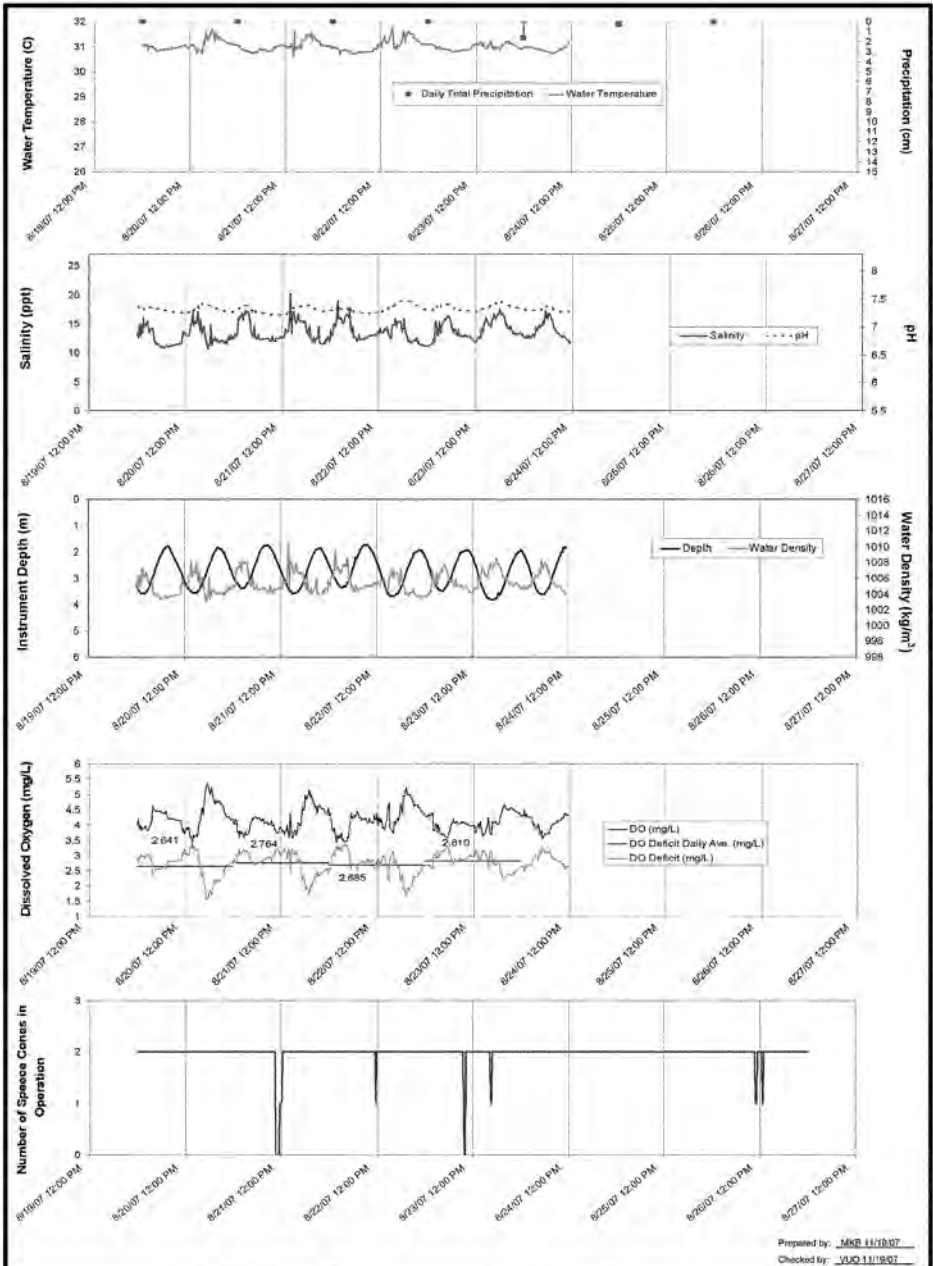
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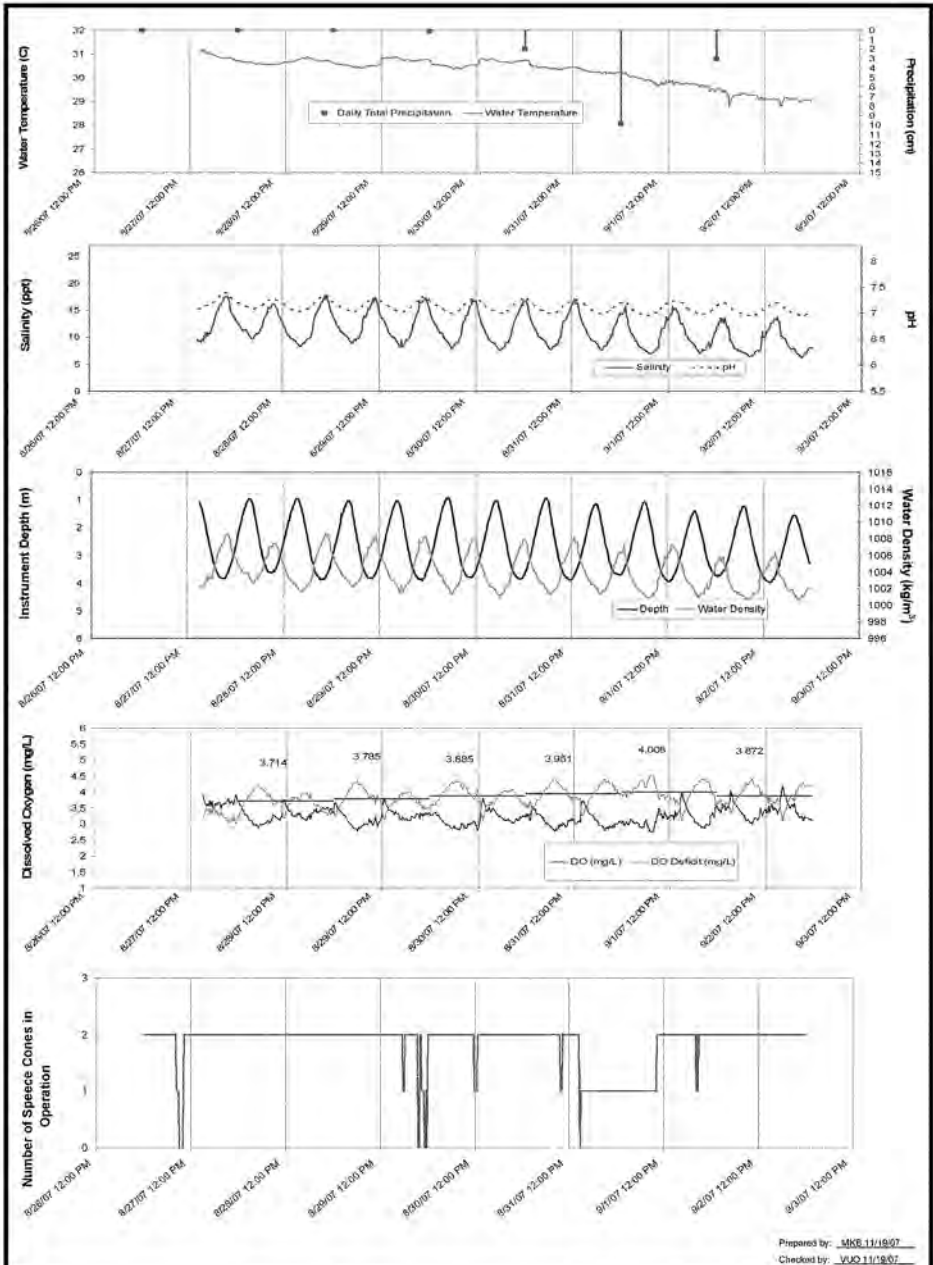
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SAVANNAH, GEORGIA

MACTEC

Continuous Monitoring Station
USACE Dock- Mid Zone
Aug 20 - 26, 2007

Project Number: 6110070004

Figure 4-2.3



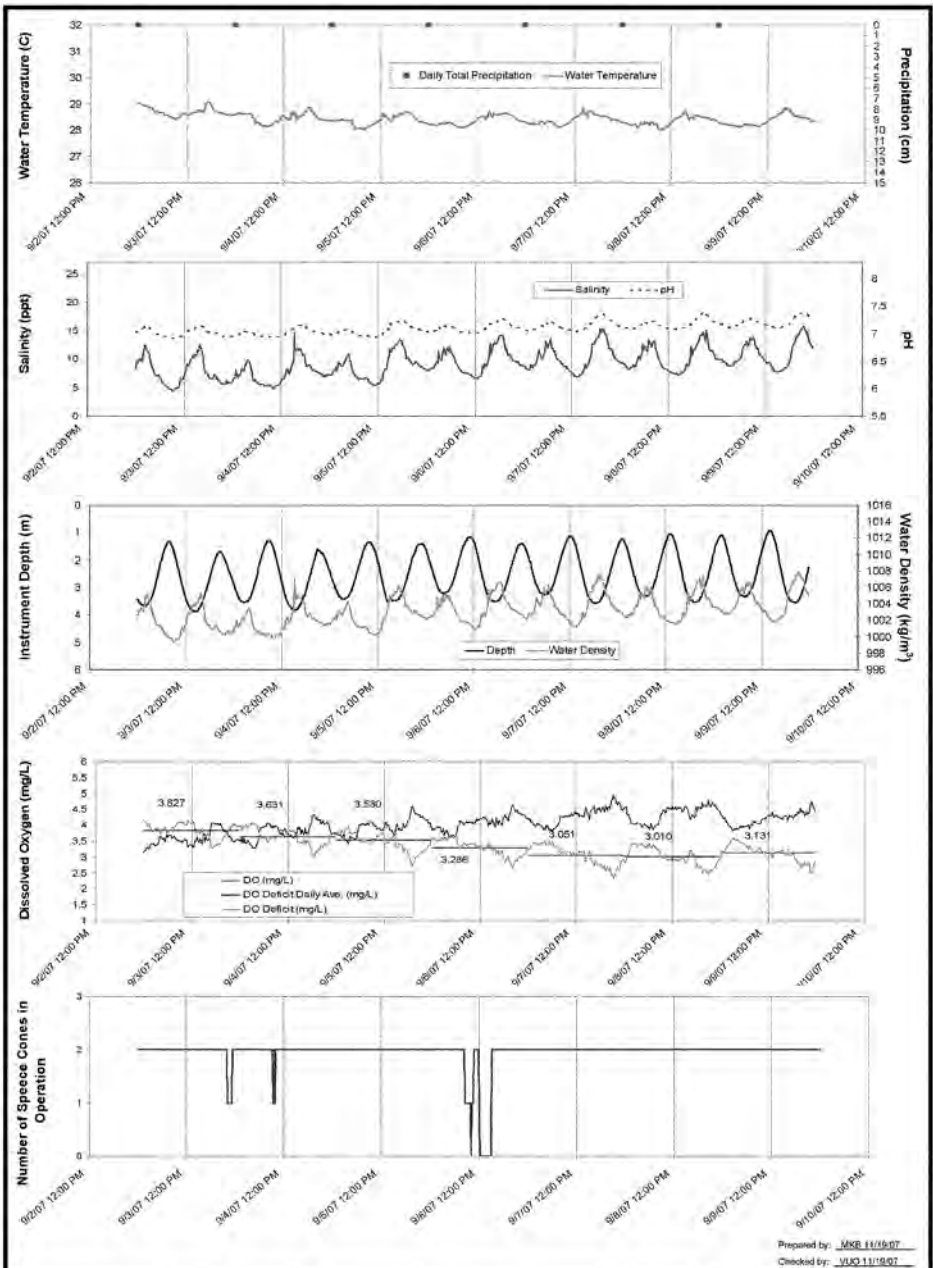
SAVANNAH HARBOR
 REOXYGENATION DEMONSTRATION
 PROJECT
 GEORGIA PORTS AUTHORITY
 SAVANNAH, GEORGIA



Continuous Monitoring Station
 USACE Dock-Mid Zone
 Aug 27 – Sep 2, 2007

Project Number: 6110070004

Figure 4-2.3



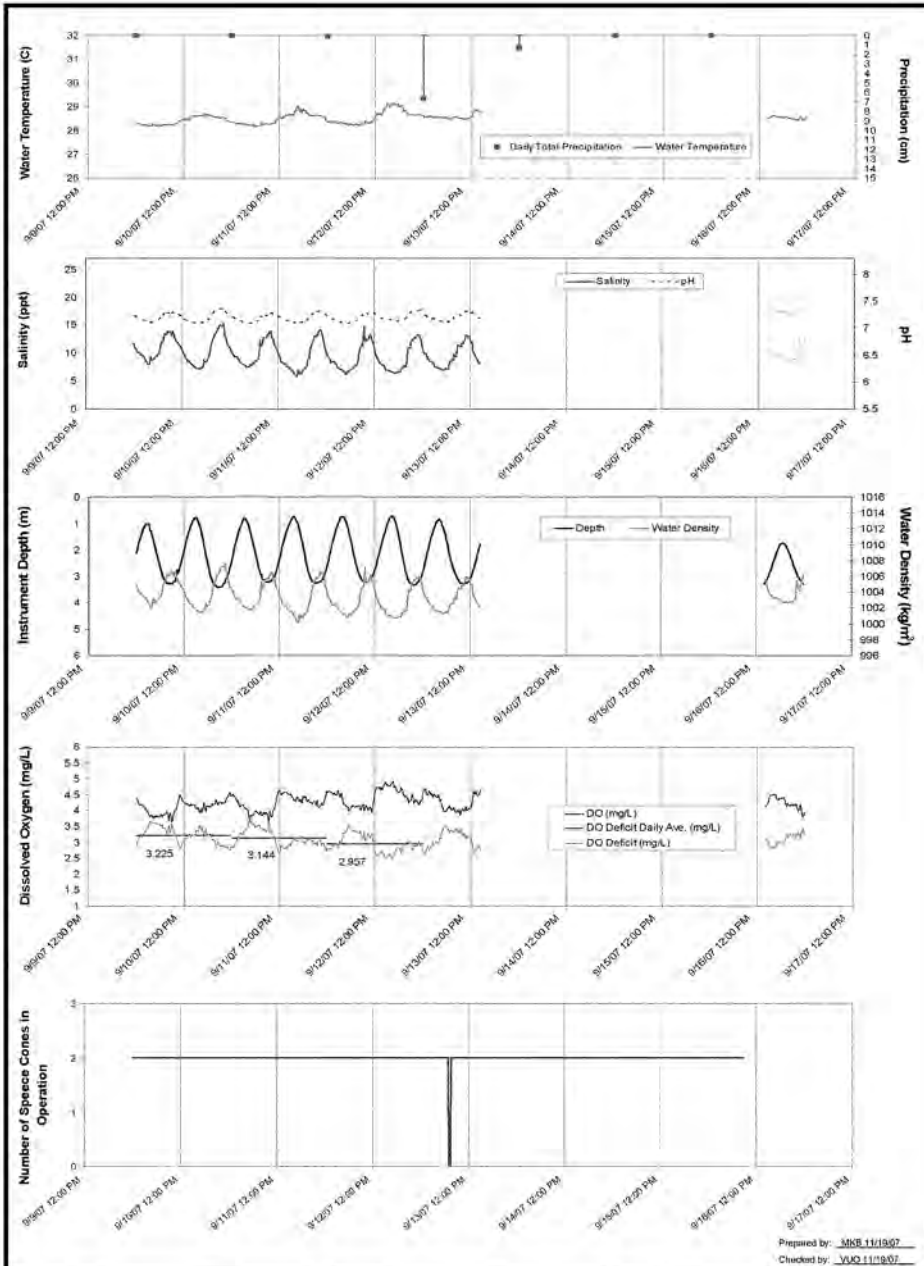
SAVANNAH HARBOR
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MACTEC

Continuous Monitoring Station
 USACE Dock- Mid Zone
 Sep 3 – Sep 9, 2007

Project Number: 6110070004

Figure 4-2.3



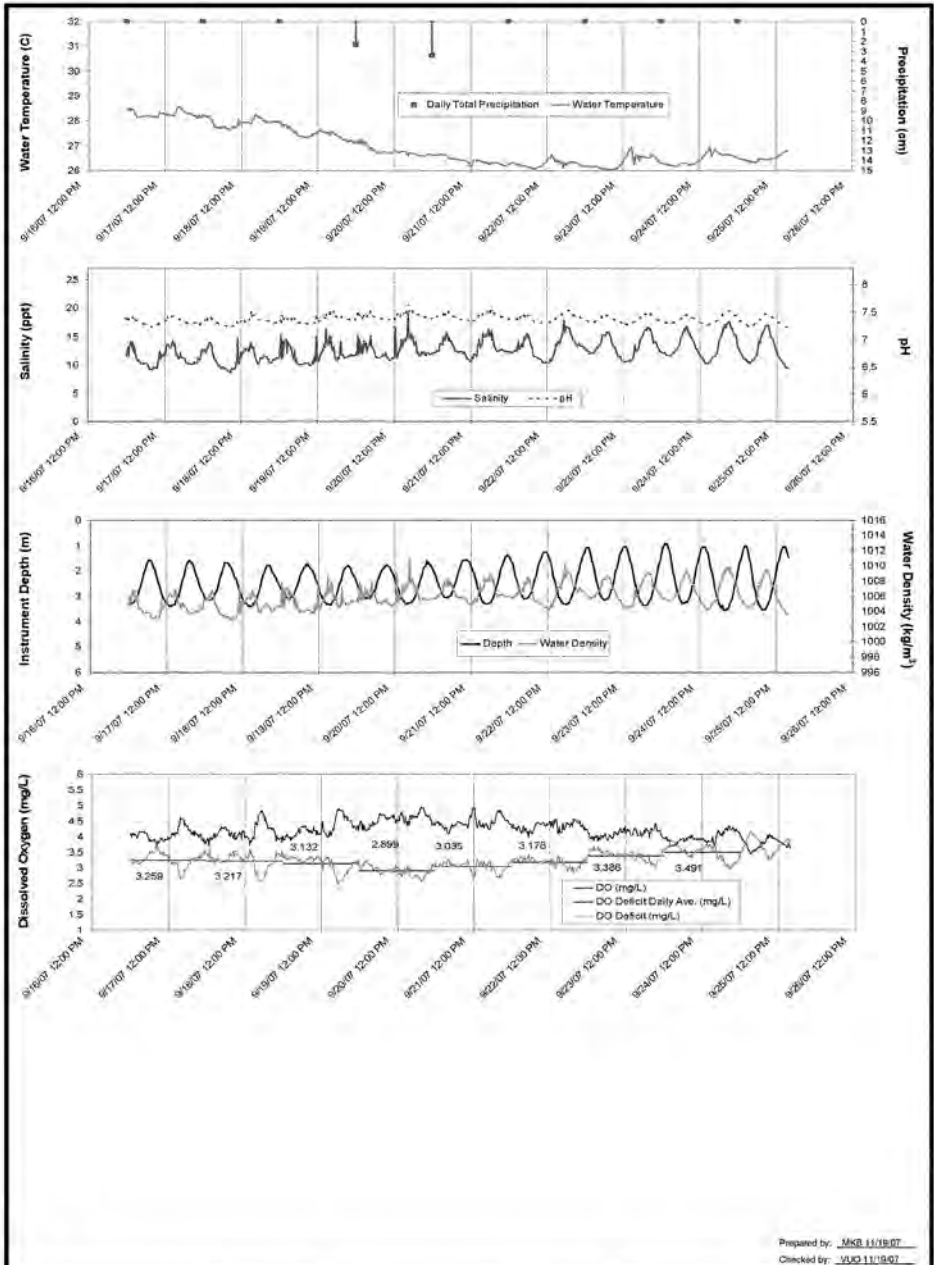
SAVANNAH HARBOR
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 GEORGIA PORTS AUTHORITY
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Continuous Monitoring Station
 USACE Dock- Mid Zone
 Sep 10 – Sep 16, 2007

Project Number: 0110070004

Figure 4-2.3



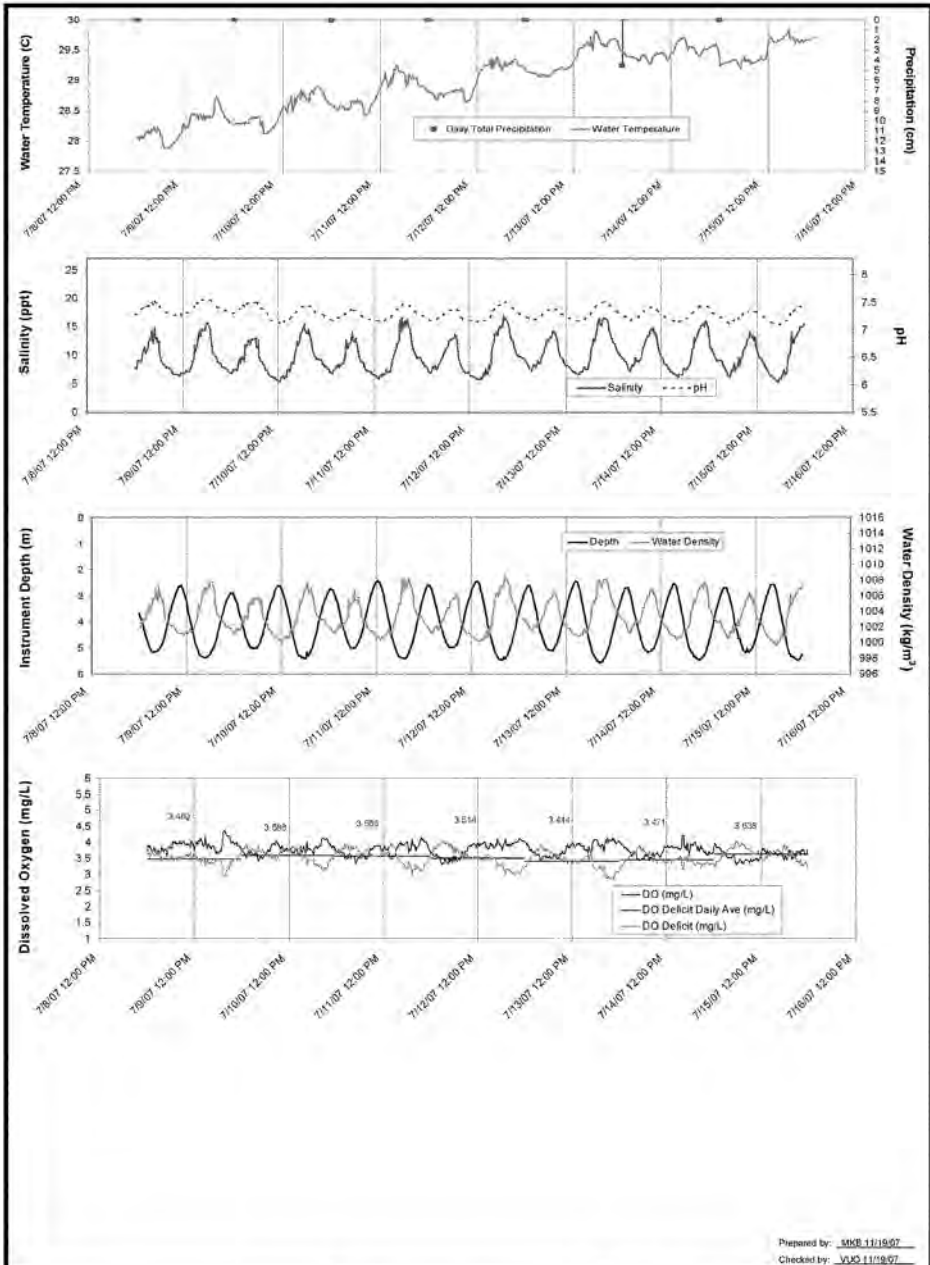
SAVANNAH HARBOR
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 PROJECT
 GEORGIA PORTS AUTHORITY
 SAVANNAH, GEORGIA



Continuous Monitoring Station
 USACE Dock - Mid Zone
 Sep 17 - Sep 25, 2007

Project Number: 6110070004

Figure 4-2.3



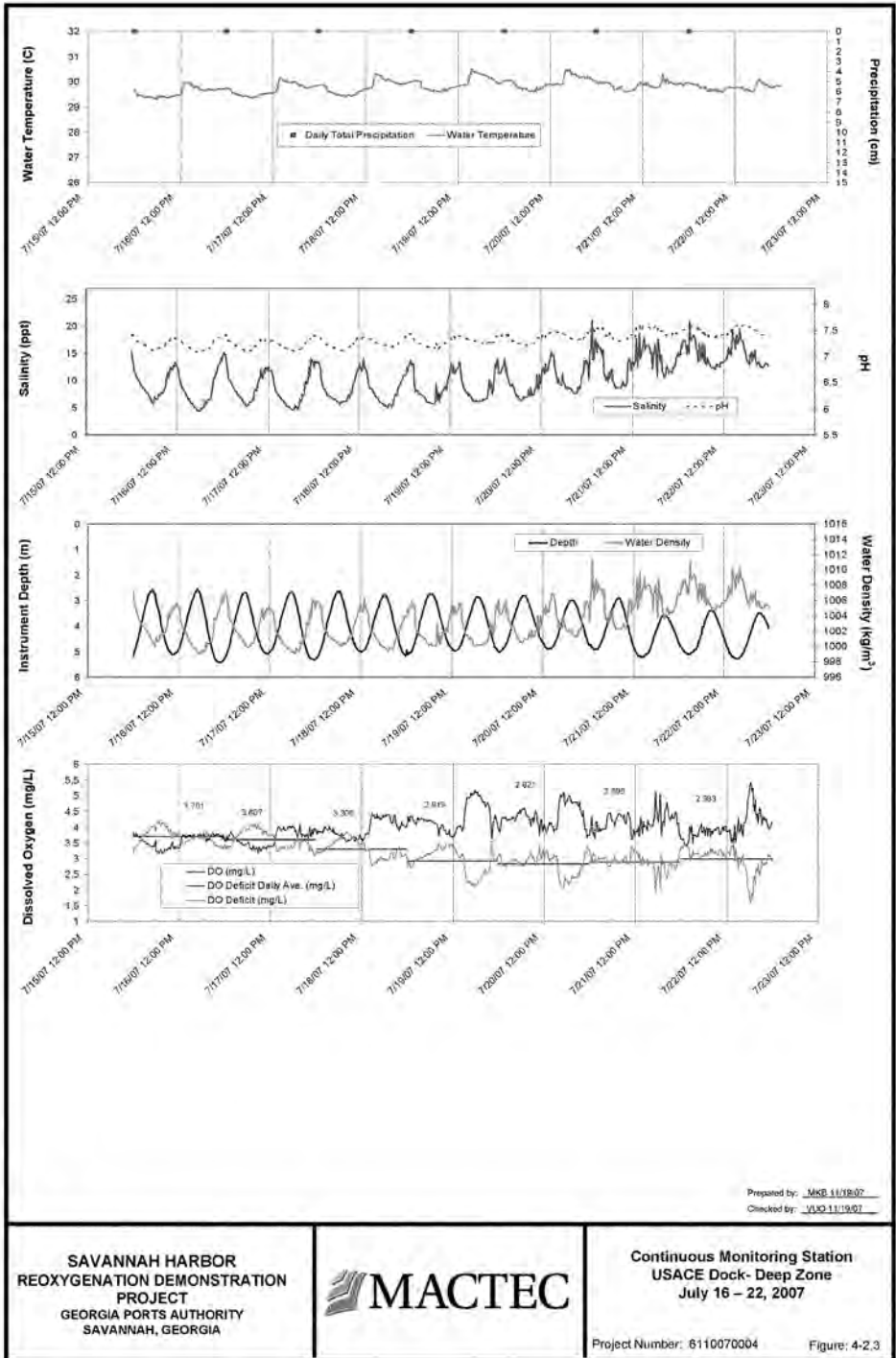
SAVANNAH HARBOR
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 PROJECT
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 SAVANNAH, GEORGIA

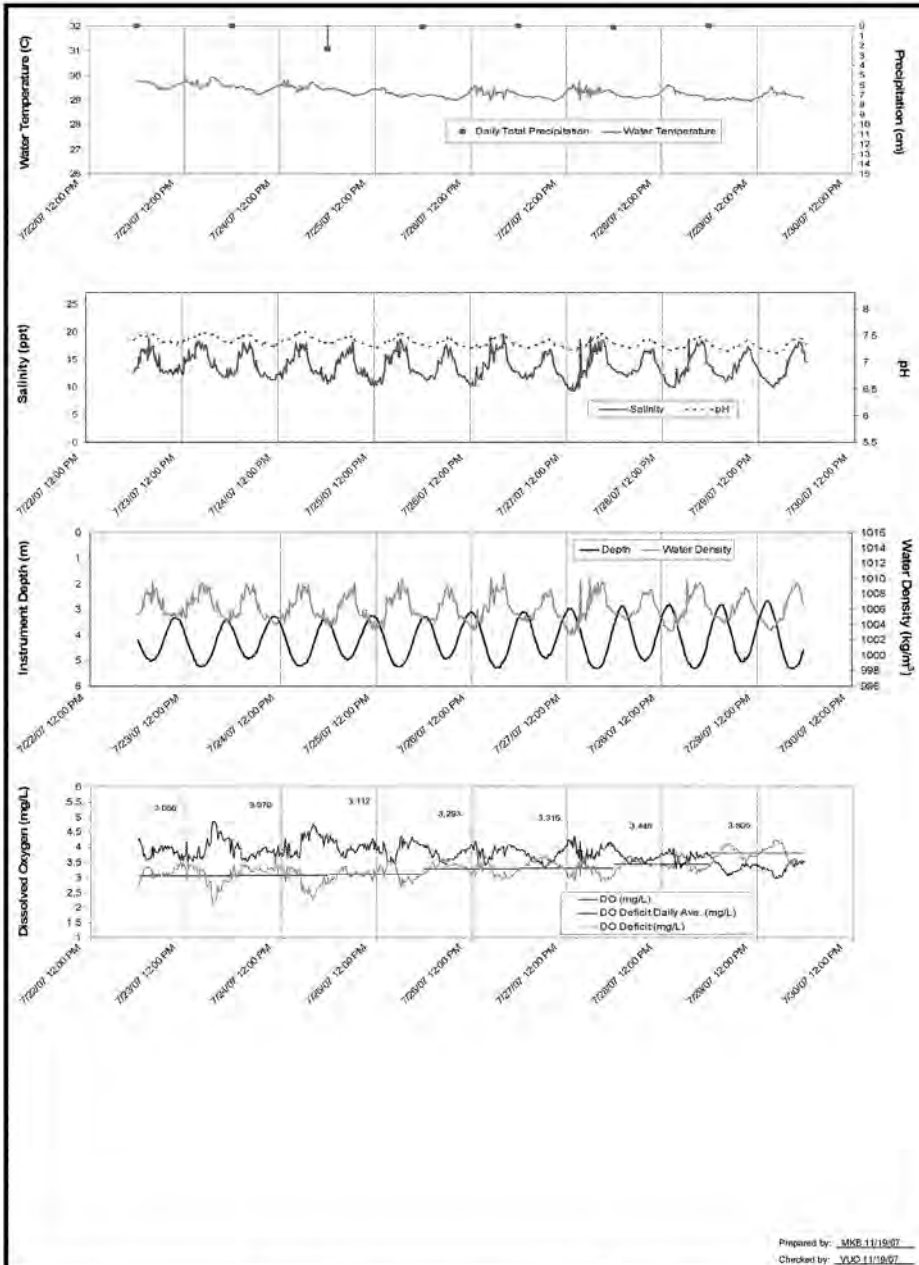


Continuous Monitoring Station
 USACE Dock- Deep Zone
 July 9 - 15, 2007

Project Number: 6110070004

Figure: 4-2.3





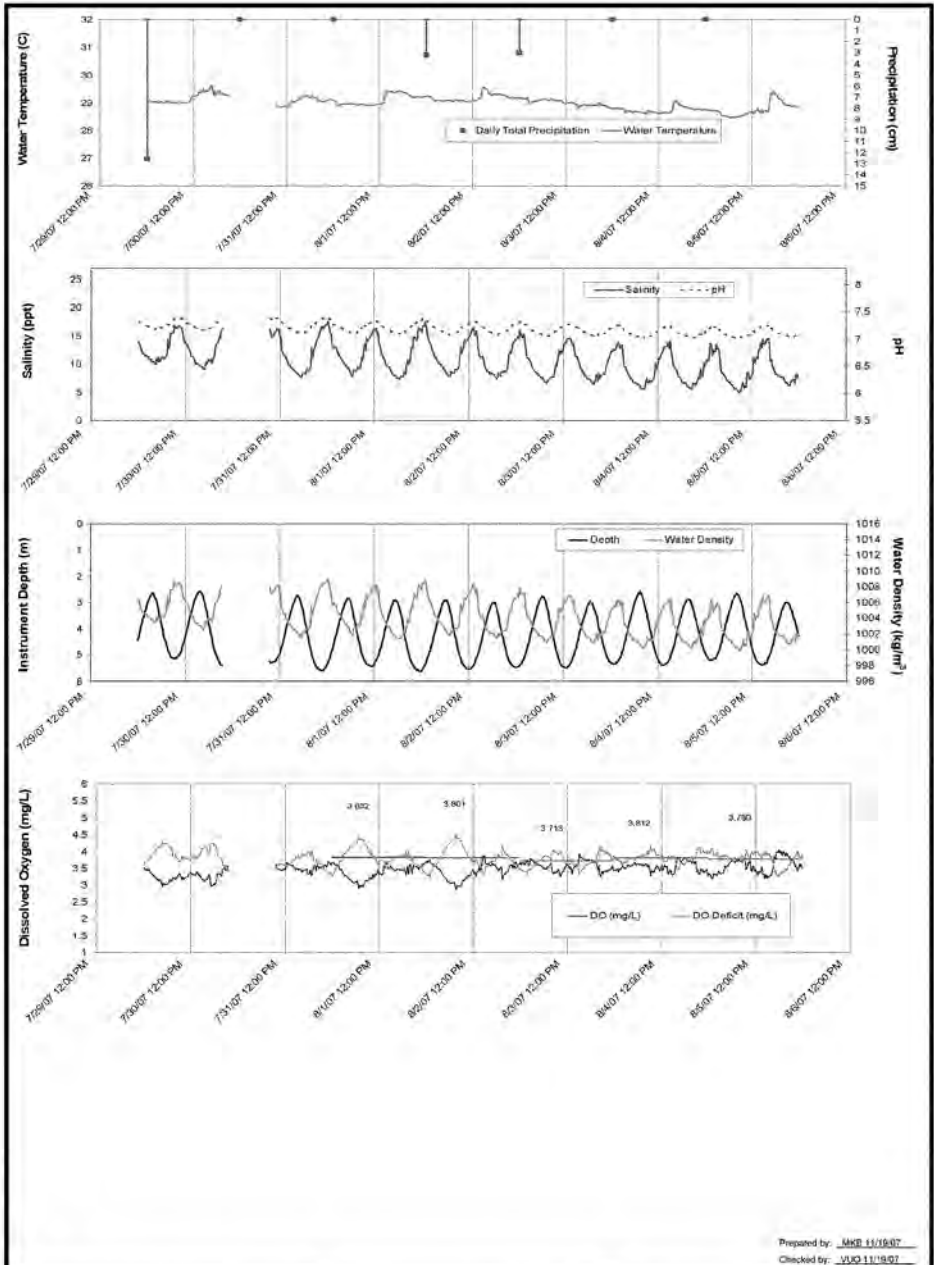
SAVANNAH HARBOR
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Continuous Monitoring Station
 USACE Dock- Deep Zone
 July 23 – 29, 2007

Project Number: 6110070004

Figure: 4-2.3



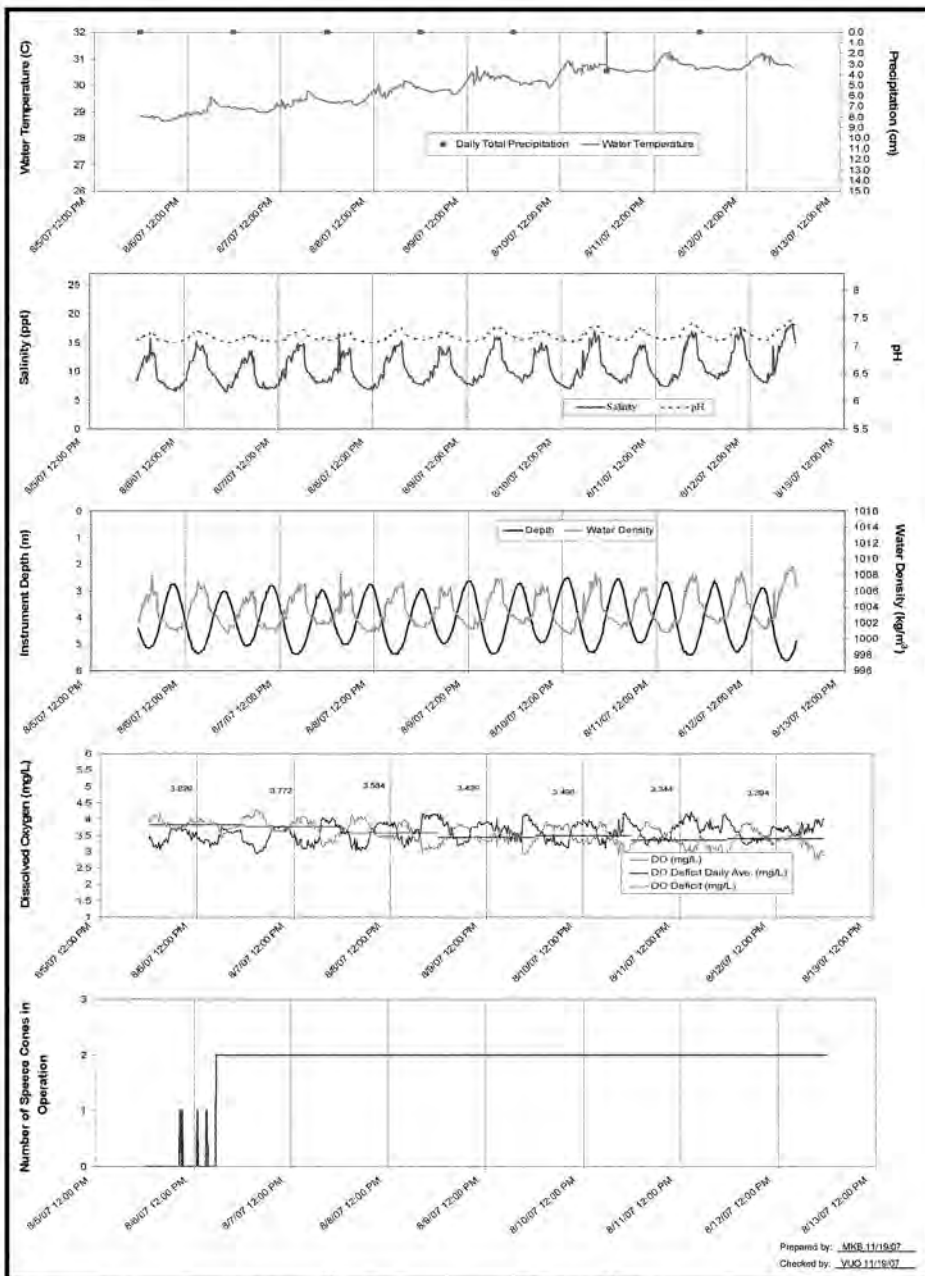
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Continuous Monitoring Station
 USACE Dock- Deep Zone
 July 30 – Aug 5, 2007

Project Number: 6110070004

Figure: 4-2.3

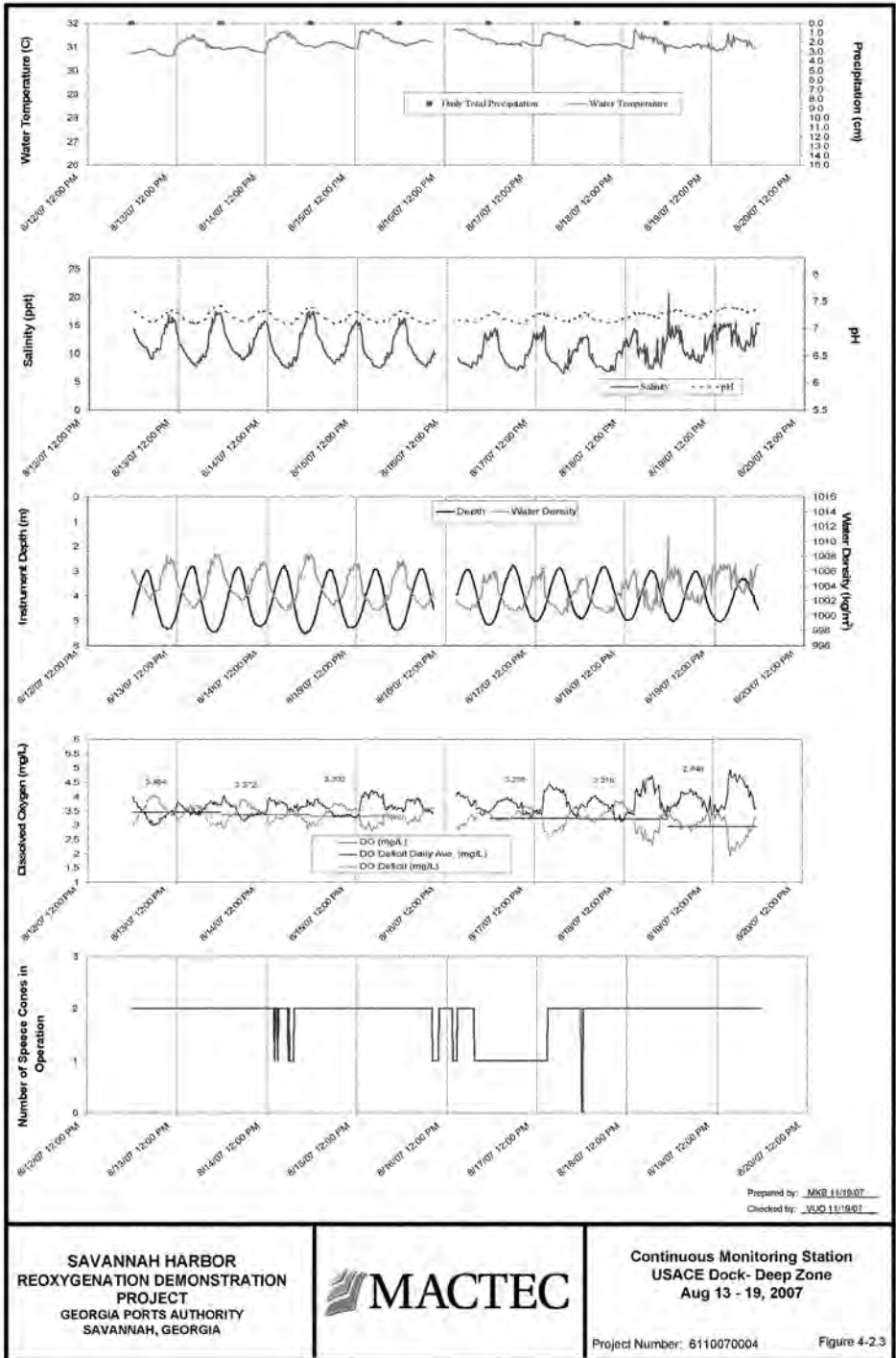


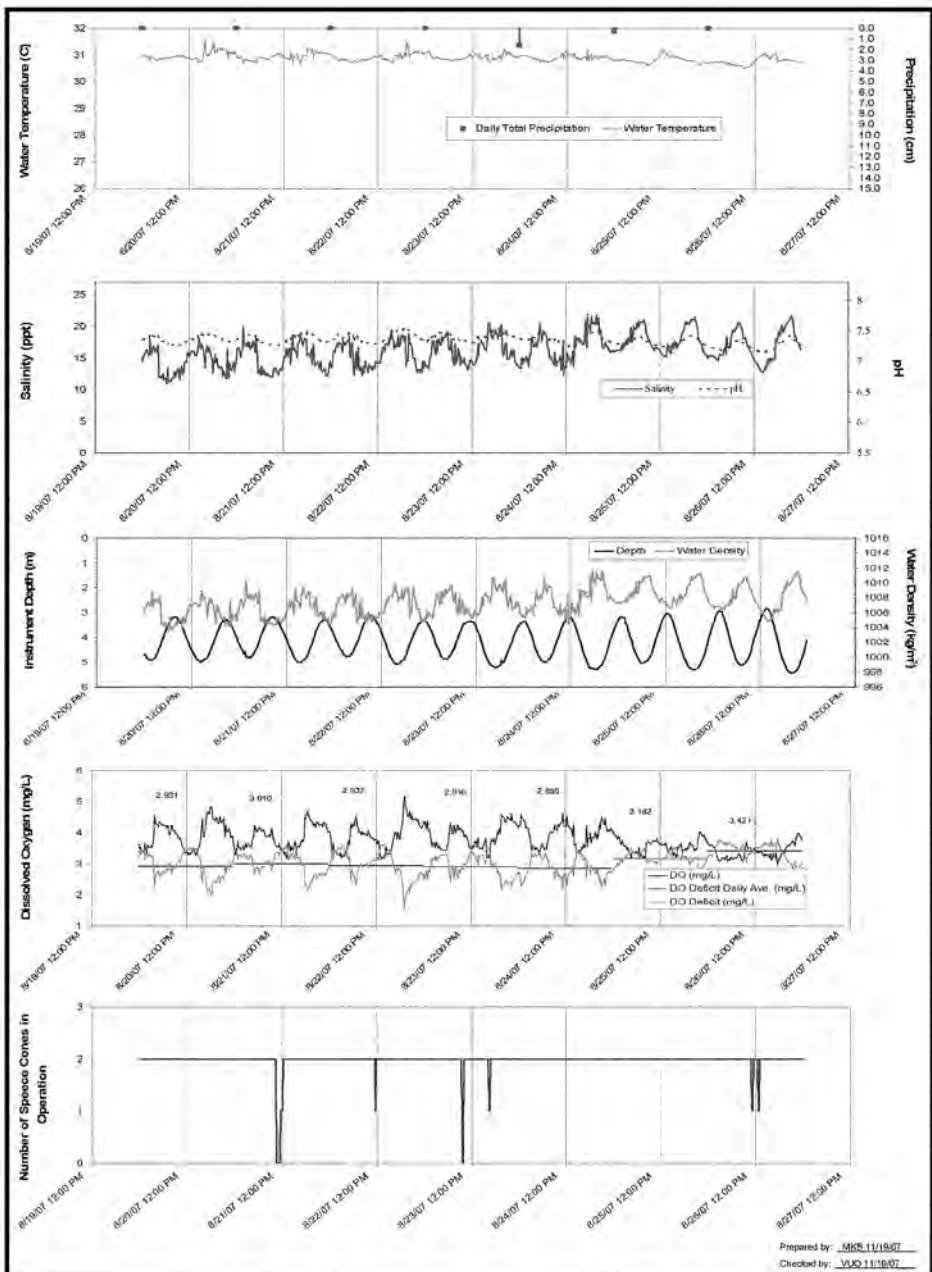
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GEORGIA PORTS AUTHORITY
SAVANNAH, GEORGIA

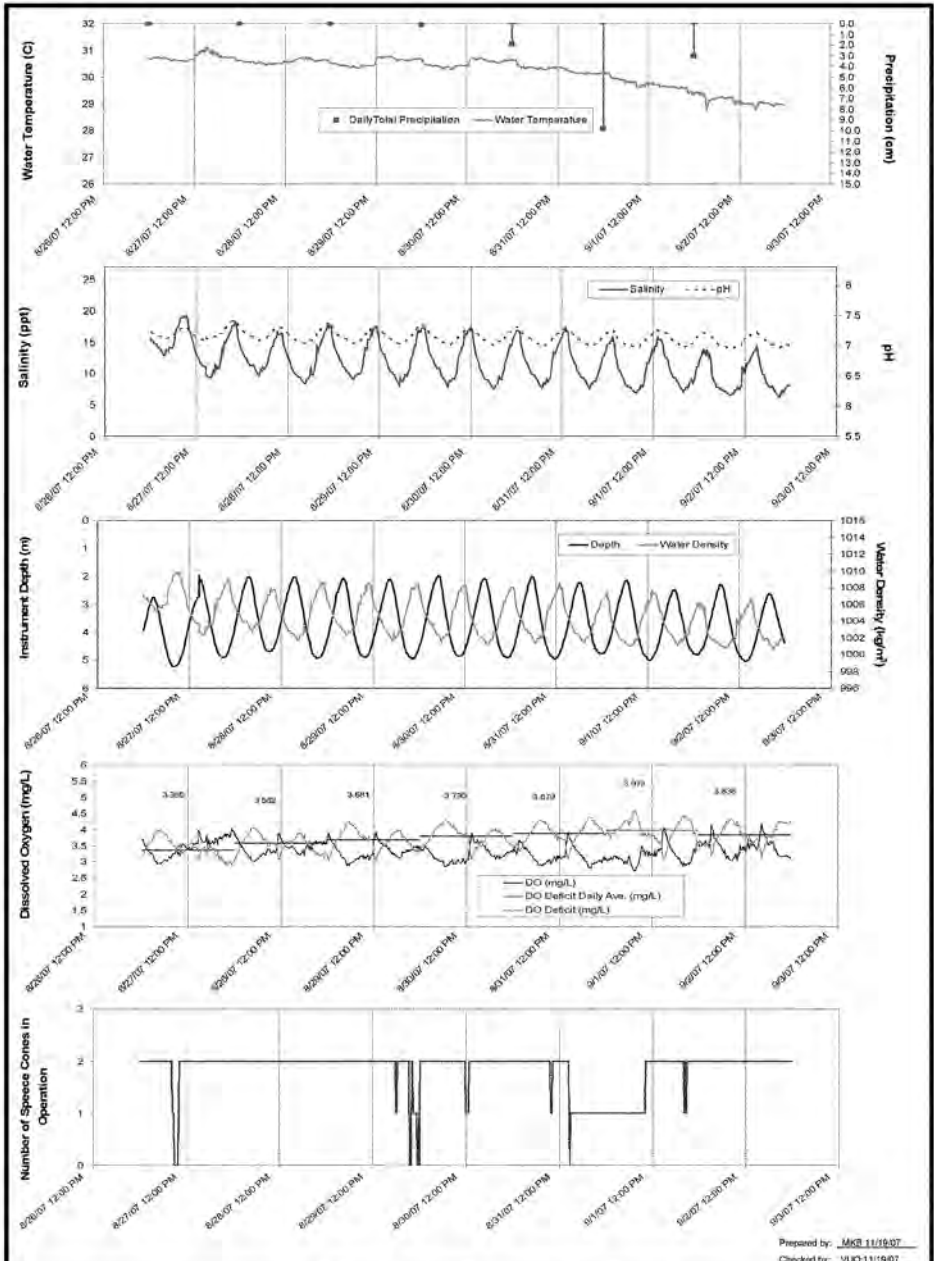


Continuous Monitoring Station
USACE Dock- Deep Zone
Aug 6 - 12, 2007

Project Number: 8110070004 Figure: 4-2.3







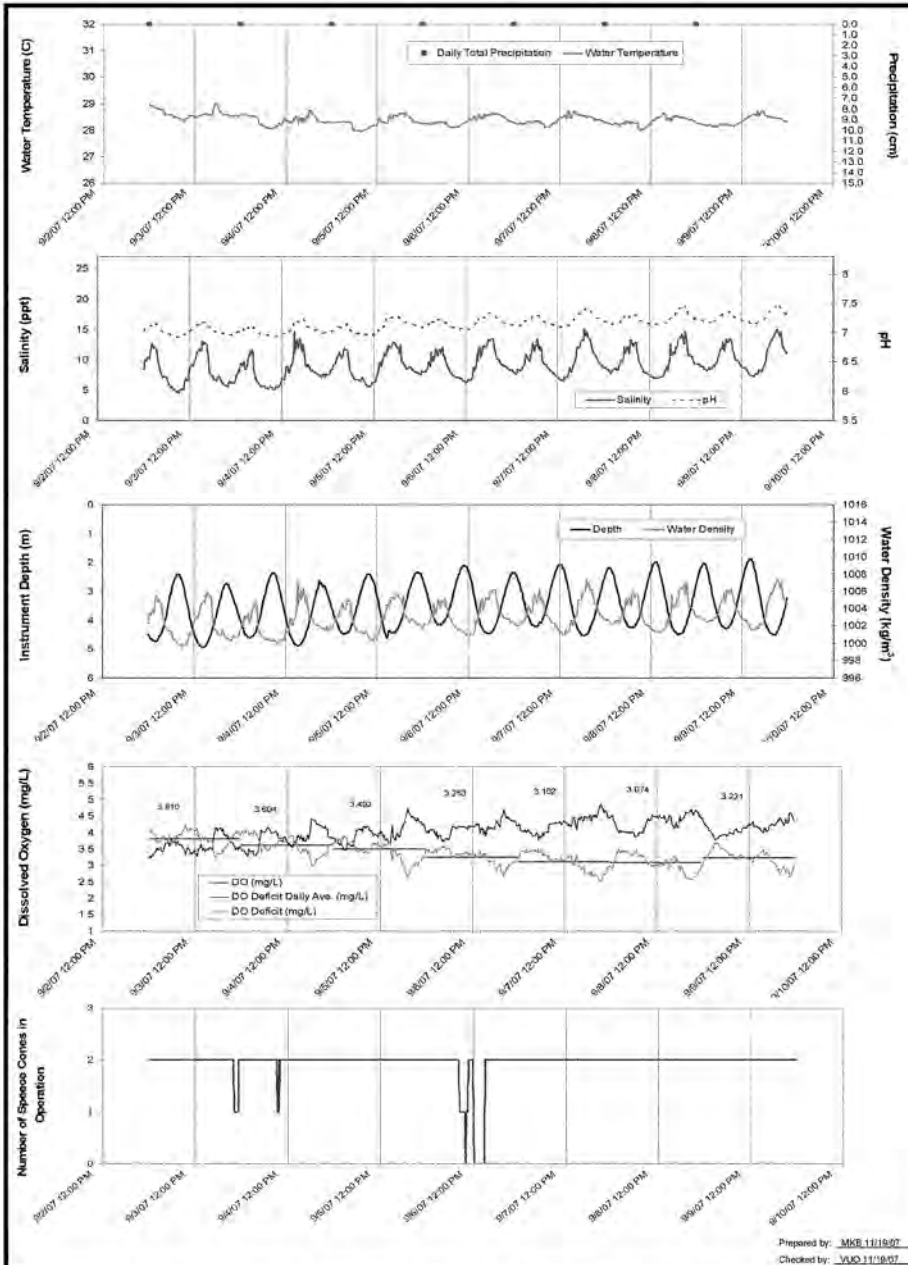
SAVANNAH HARBOR
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Continuous Monitoring Station
 USACE Dock- Deep Zone
 Aug 27 – Sep 2, 2007

Project Number: 6110070004

Figure 4-2.3



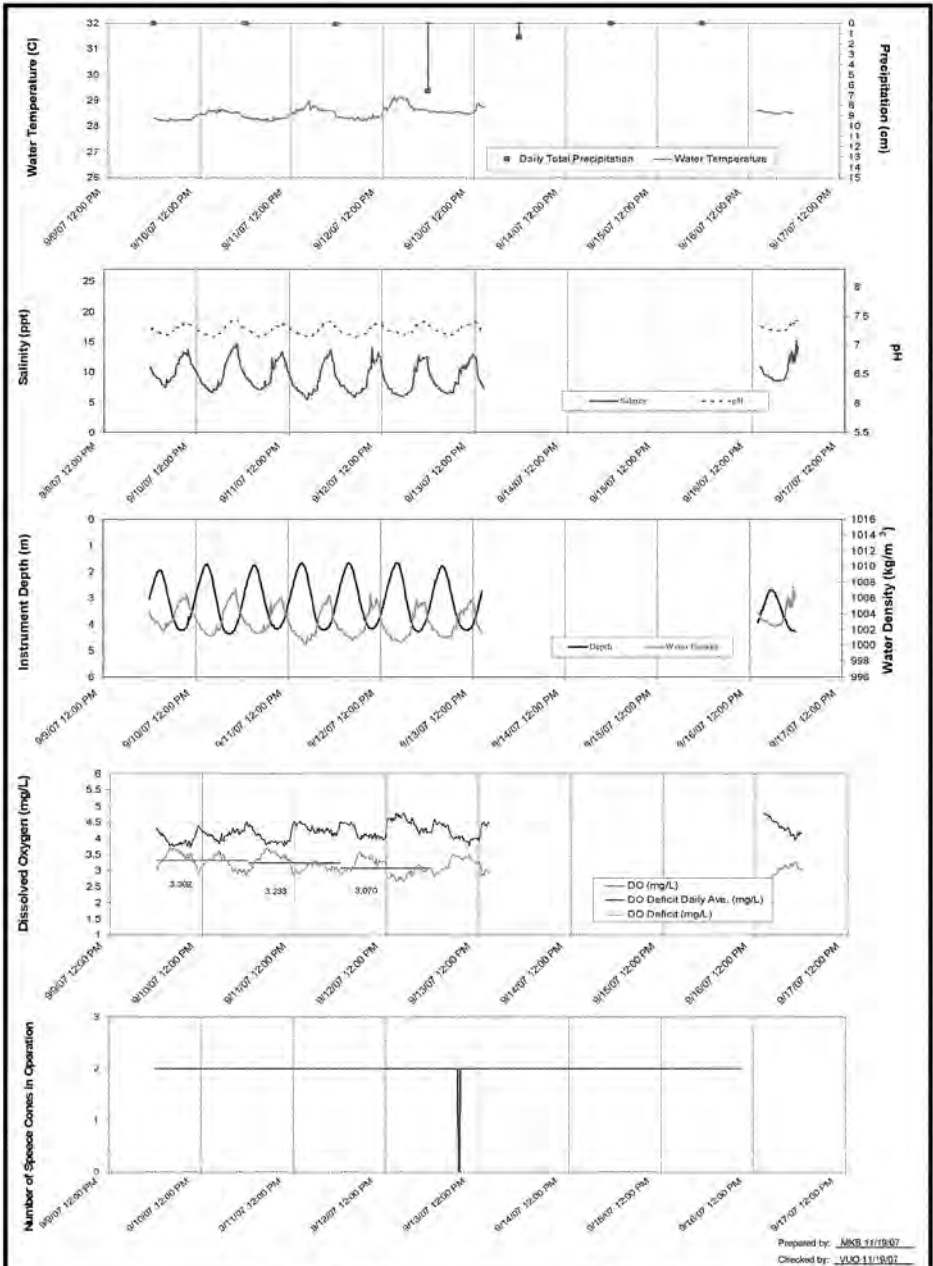
SAVANNAH HARBOR
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Continuous Monitoring Station
 USACE Dock- Deep Zone
 Sep 3 – 9, 2007

Project Number: 6110070004

Figure 4-2.3



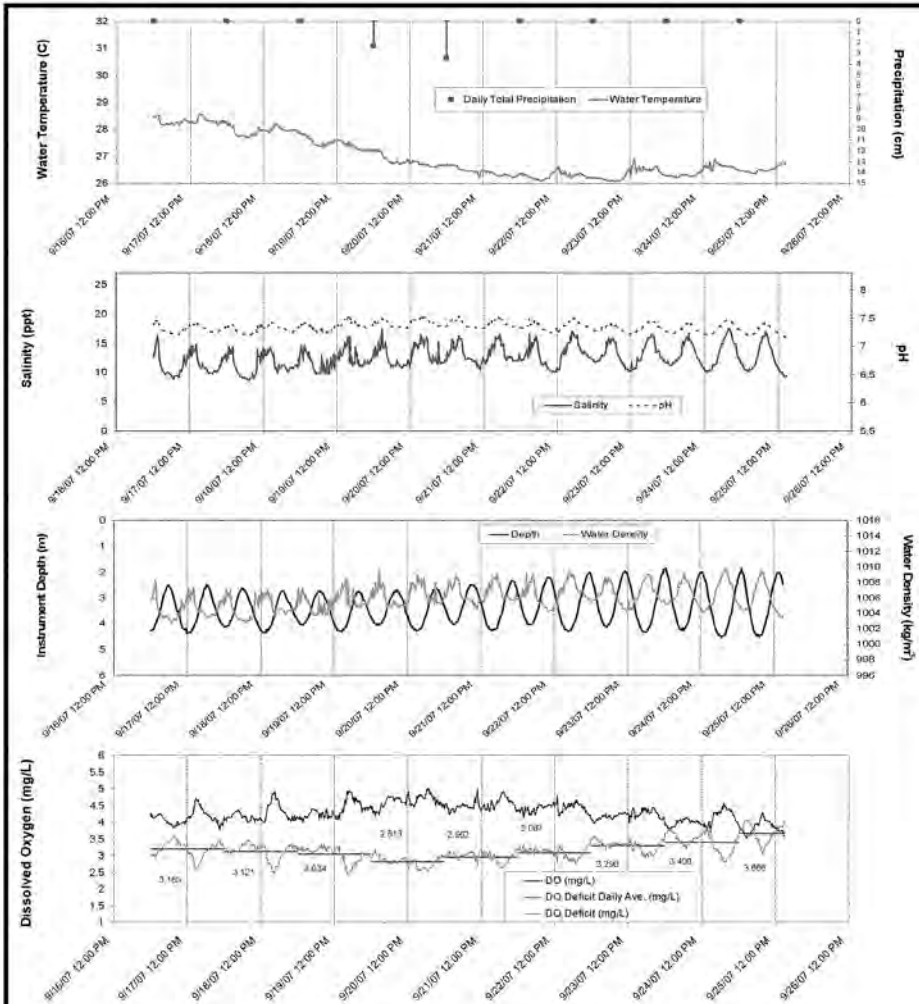
SAVANNAH HARBOR
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Continuous Monitoring Station
 USACE Dock-Deep Zone
 Sep 10 - 16, 2007

Project Number: 6110070004

Figure 4-2.3



Prepared by: MRB 11/19/07
 Checked by: VJD 11/19/07

SAVANNAH HARBOR
 REOXYGENATION DEMONSTRATION
 PROJECT
 GEORGIA PORTS AUTHORITY
 SAVANNAH, GEORGIA



Continuous Monitoring Station
 USACE Dock- Deep Zone
 Sep 17 - 25, 2007

Project Number: 6110070004

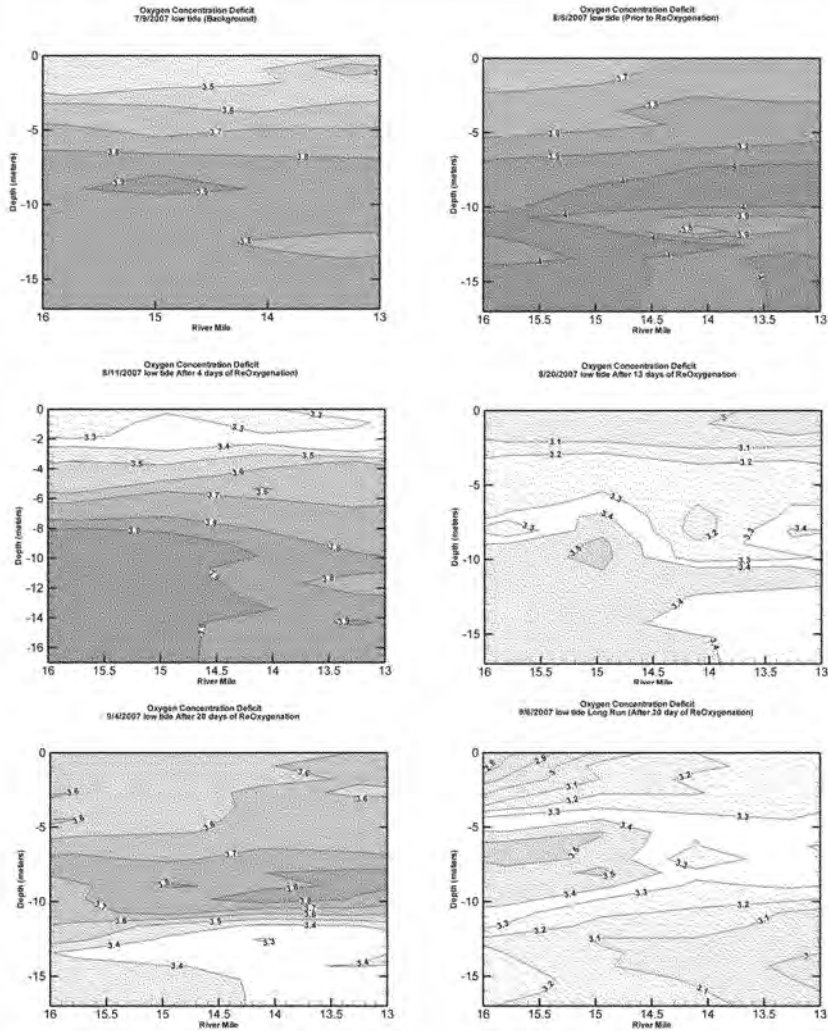
Figure 4-2.3



SAVANNAH HARBOR
REOXYGENATION DEMONSTRATION PROJECT
GEORGIA PORTS AUTHORITY
SAVANNAH, GEORGIA

Mid-Channel Monitoring Locations

Project Number: 811070004	Prepared by: Date: THP-10/26/07	Checked by: Date: TRK-10/26/07	Figure Number: 4-3
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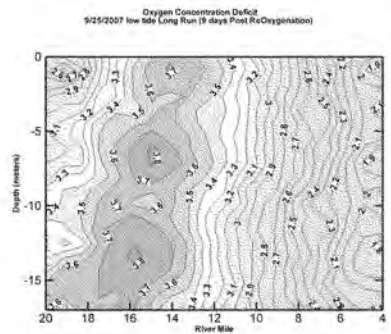
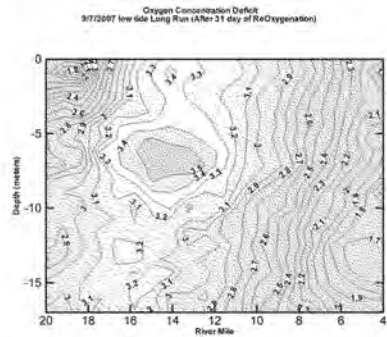
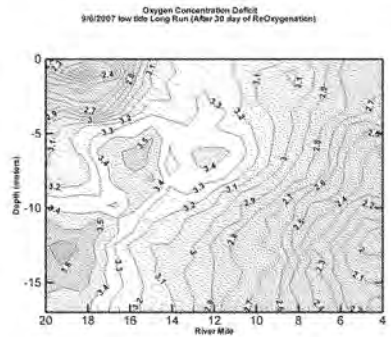
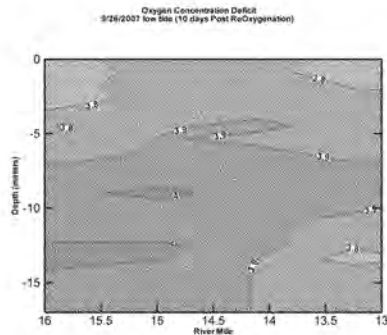
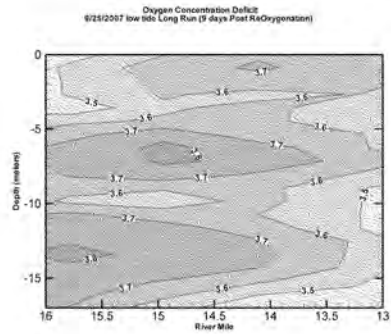
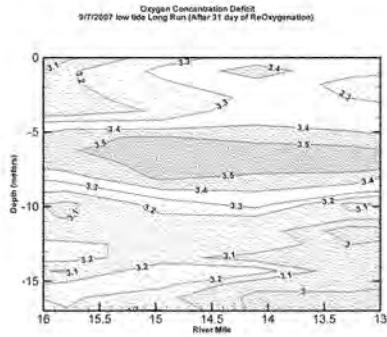
Prepared by: NTG 11/16/07
 Checked by: JTP 11/16/07

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Mid-channel
 DO Deficit (mg/L)
 Low Tide Event

Project Number: 6110070004 Figure-4-3.1 a



Prepared by: NTG 11/16/07

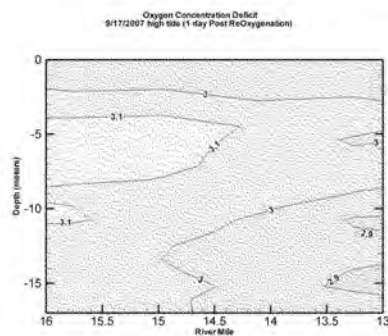
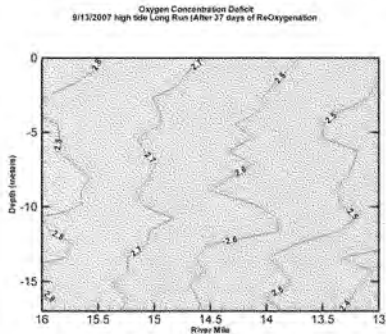
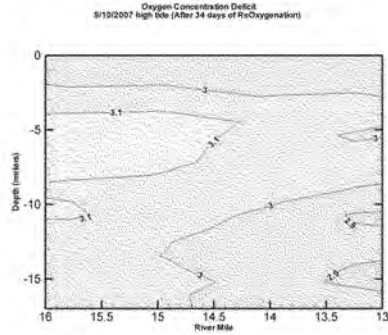
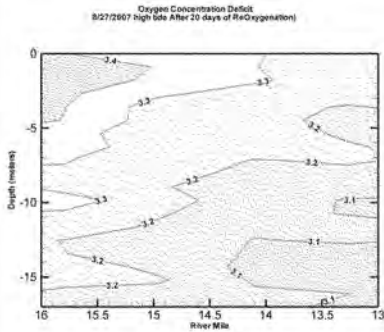
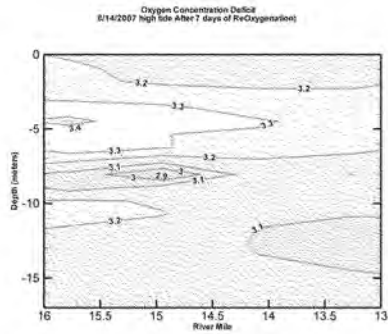
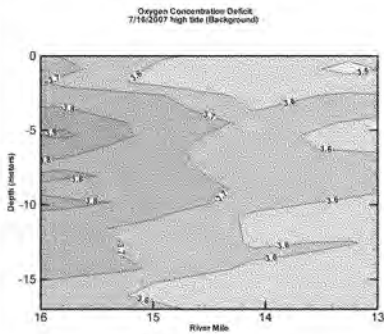
Checked by: JTP 11/16/07

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SAVANNAH, GEORGIA

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Mid-channel
DO Deficit (mg/L)
Low Tide Event

Project Number: 6110070004 Figure:4-3.1 b



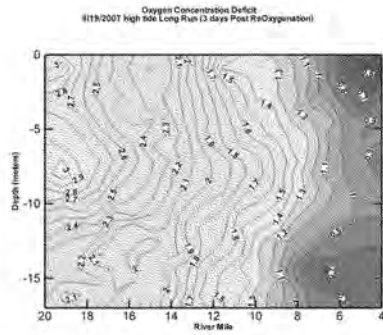
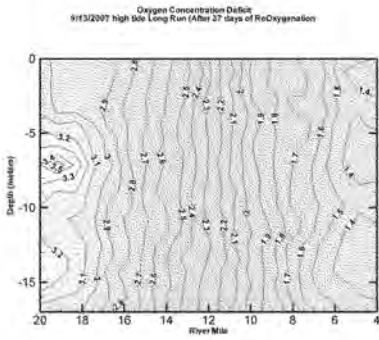
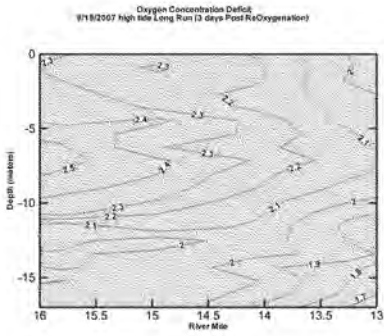
Prepared by: NTG 11/16/07
Checked by: JTP 11/16/07

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SAVANNAH, GEORGIA

 **MACTEC**

Mid-channel
DO Deficit (mg/L)
High Tide Event

Project Number: 6110070004 Figure: 4-3.1 c



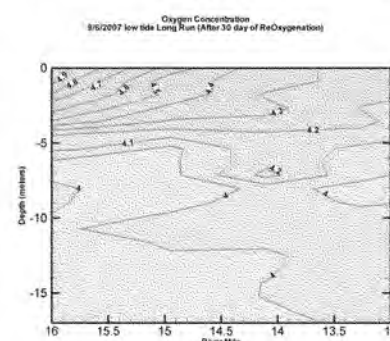
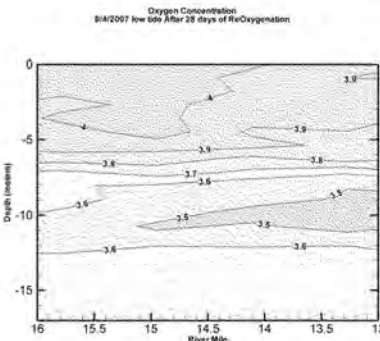
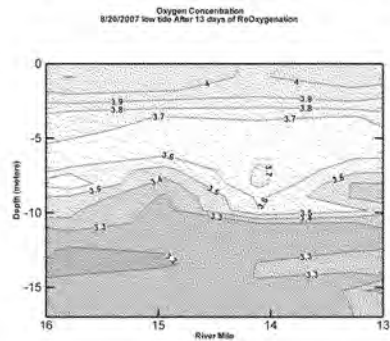
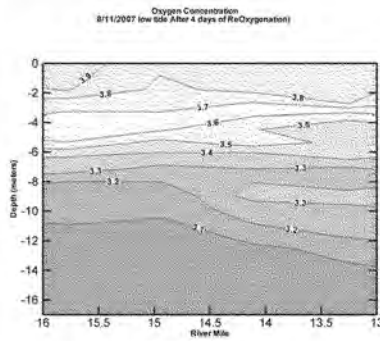
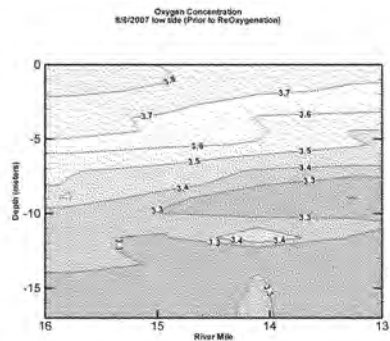
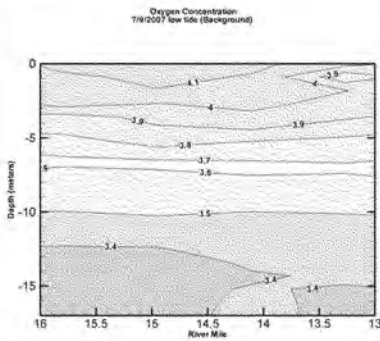
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 SAVANNAH, GEORGIA

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Mid-channel
 DO Deficit (mg/L)
 High Tide Event

Project Number: 6110070004 Figure: 4-3.1 d



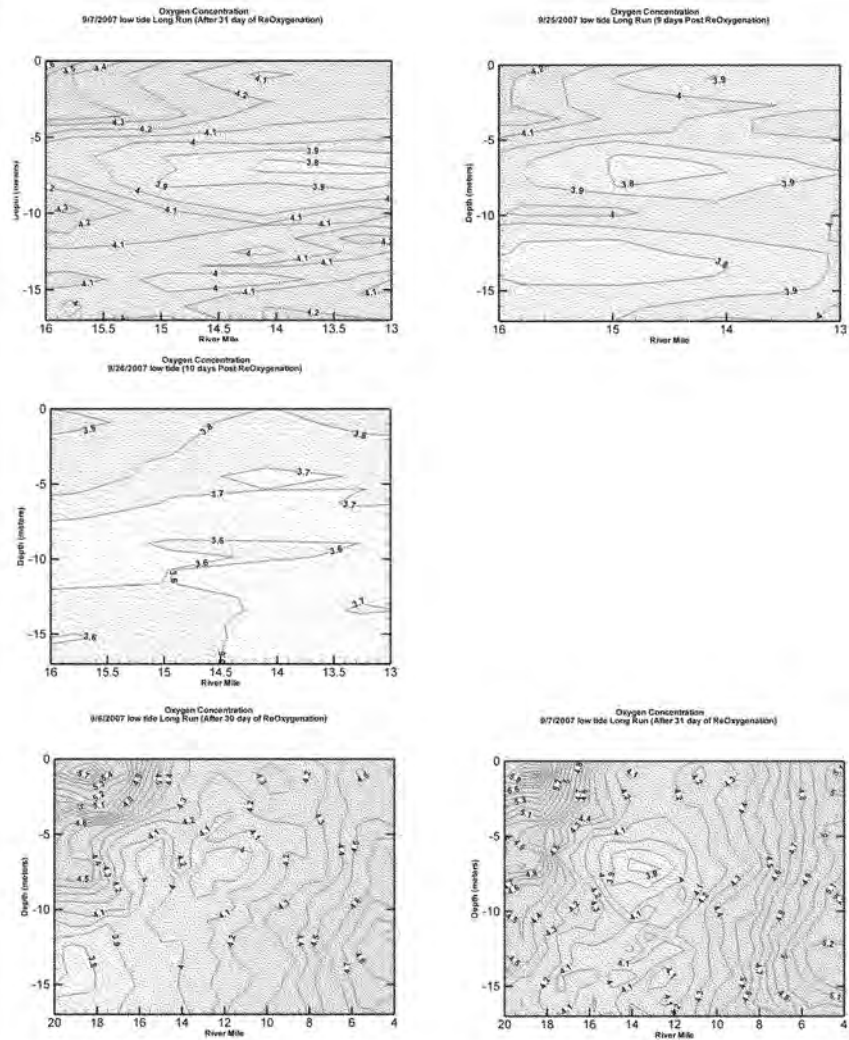
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Mid-channel
DO Concentration (mg/L)
Low Tide Event

Project Number: 6110070004 Figure-4-3.1 e



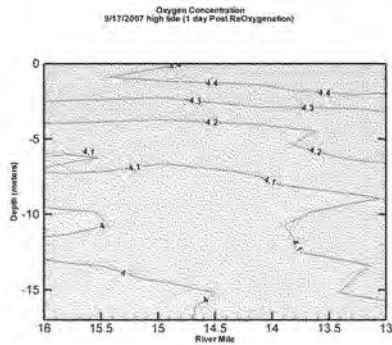
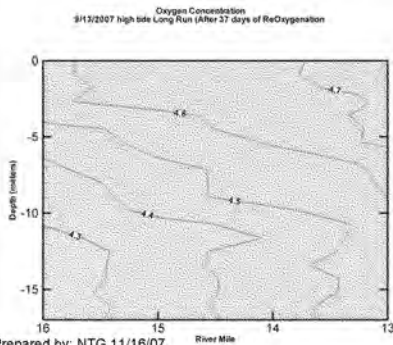
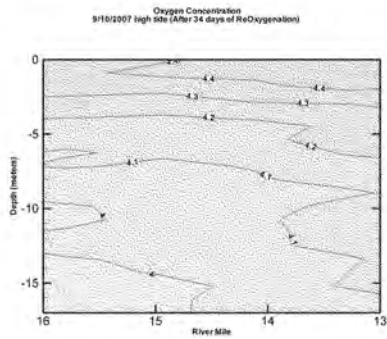
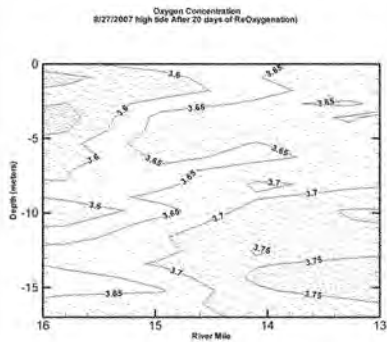
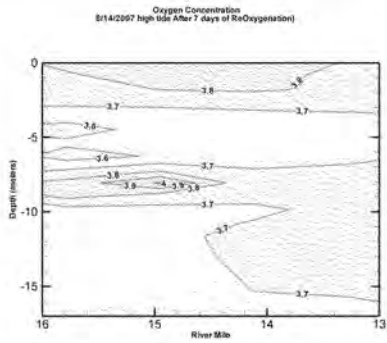
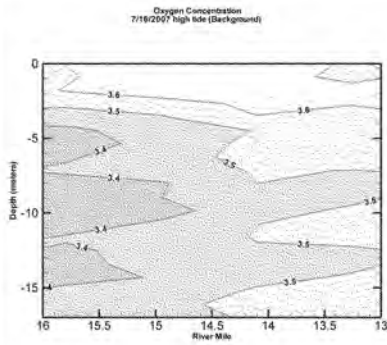
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 SAVANNAH, GEORGIA

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Mid-channel
 DO Concentration (mg/L)
 Low Tide Event

Project Number: 6110070004 Figure:4-3.1 f



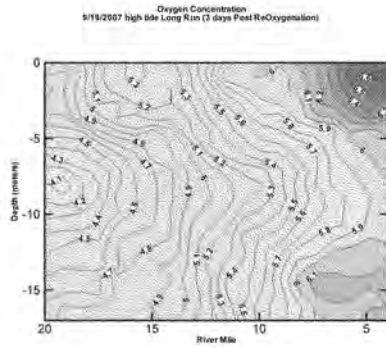
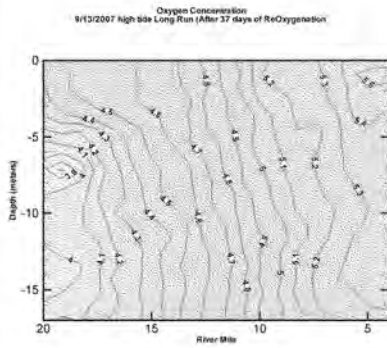
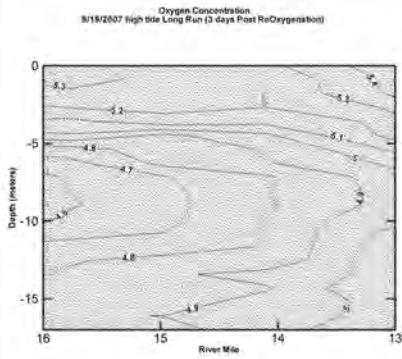
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REOXYGENATION DEMONSTRATION
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SAVANNAH, GEORGIA

MACTEC

Mid-channel
DO Concentration (mg/L)
High Tide Event

Project Number: 6110070004 Figure-4.3.1 g



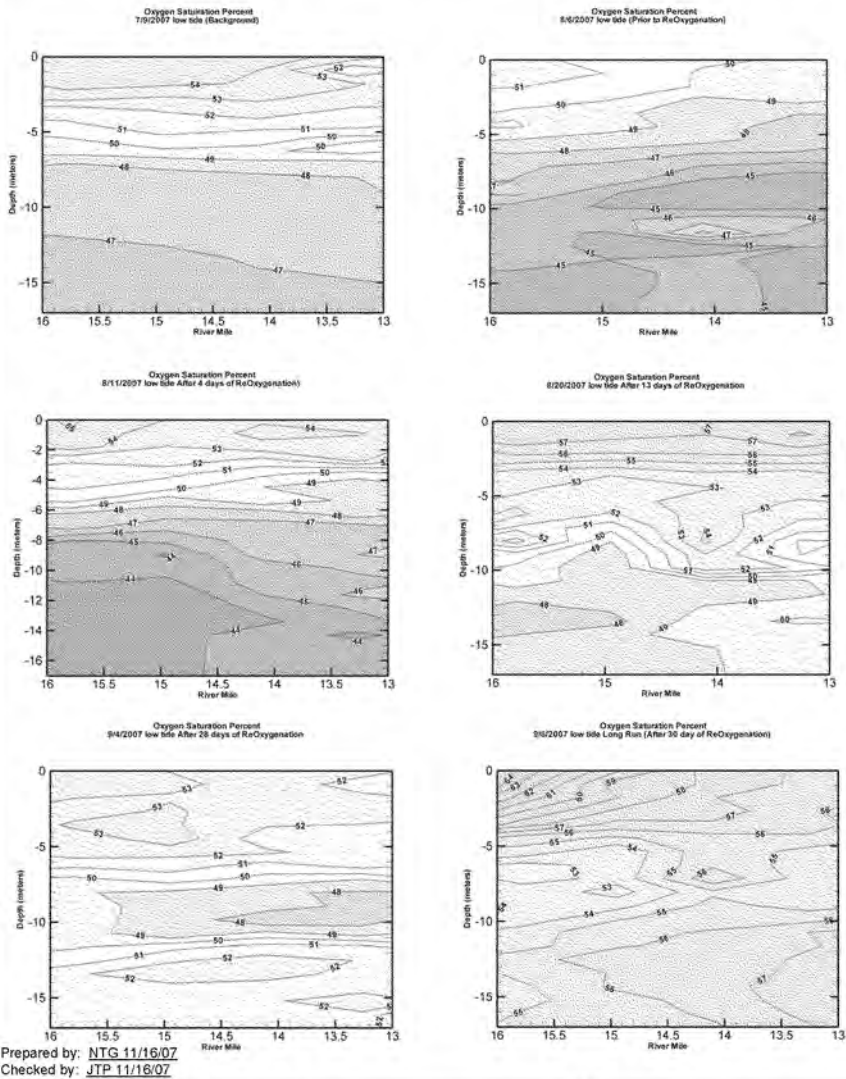
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SAVANNAH, GEORGIA

MACTEC

Mid-channel
DO Concentration (mg/L)
High Tide Event

Project Number: 6110070004 Figure:4-3.1 h

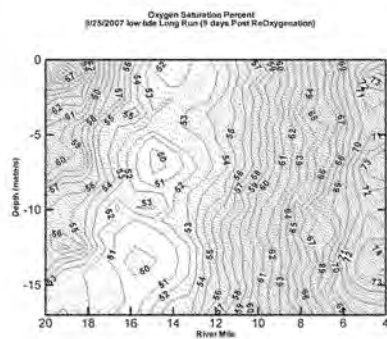
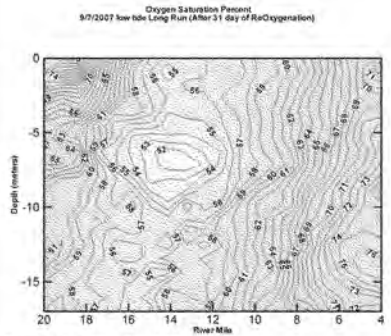
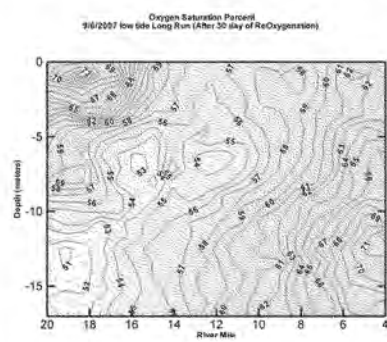
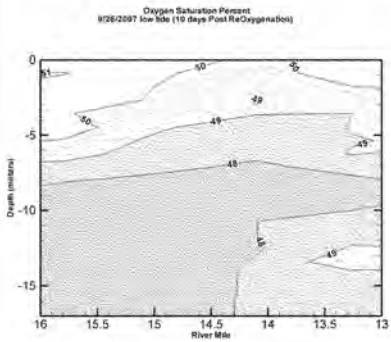
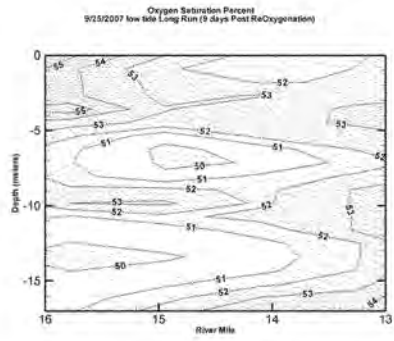
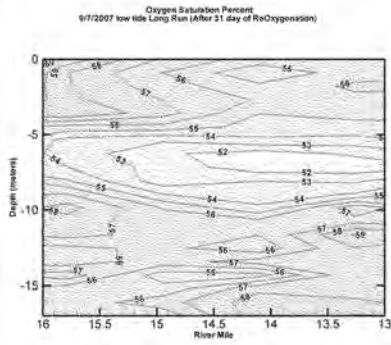


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SAVANNAH, GEORGIA

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Mid-channel
DO Percent Saturation (%)
Low Tide Event

Project Number: 6110070004 Figure: 4-3.1 i



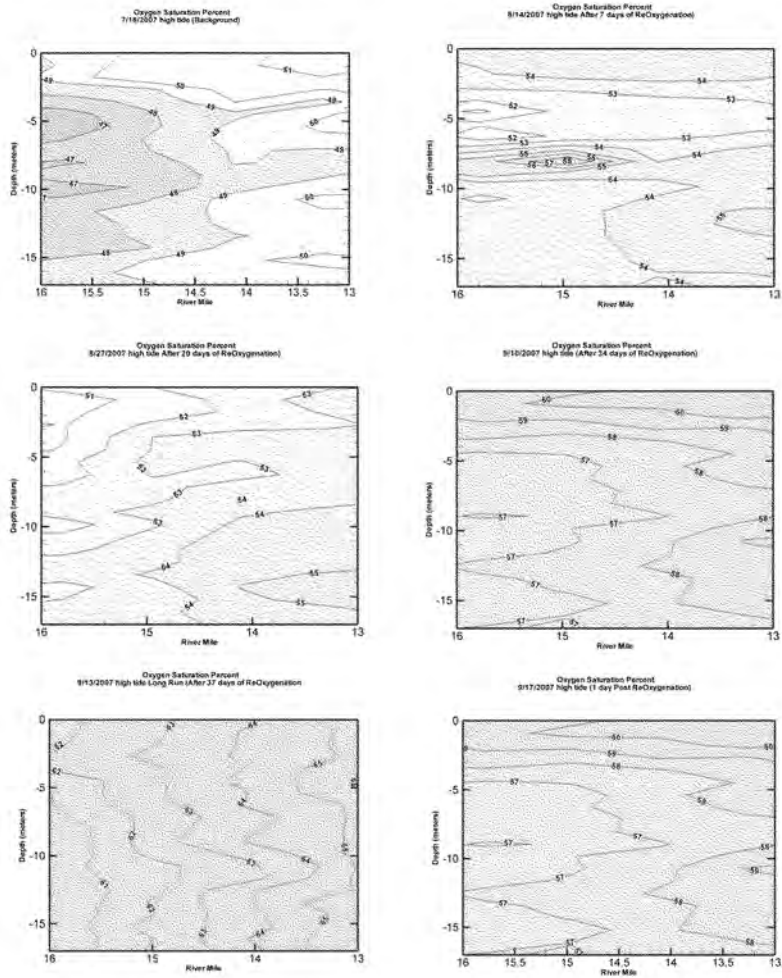
Prepared by: NTG 11/16/07
Checked by: JTP 11/16/07

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REOXYGENATION DEMONSTRATION
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SAVANNAH, GEORGIA

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Mid-channel
DO Percent Saturation (%)
Low Tide Event

Project Number: 6110070004 Figure:4-3.1 j



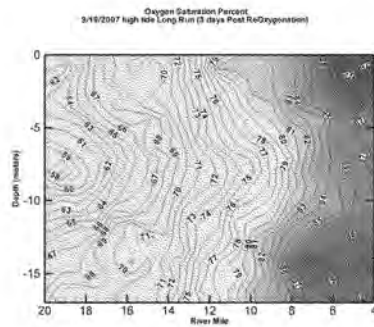
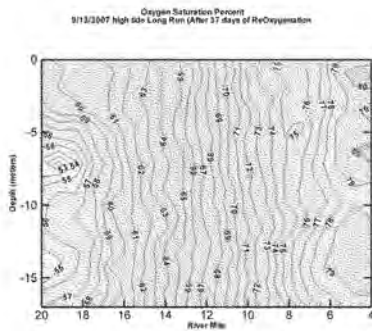
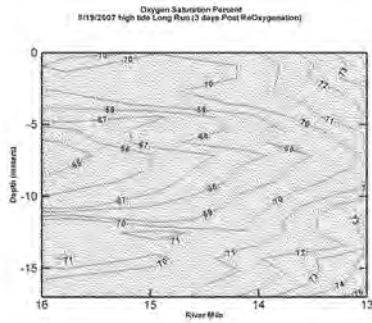
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 Checked by: JTP 11/16/07

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 REOXYGENATION DEMONSTRATION
 PROJECT**
 GEORGIA PORTS AUTHORITY
 SAVANNAH, GEORGIA



Mid-channel
 DO Percent Saturation (%)
 High Tide Event

Project Number: 6110070004 Figure:4-3.1 k



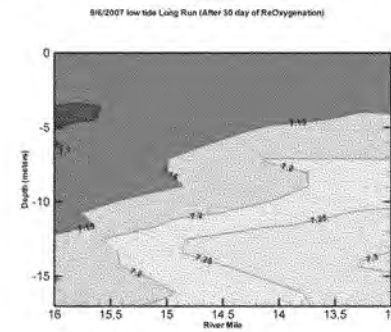
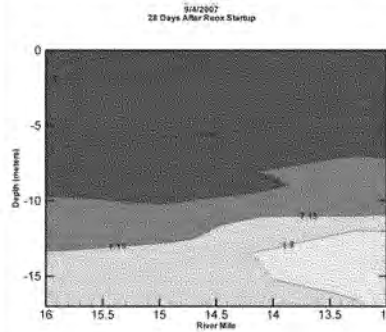
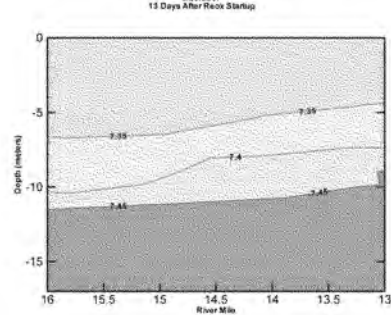
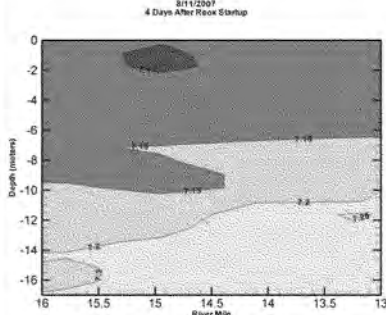
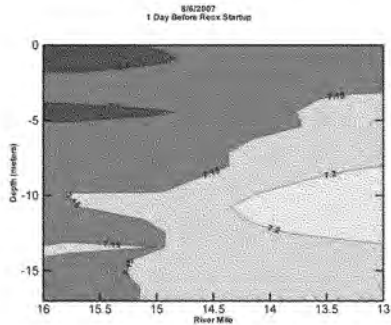
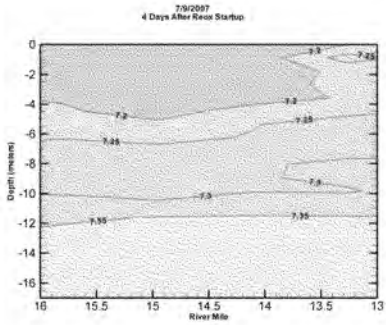
Prepared by: NTG 11/16/07
Checked by: JTP 11/16/07

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REOXYGENATION DEMONSTRATION
PROJECT**
GEORGIA PORTS AUTHORITY
SAVANNAH, GEORGIA

MACTEC

Mid-channel
DO Percent Saturation (%)
High Tide Event

Project Number: 6110070004 Figure:4-3.1 i



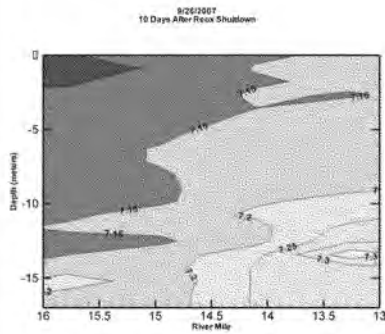
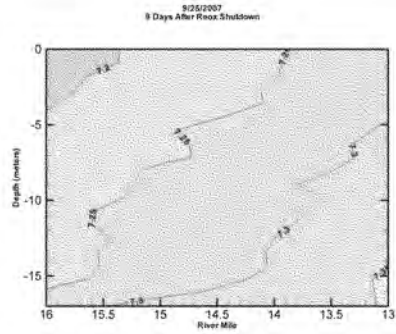
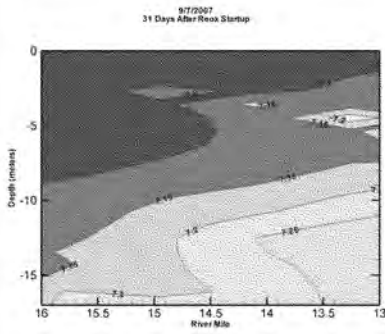
Prepared by: NTG 11/16/07
Checked by: JTP 11/16/07

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 **MACTEC**

Mid-channel
pH
Low Tide Event

Project Number: 6110070004 Figure: 4-3.2 a



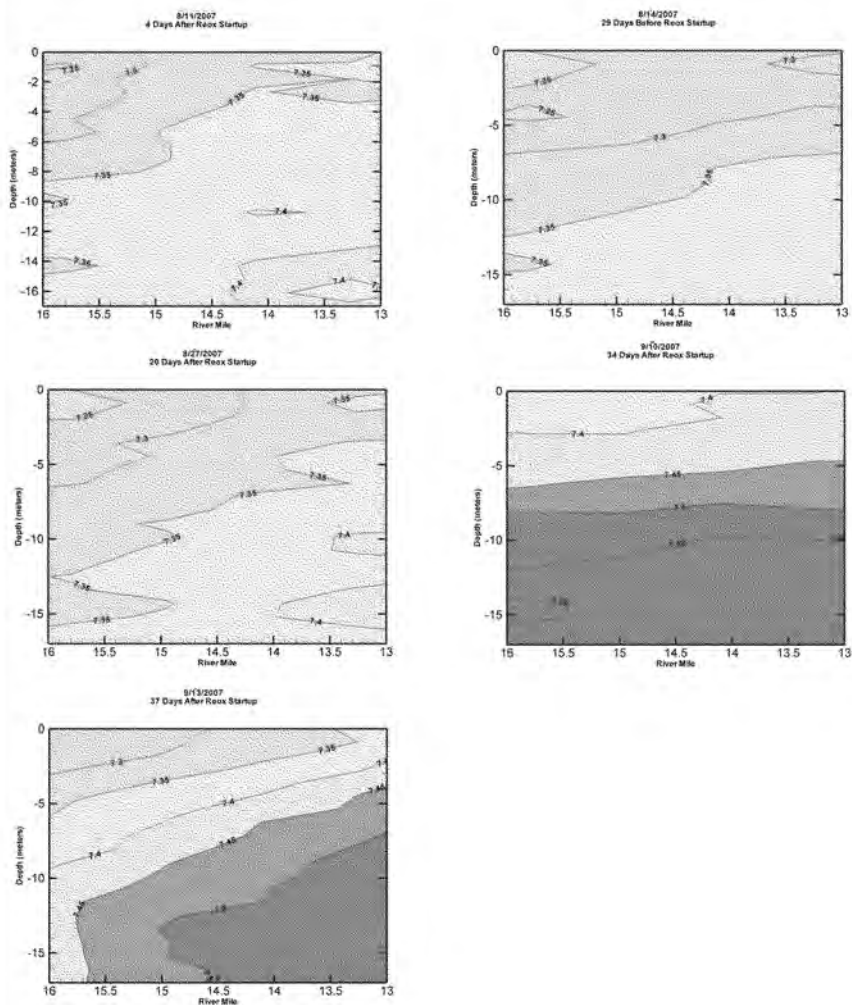
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REOXYGENATION DEMONSTRATION
PROJECT
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SAVANNAH, GEORGIA

MACTEC

Mid-channel
pH
Low Tide Event

Project Number: 6110070004 Figure: 4-3.2 b



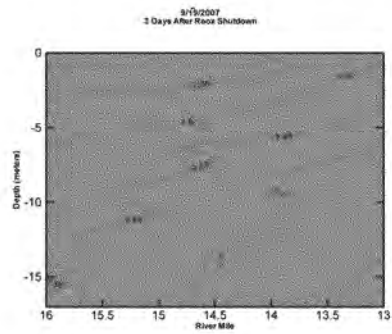
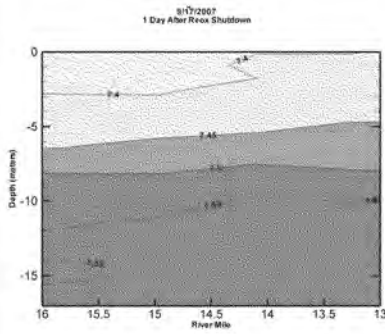
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Mid-channel
pH
High Tide Event

Project Number: 6110070004 Figure:4-3.2 c



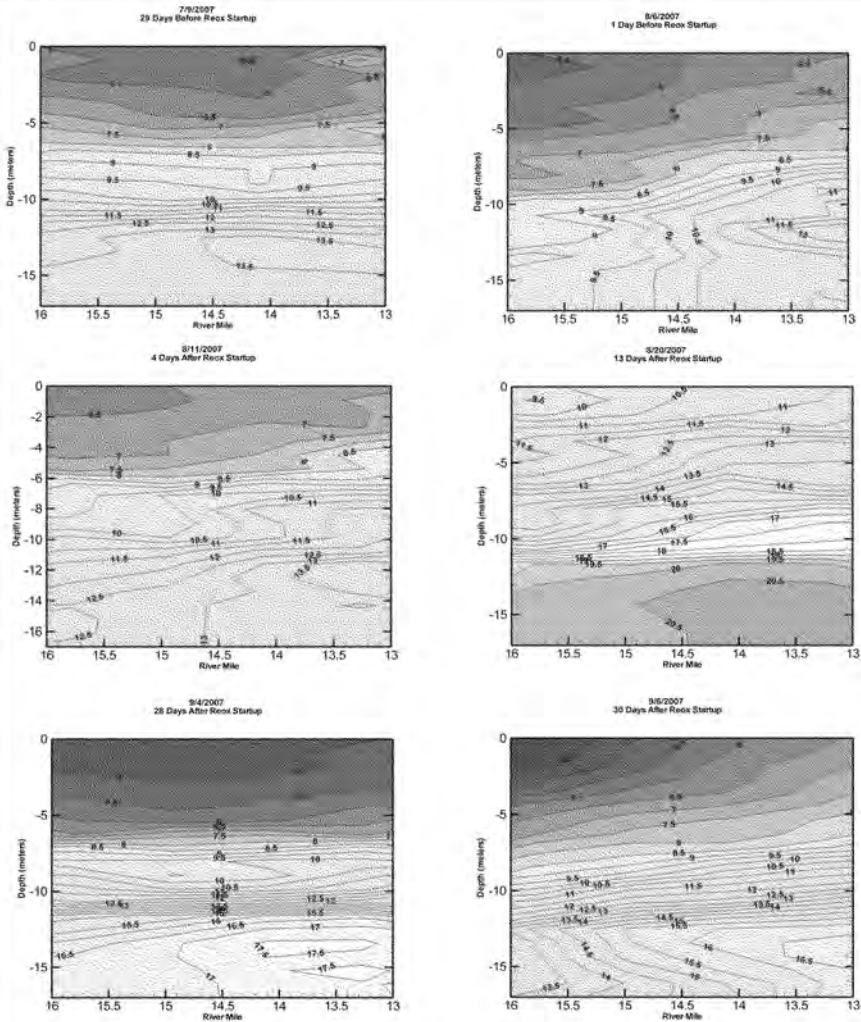
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Mid-channel
pH
High Tide Event

Project Number: 6110070004 Figure 4-3.2 d



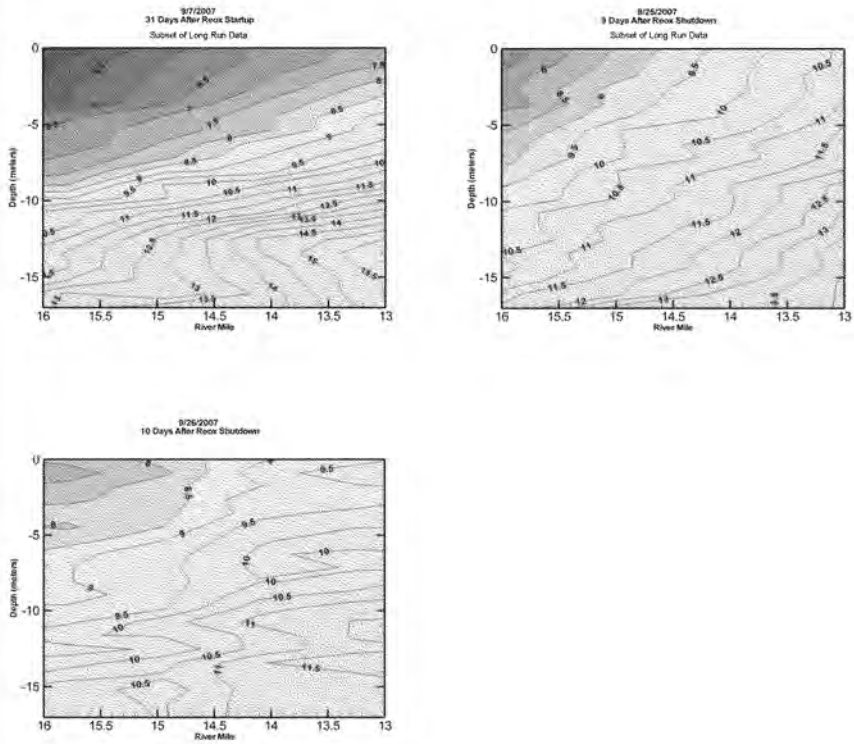
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Mid-channel
 Salinity
 Low Tide Event

Project Number: 6110070004 Figure-4-3.2 e



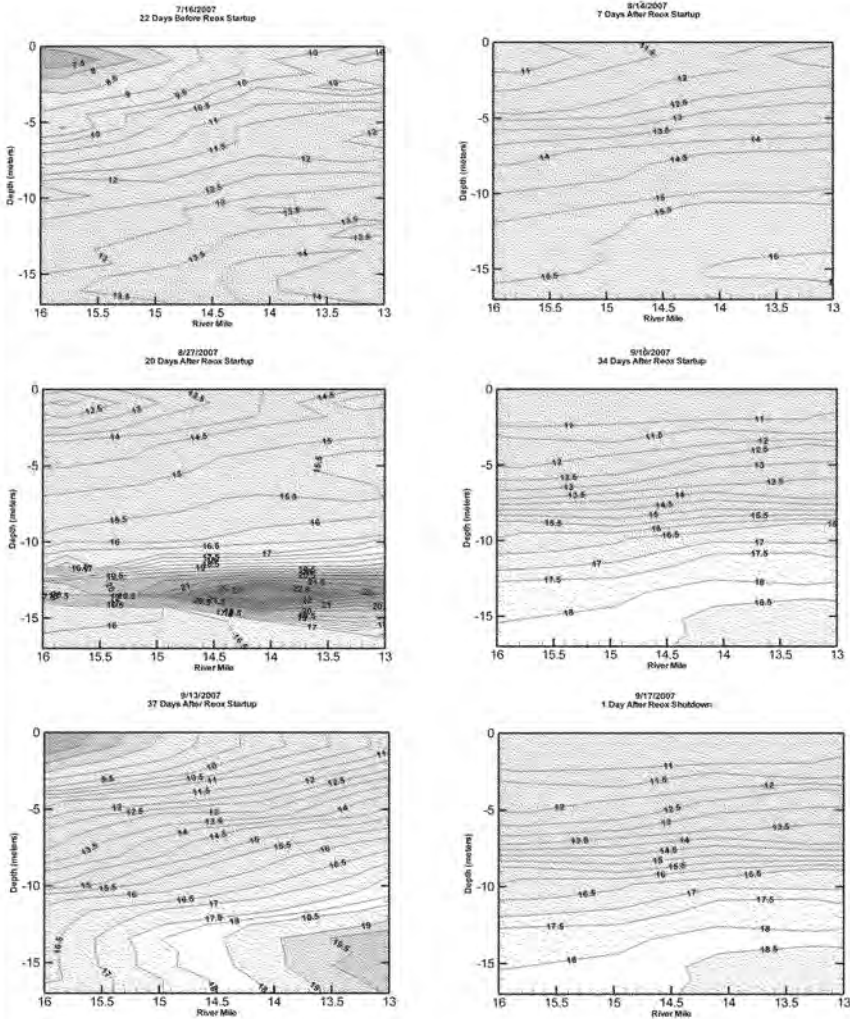
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**Mid-channel
 Salinity
 Low Tide Event**

Project Number: 6110070004 Figure:4-3.2 f



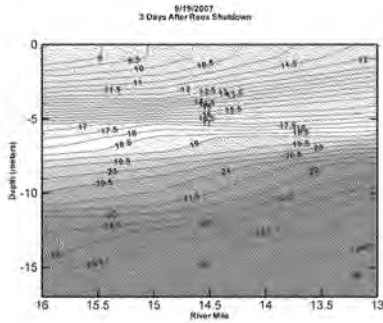
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Mid-channel
Salinity
High Tide Event

Project Number: 6110070004 Figure 4-3.2 g



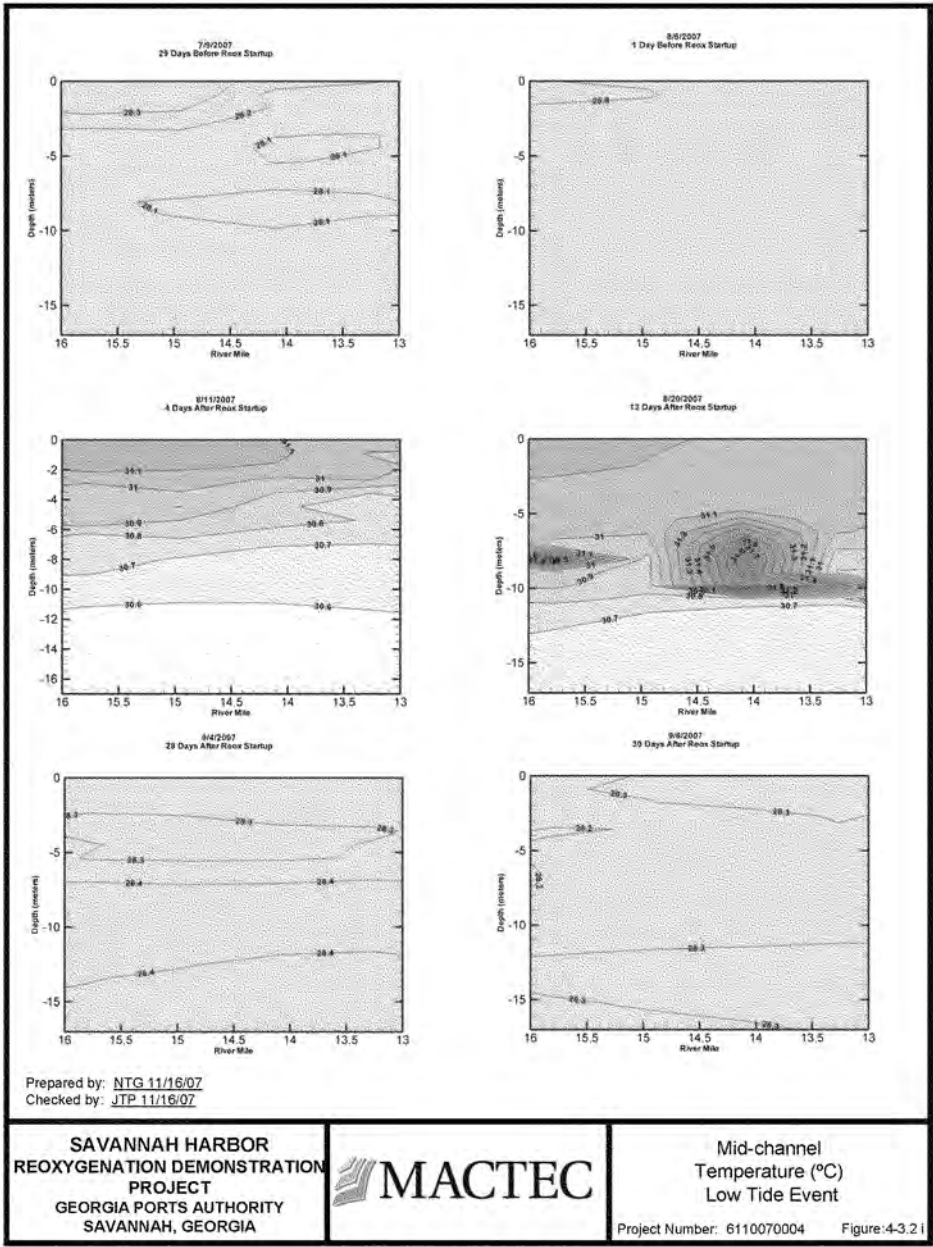
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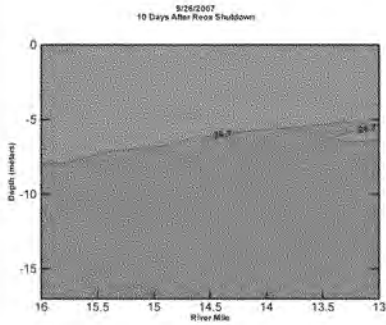
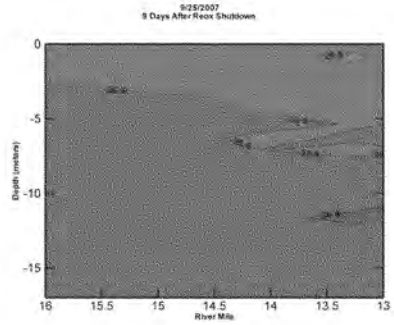
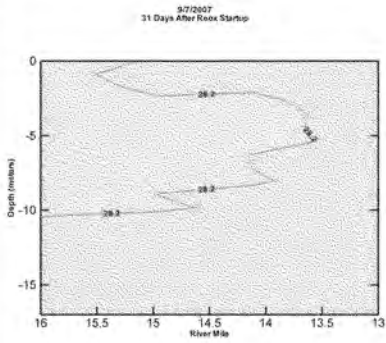
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Mid-channel
 Salinity
 High Tide Event

Project Number: 6110070004 Figure: 4-3.2 h





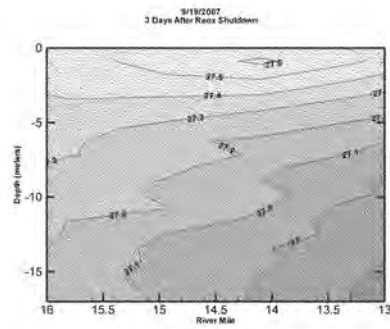
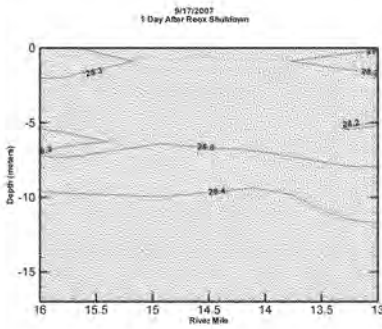
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Mid-channel
Temperature (°C)
Low Tide Event

Project Number: 6110070004 Figure:4-3.2



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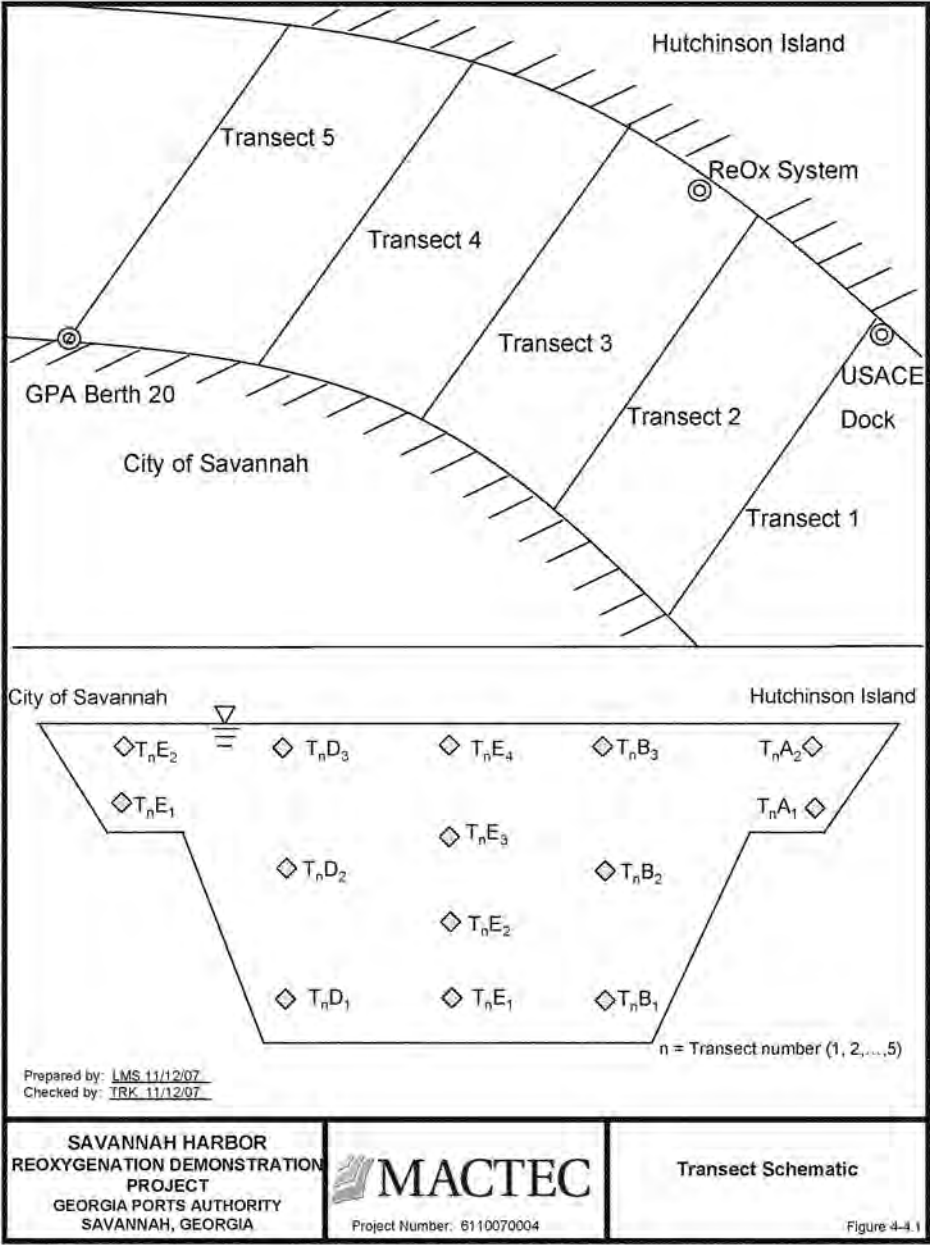
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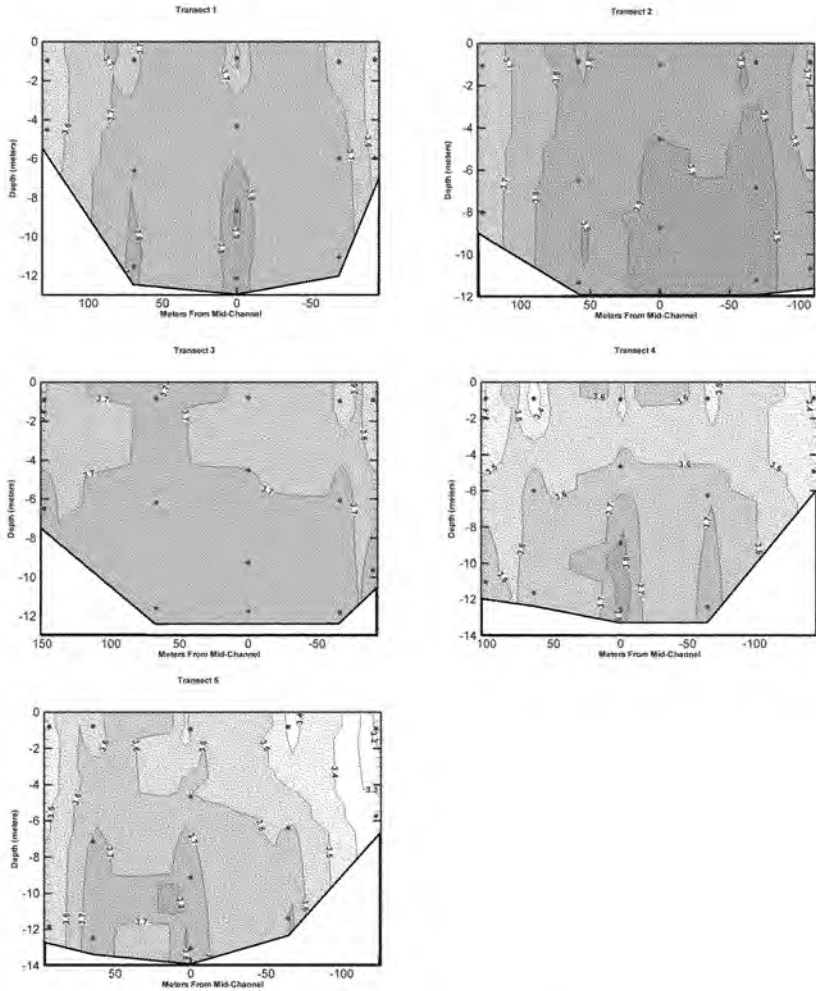


Mid-channel
Temperature (°C)
High Tide Event

Project Number: 6110070004 Figure:4-3.2







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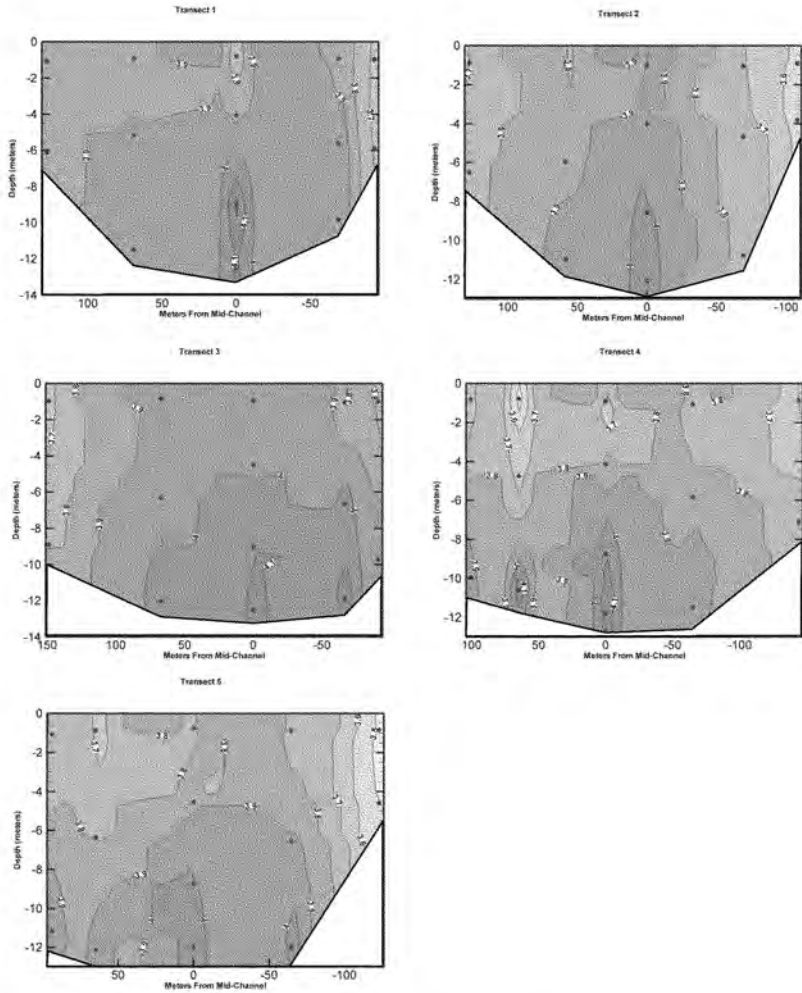
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Cross-Sections
 DO Deficit (mg/L)
 Low Tide 7/10/2007

Figure:4-4.2 a



Prepared by: NTG 11/15/07
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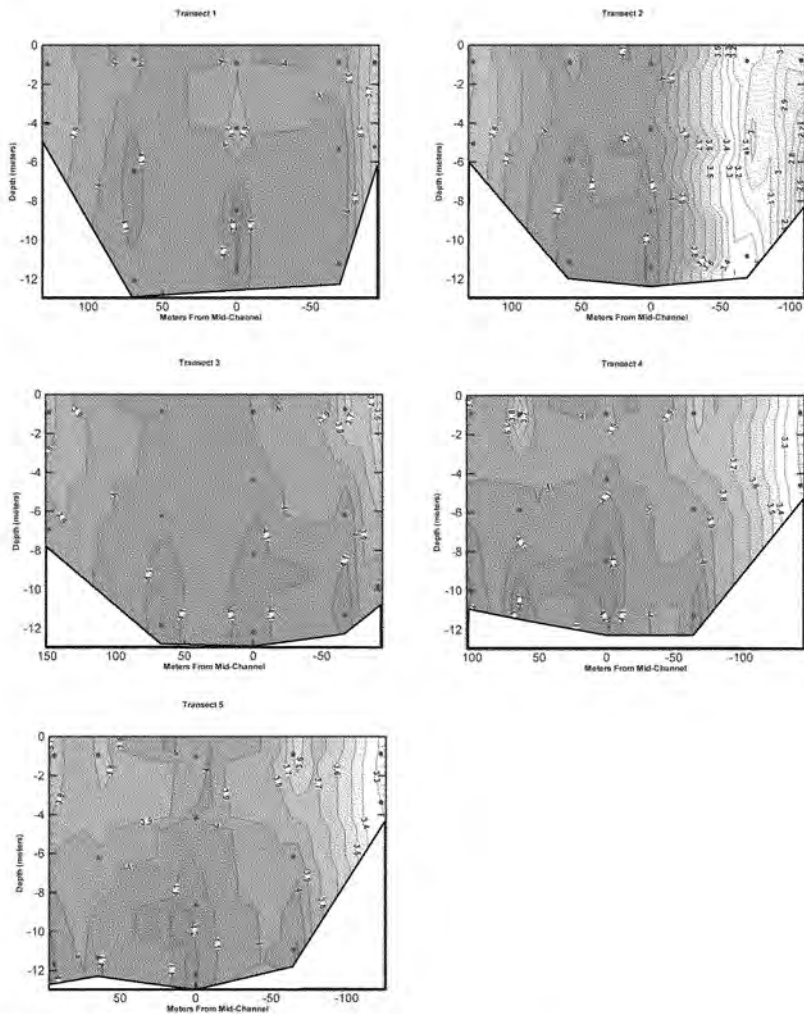
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Cross-Sections
 DO Deficit (mg/L)
 Low Tide 8/7/2007

Figure 4-4.2 b



Prepared by: NTG 11/15/07
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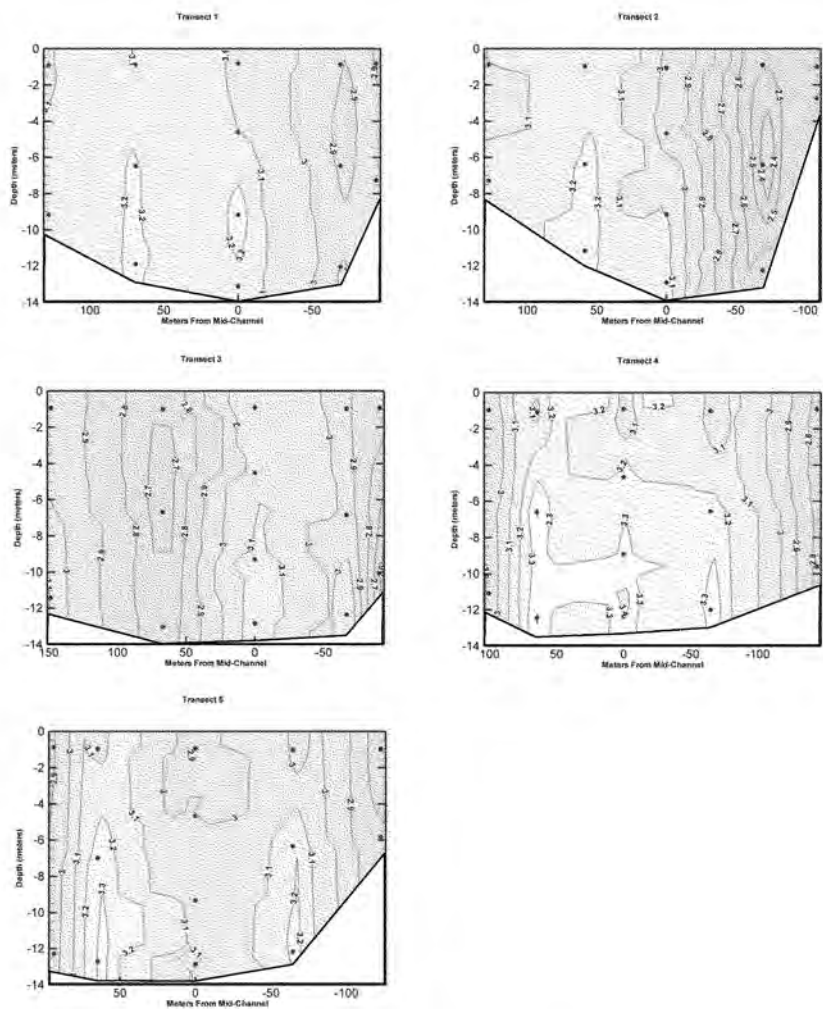
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Cross-Sections
 DO Deficit (mg/L)
 Low Tide 8/10/2007

Figure: 4-4.2 c



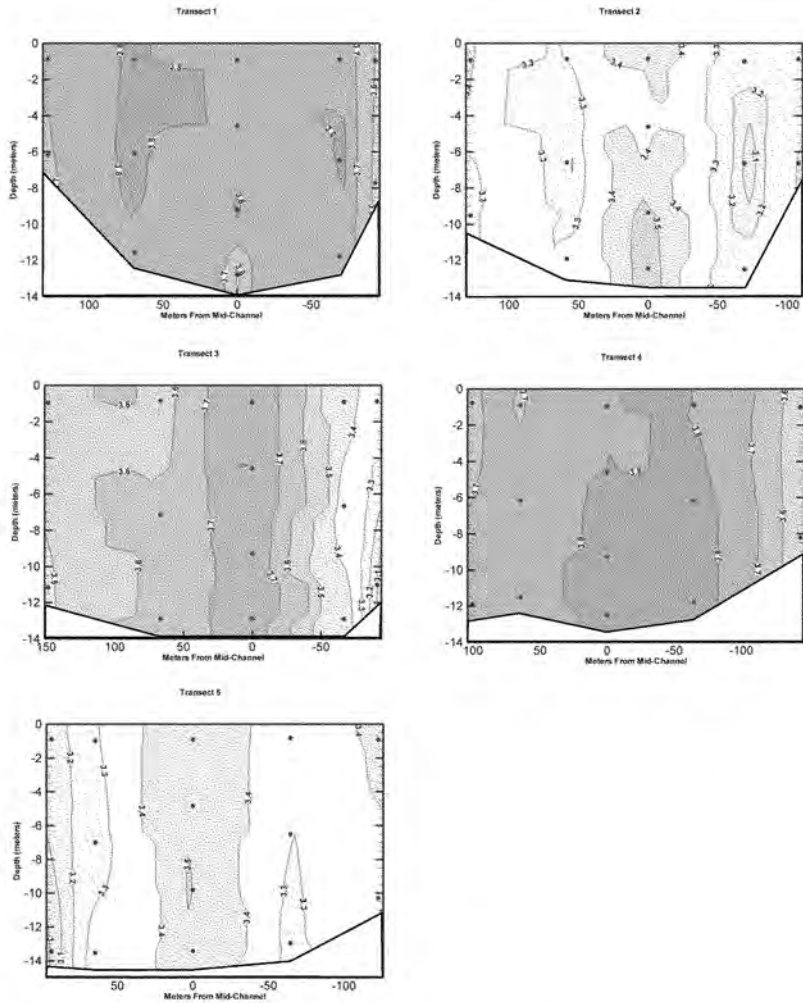
Prepared by: NTG 11/15/07
Checked by: JTP 11/15/07

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Cross-Sections
DO Deficit (mg/L)
Low Tide 8/21/2007

Figure: 4-4.2 d



Prepared by: NTG 11/15/07
 Checked by: JTP 11/15/07

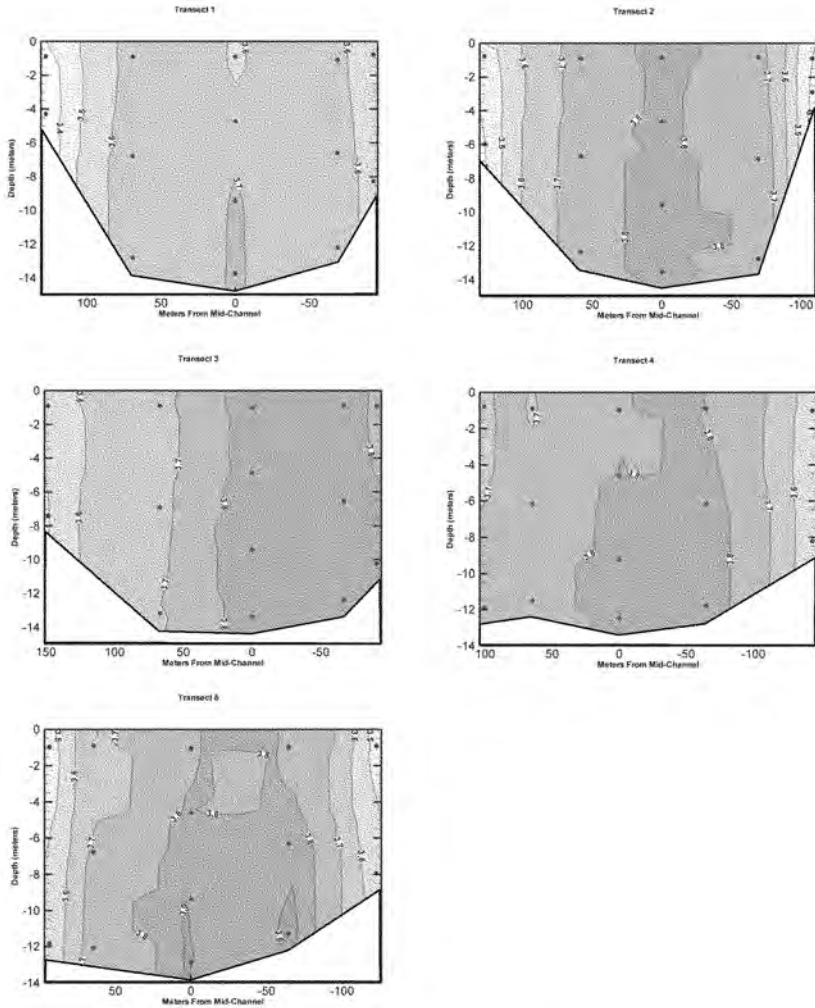
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Project Number: 6110070004

Cross-Sections
 DO Deficit (mg/L)
 Low Tide 9/5/2007

Figure:4-4.2 e



Prepared by: NTG 11/15/07
 Checked by: JTP 11/15/07

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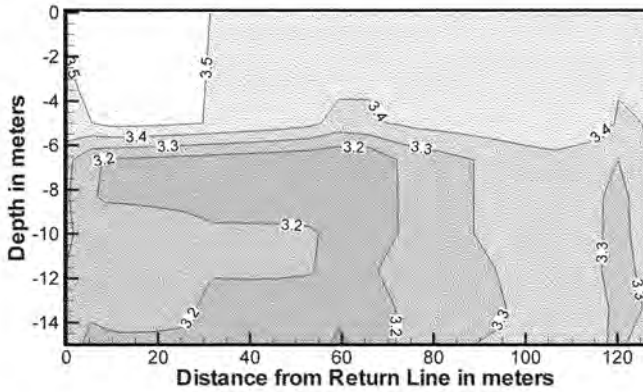
Project Number: 6110070004

Cross-Sections
 DO Deficit (mg/L)
 Low Tide 9/24/2007

Figure 4-4.2 f



**Dissolved Oxygen Concentration - Near Barge
Return Flow Centerline**



Prepared by: NTG 11/13/07
Checked by: TRK 11/13/07

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Near Barge Monitoring
DO Concentration (mg/L)
8/7/2007

Project Number: 6110070004

Figure: 4-5.1



Prepared by: LMS 11/16/07
Checked by: MET 11/16/07

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Effervescence at Slack Tide

Project Number: 6110070004

Figure: 4-6



Photo 1: Surface dye injection (5 gallons) - Dye injected into river from water's surface. This showed the expected dye color if the deep injected dye had made it to the surface.



Photo 2: System dye injection (55 gallons) - Dye injected thirty feet below water surface through ReOx System. Dye has been churned up from the deeper zone by the boat. Surface dispersion of dye minimal, majority of dye remaining in the deep zone of the river.

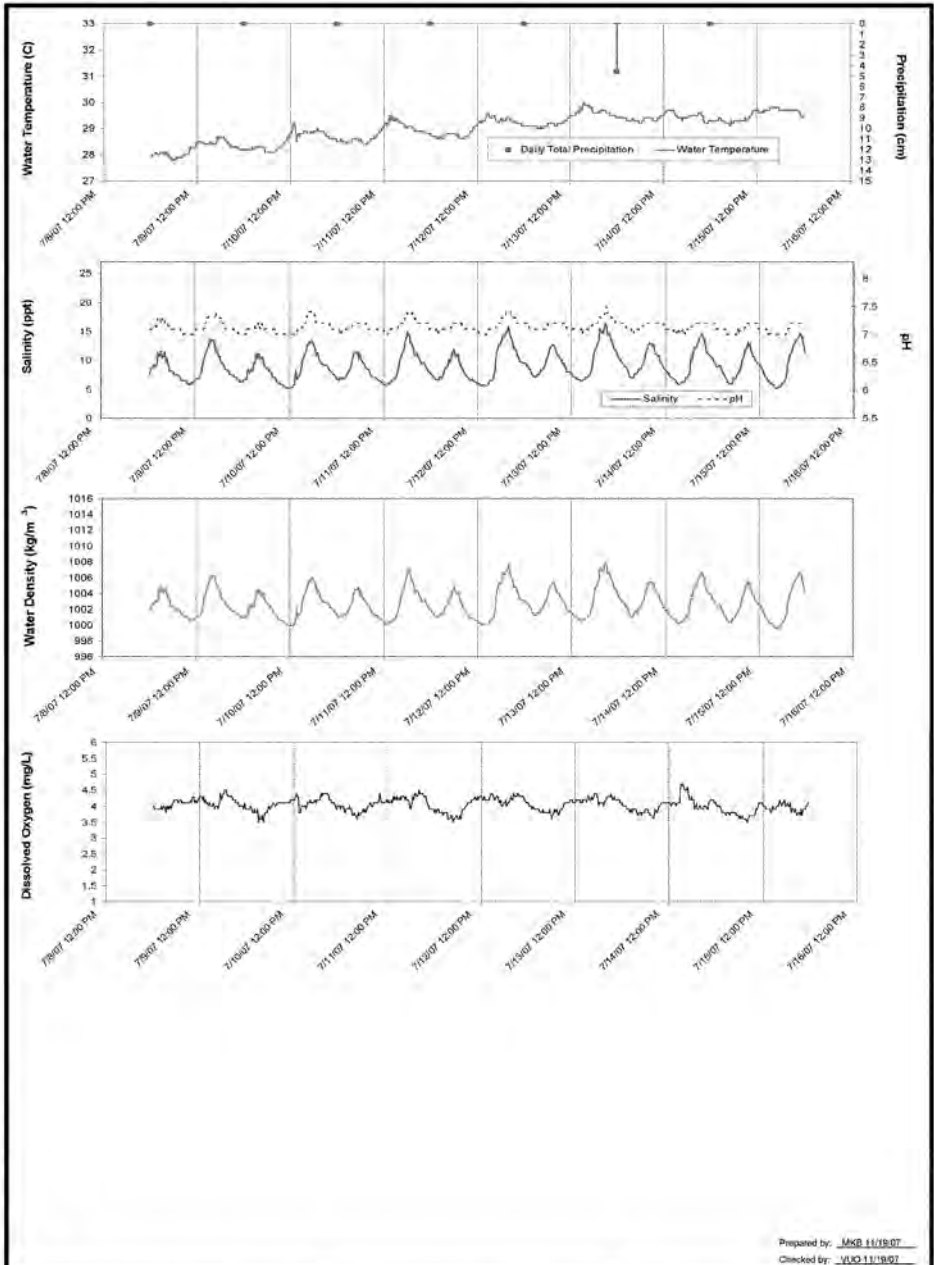
Prepared by: JTP 11/19/07
Checked by: MET 11/19/07

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Dye Test Photos

Project Number: 6110070004 Figure: 4-7



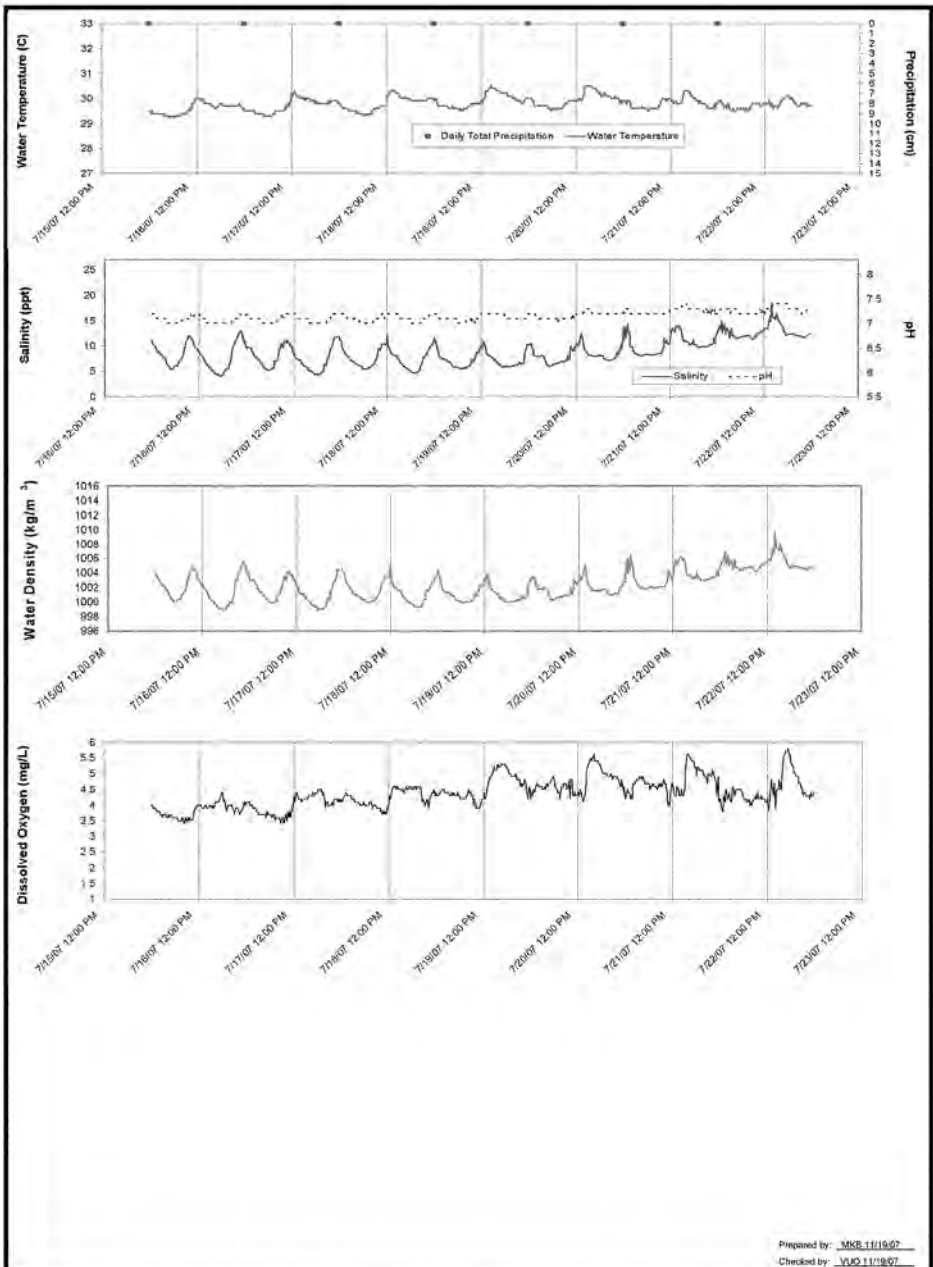
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USGS Gage Station at USACE Dock
 July 9 – 15, 2007

Project Number: 6110070004

Figure 4-8.1



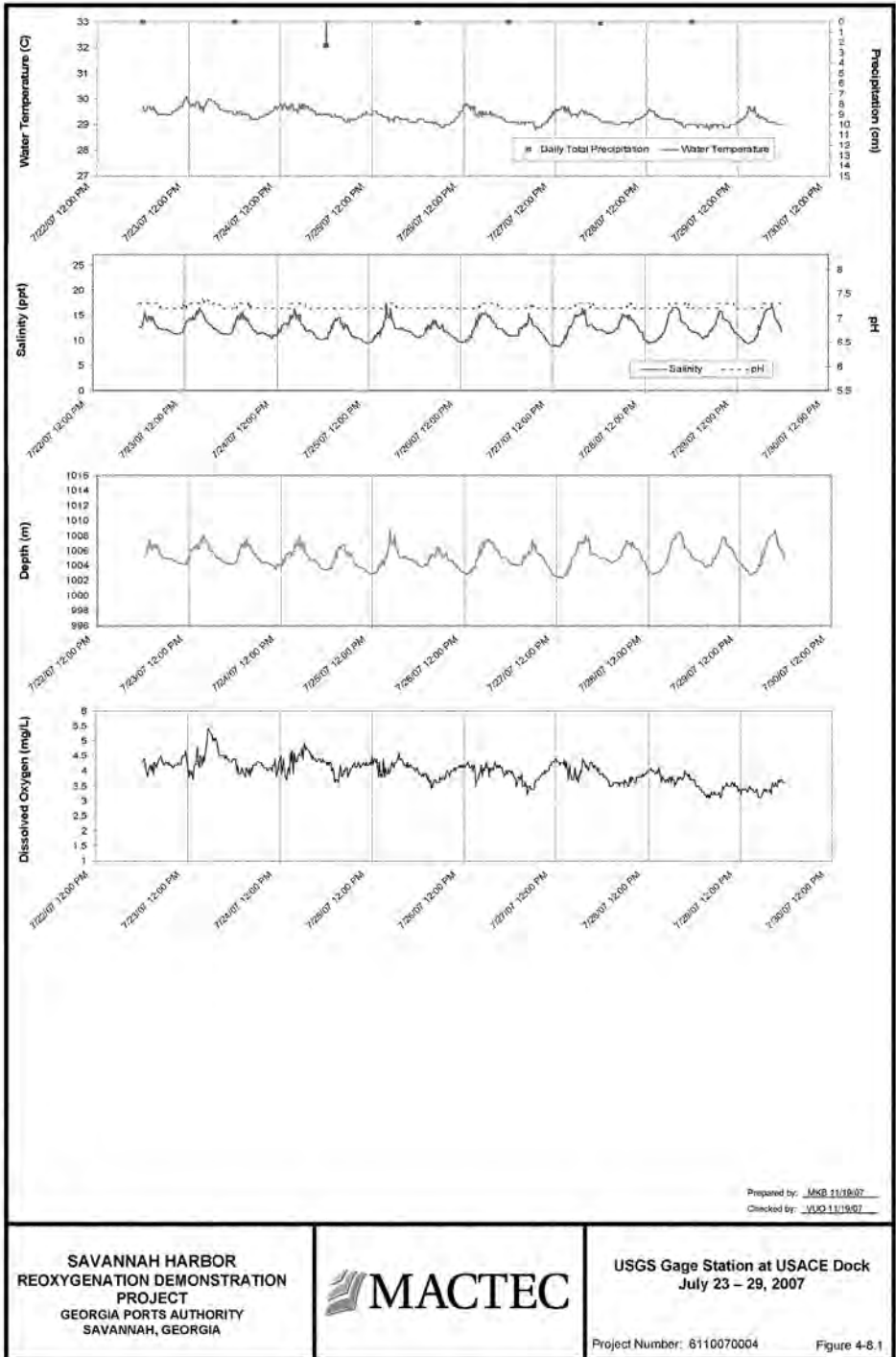
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 REOXYGENATION DEMONSTRATION
 PROJECT
 GEORGIA PORTS AUTHORITY
 SAVANNAH, GEORGIA

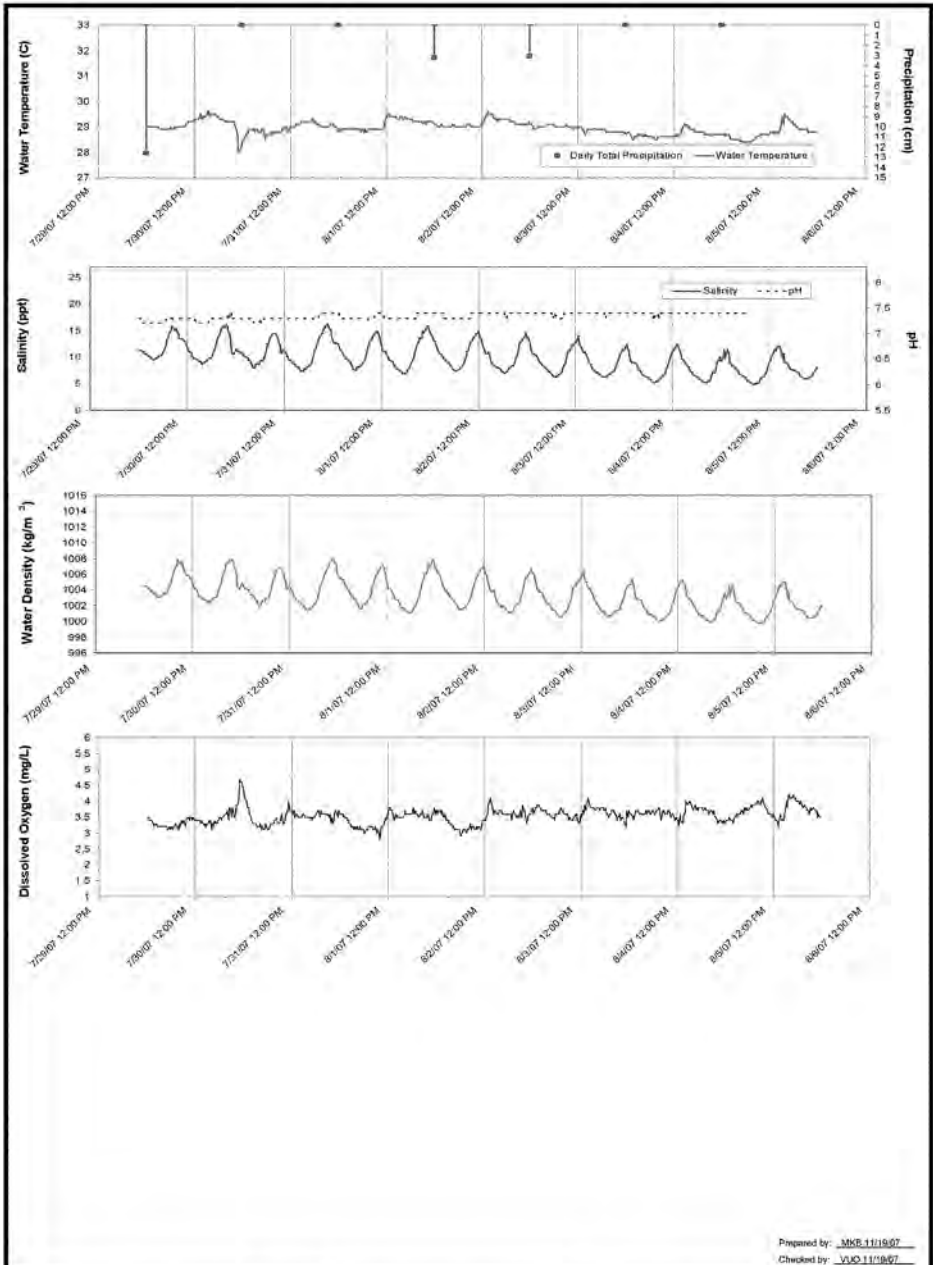


USGS Gage Station at USACE Dock
 July 16 – 22, 2007

Project Number: 6110070004

Figure 4-B.1





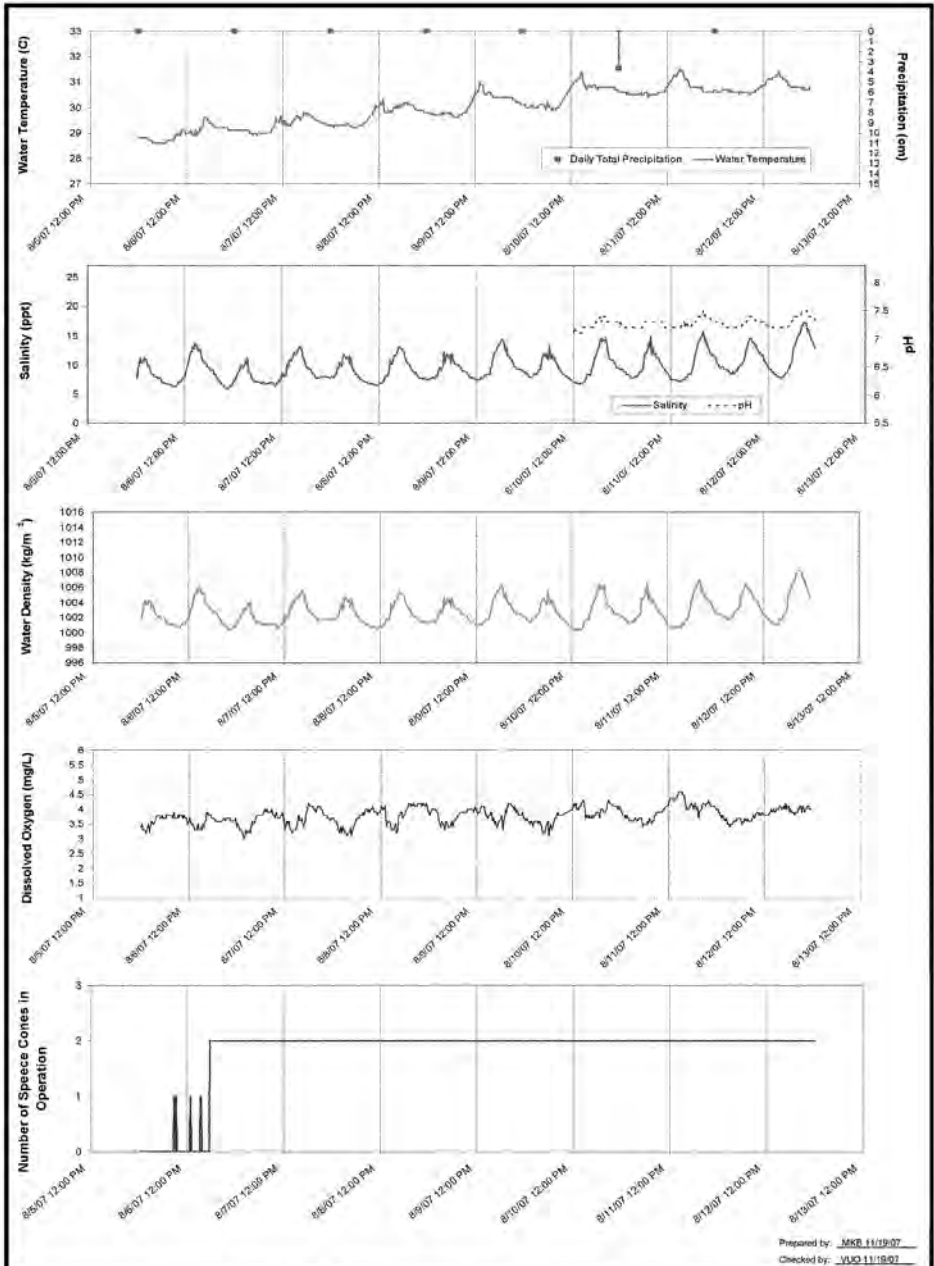
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 PROJECT
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USGS Gage Station at USACE Dock
 July 30 – Aug 5, 2007

Project Number: 6110070004

Figure 4-B.1

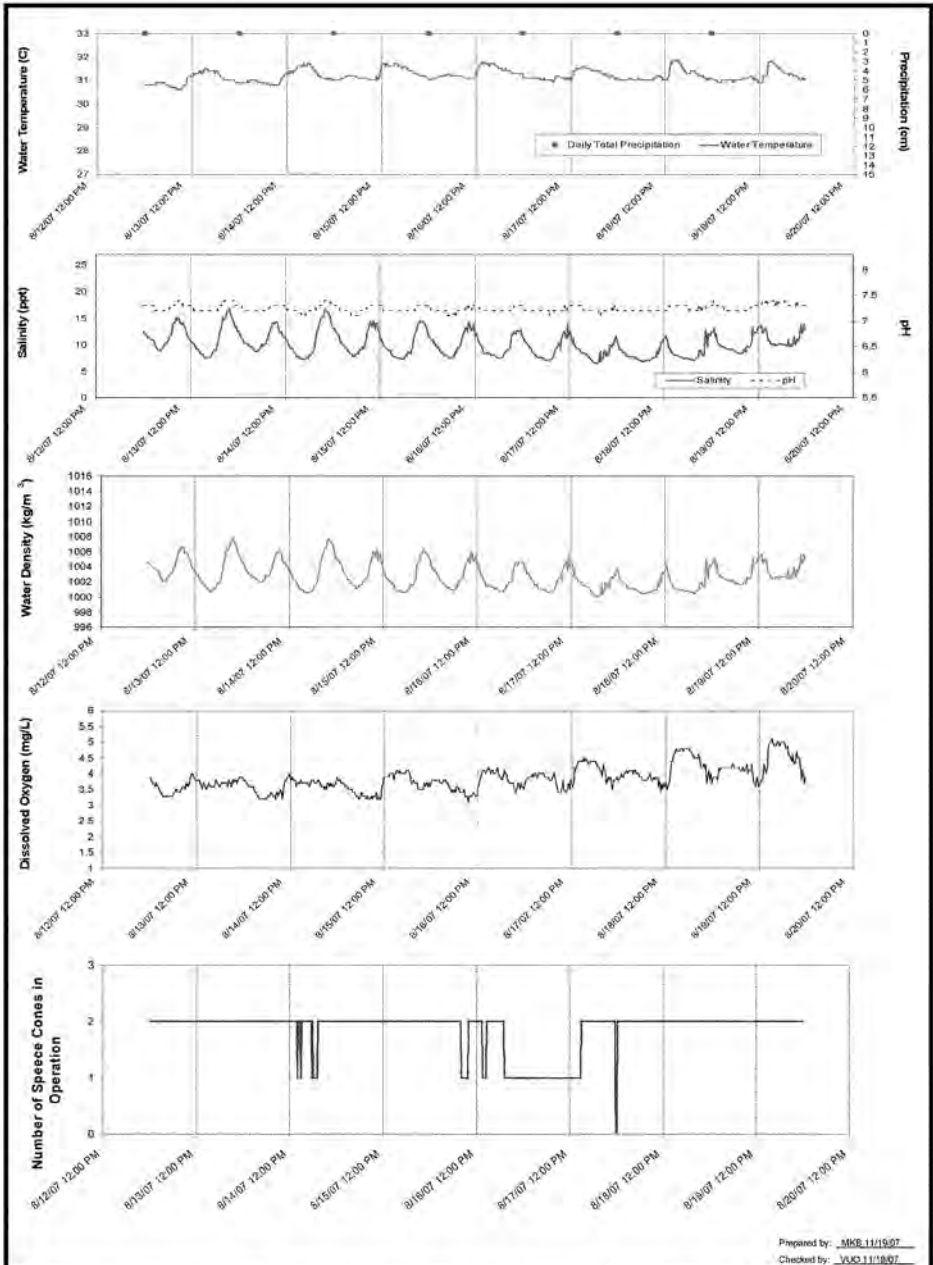


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USGS Gage Station at USACE Dock
 Aug 6 – 12, 2007

Project Number: 6110070004 Figure 4-B.1



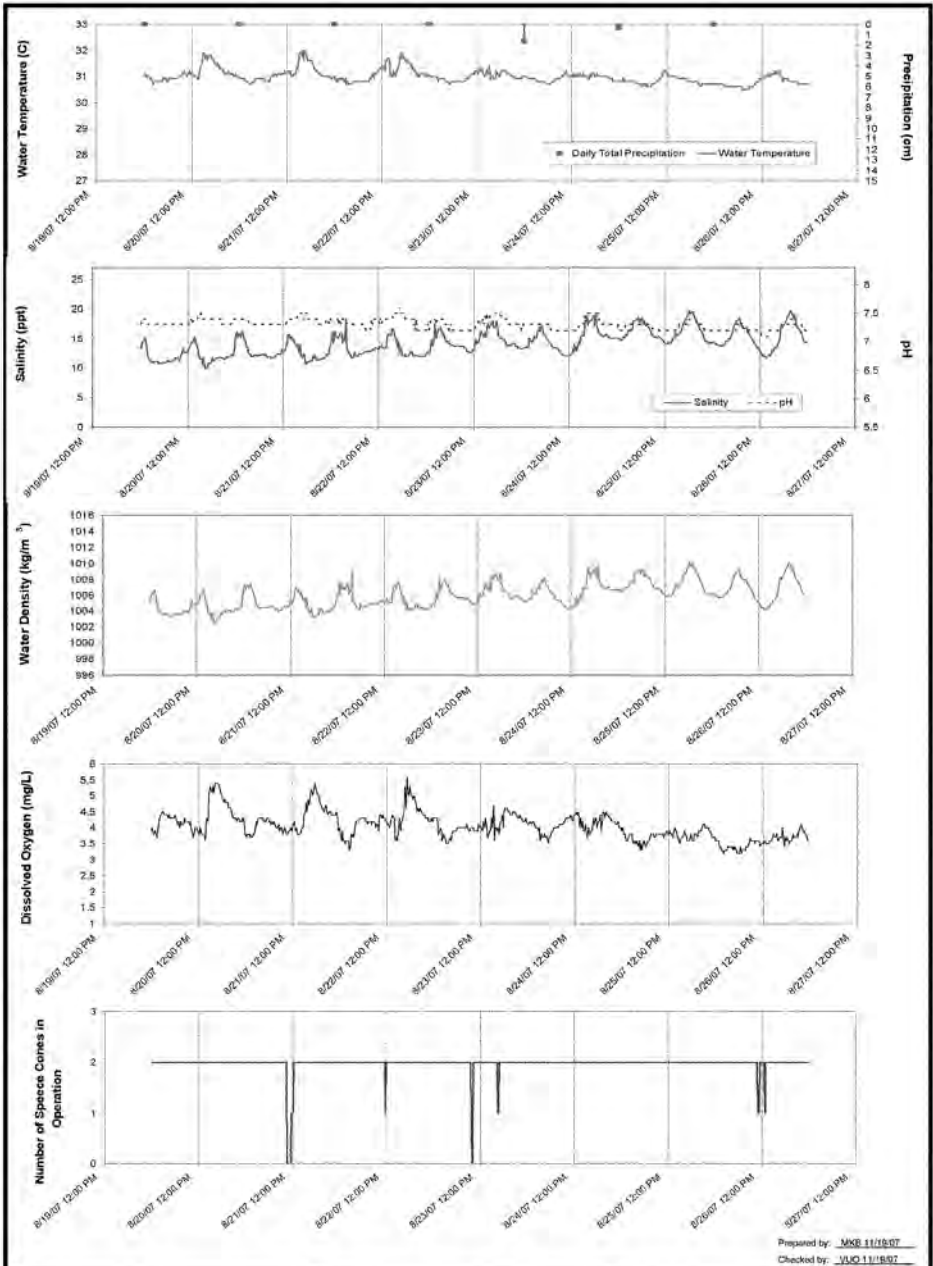
Prepared by: MRB_11/19/07
 Checked by: VSD_11/19/07

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USGS Gage Station at USACE Dock
 Aug 13 – 19, 2007

Project Number: 6110070004 Figure 4-3.1

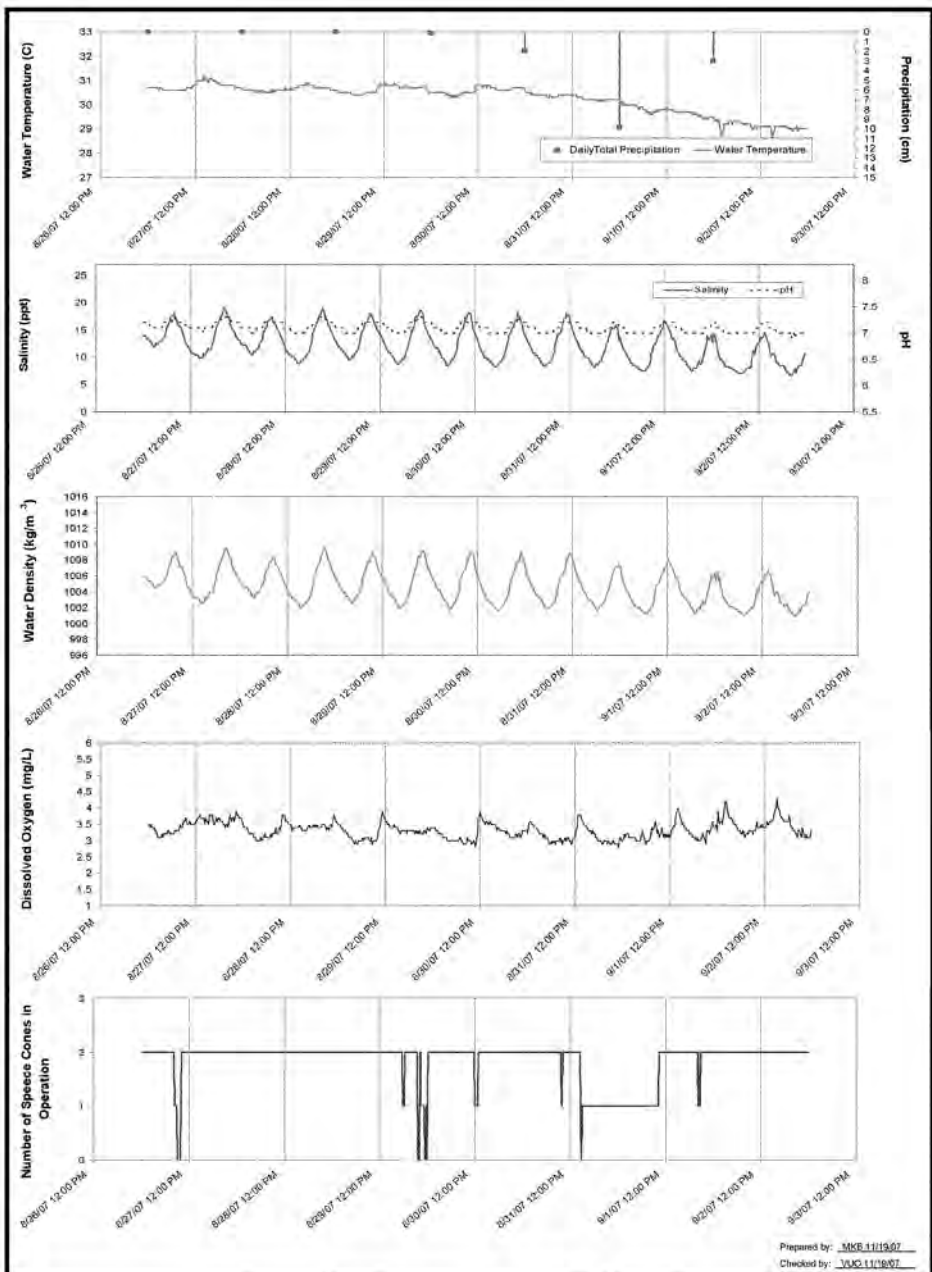


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USGS Gage Station at USACE Dock
Aug 20 - 26, 2007

Project Number: 6110070004 Figure 4-3.1

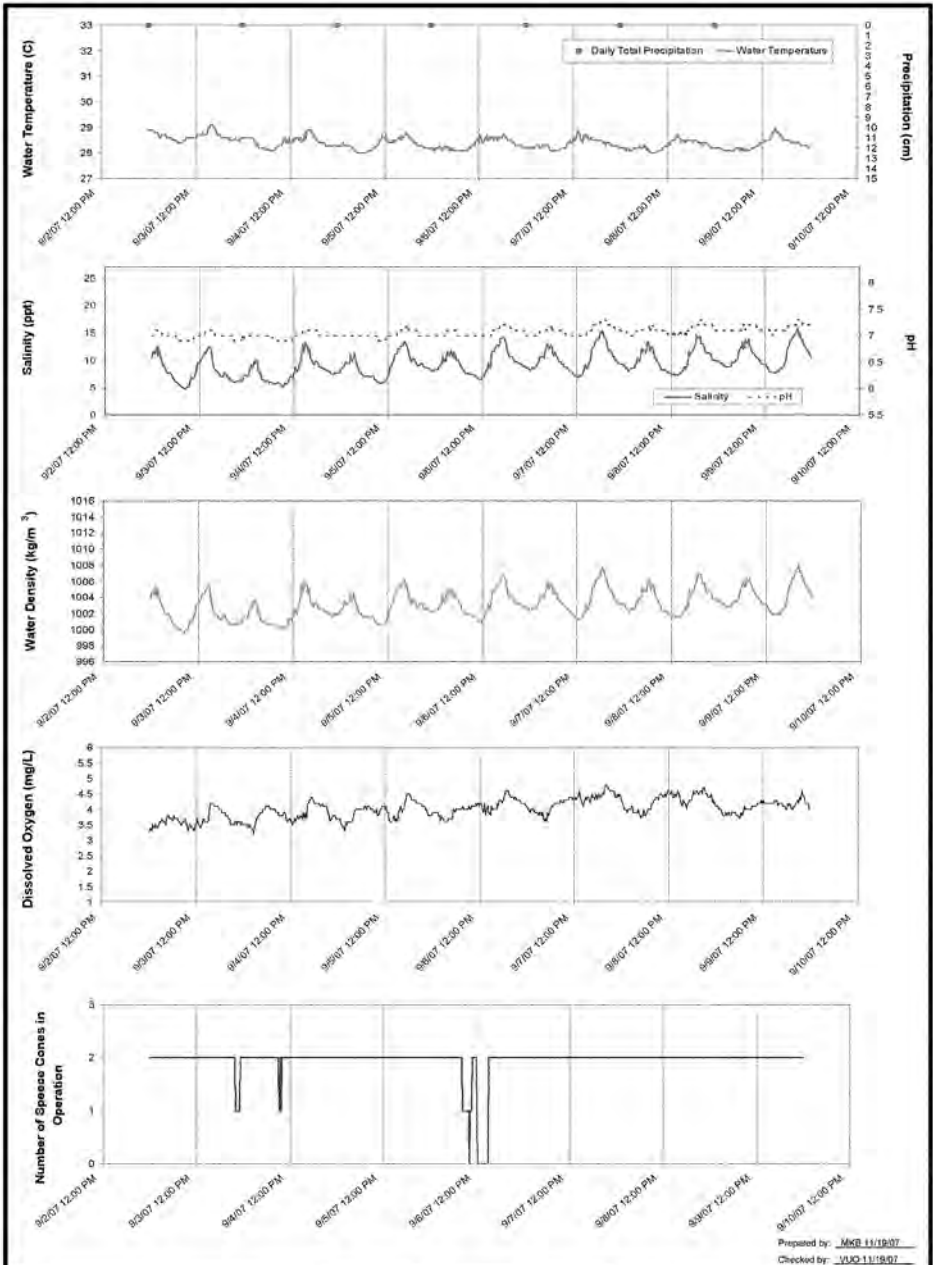


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SAVANNAH, GEORGIA



USGS Gage Station at USACE Dock
Aug 27 – Sep 2, 2007

Project Number: 6110070004 Figure 4-B.1

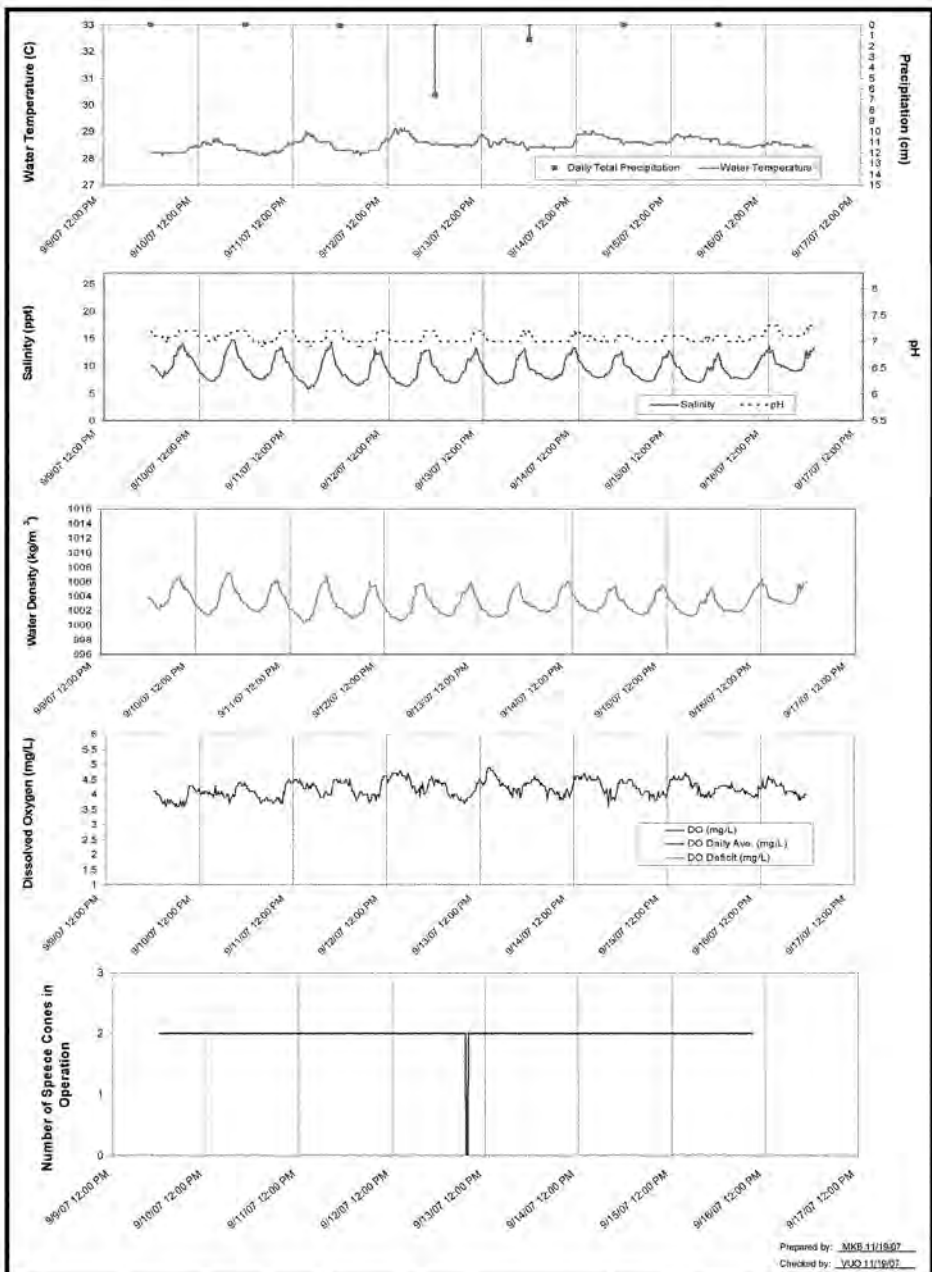


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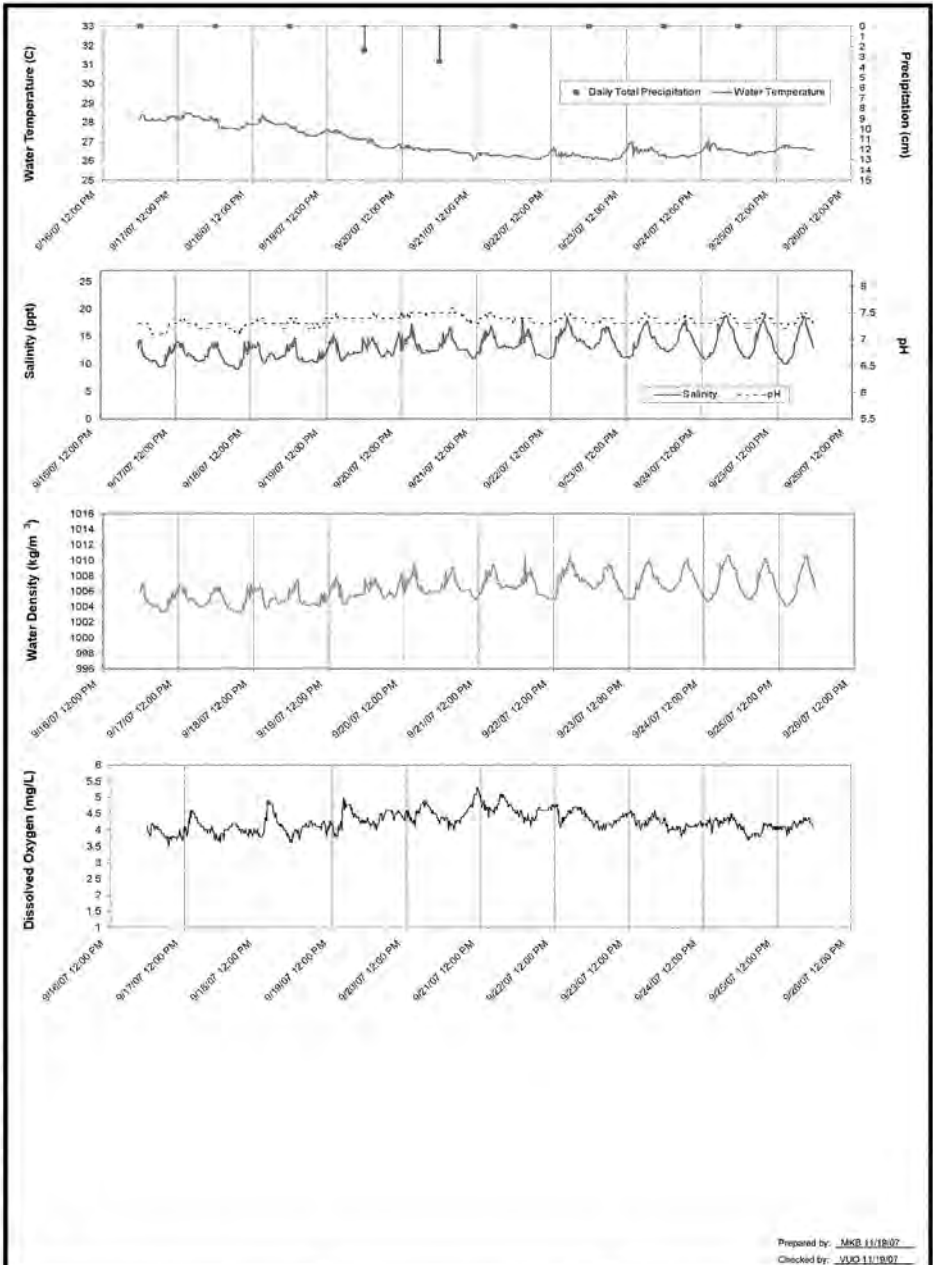
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USGS Gage Station at USACE Dock
 Sep 3 – 9, 2007

Project Number: 6110070004 Figure 4-9.1



Prepared by: MKS11/06/07
Checked by: V0211/06/07



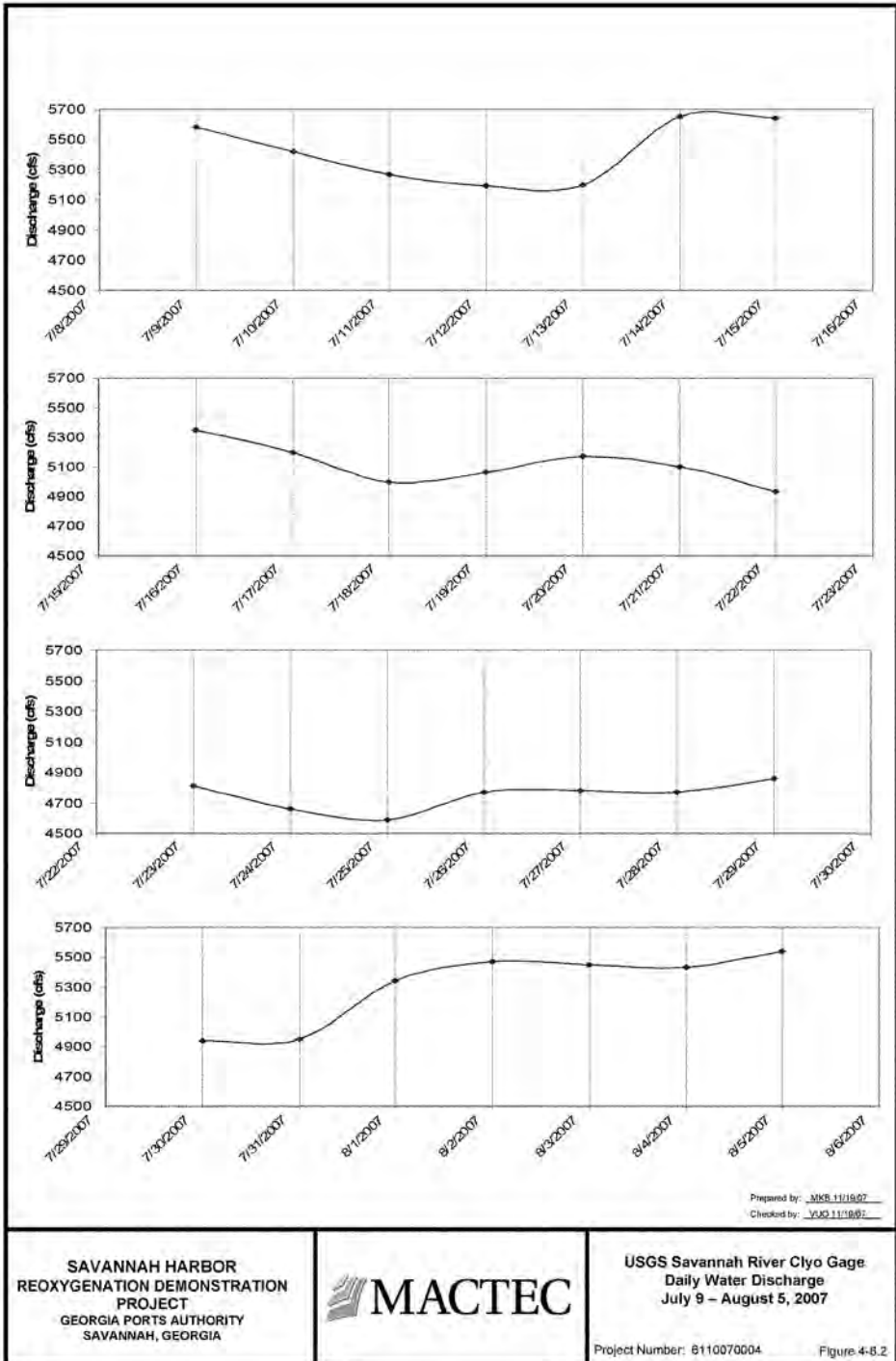
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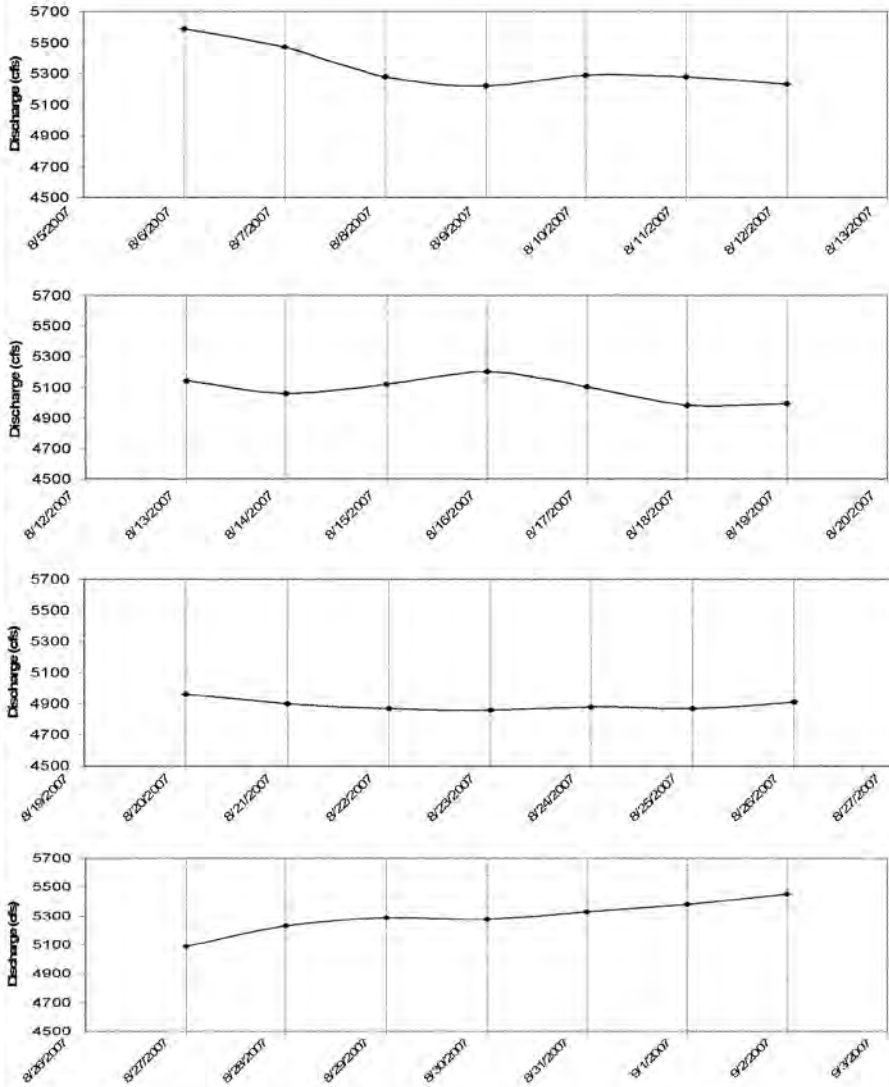
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USGS Gage Station at USACE Dock
Sep 17 – 25, 2007

Project Number: 6110070004

Figure 4-8.1





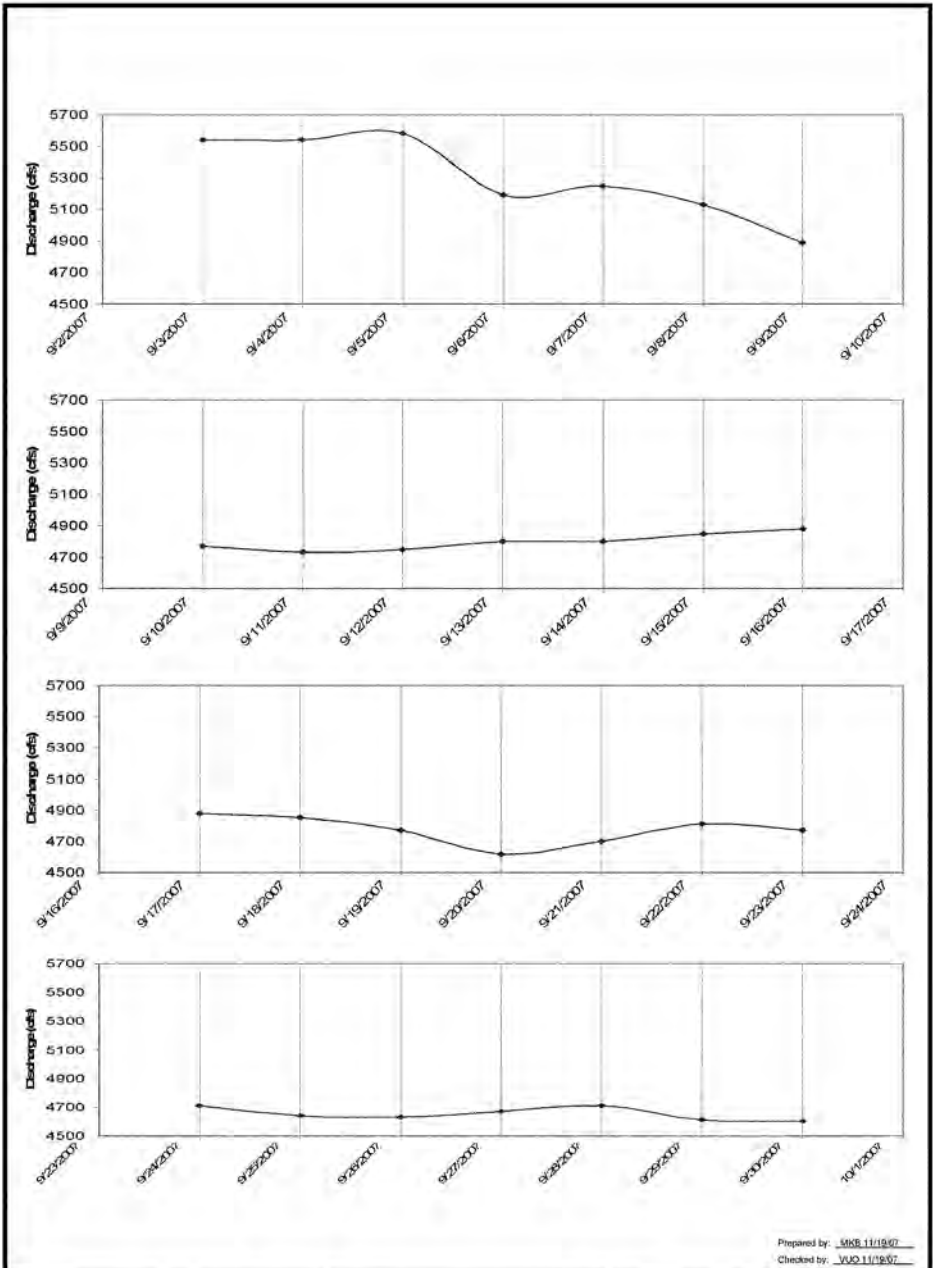
Prepared by: MKB 11/18/07
 Checked by: VSD 11/19/07

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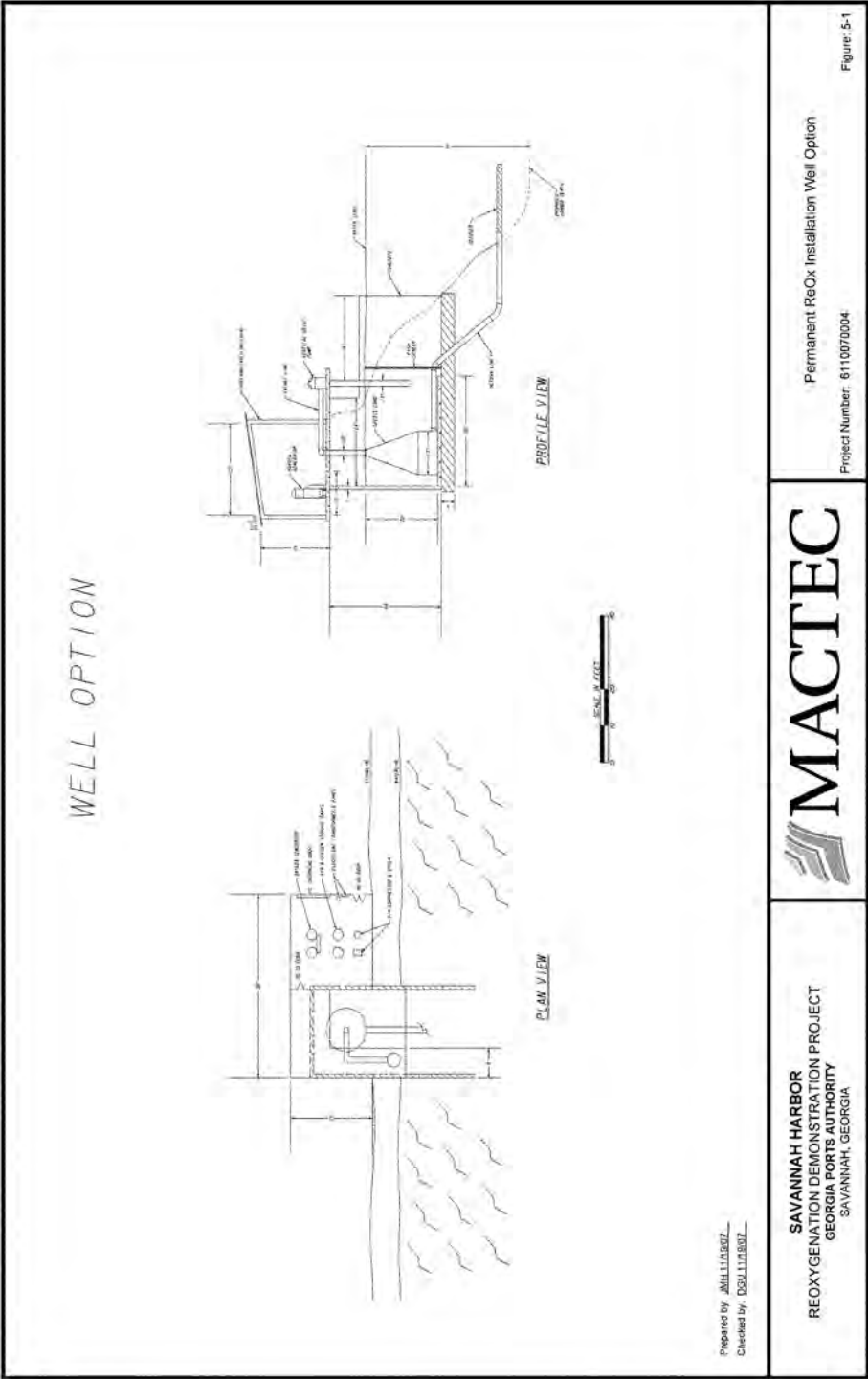
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USGS Savannah River Clio Gage
 Daily Water Discharge
 August 6 – September 2, 2007

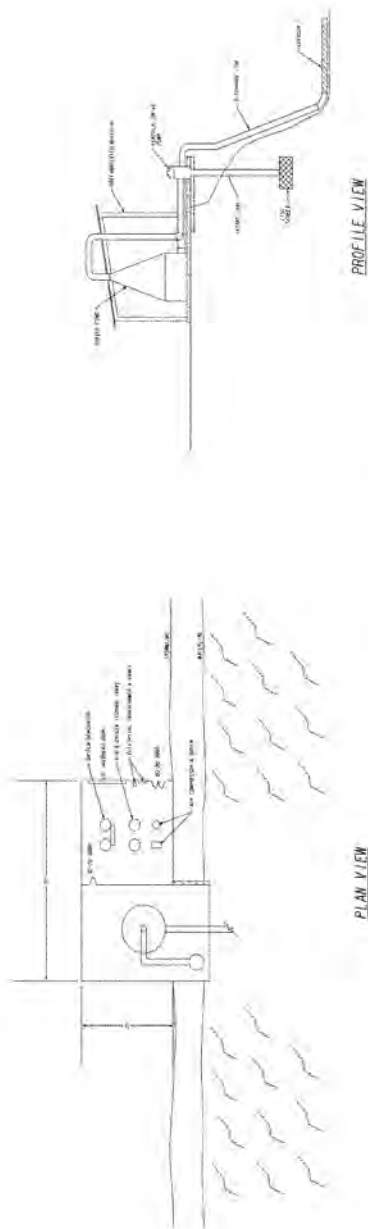
Project Number: 6110070004 Figure 4-B.2



Prepared by: MSB, 11/19/07
 Checked by: VUD, 11/19/07



ABOVE GROUND OPTION



Prepared by: ASH/11/1907
Checked by: DSH/11/1907

SAVANNAH HARBOR
REOXYGENATION DEMONSTRATION PROJECT
GEORGIA PORTS AUTHORITY
SAVANNAH, GEORGIA



Permanent ReOx Installation Above Ground Option

Project Number: 8110070004

Figure: S-2

Table 5-2
Annual Operations and Maintenance ROM Cost Estimate

Projected Yearly Costs per Cone		
	Oxygen Generator	Liquid Oxygen
Maintenance		
Motors	\$1,320	\$1,320
Pump	\$1,320	\$1,320
Oxygen Generator	\$1,320	\$0
Compressor	\$1,320	\$0
Screen	\$3,119	\$3,119
Building	\$1,361	\$1,361
Subtotal	\$8,442	\$5,801
Operation		
Pump	\$5,500	\$5,500
Lighting	\$1,500	\$1,500
Oxygen Generator	\$3,500	\$0
Liquid Oxygen	\$0	\$92,120
Subtotal	\$10,500	\$99,120
25% Contingency	\$4,735	\$26,230
Total Estimated Yearly Expense	\$23,677	\$131,151

Notes:

1. Cost are based on RS Means Costwork 2007 where possible and intended to provide a rough order of magnitude (ROM) annual operations cost estimate
2. Maintenance costs based on national averages for state employees. Costs also assume standard maintenance for a three (3) month period during operations.
3. Screen costs reflect cost of diver and crew to clean and service fish screen. Also includes 2 additional dives for service during operation and are based on national average wage rates
4. Electrical costs are representative of normal operations using current pricing structure
5. Liquid oxygen based on 15,000 pounds per day and include the use of temporary tank and evaporator provided by oxygen supplier.

APPENDIX A
GEODATABASE
(Electronic Only)

APPENDIX A

Appendix A contains the project database located on the attached DVD in Microsoft Access format. In addition to the database file, selected tables have been prepared as referenced in the text.

APPENDIX B

SAVANNAH HARBOR REOXYGENATION WATER QUALITY MONITORING PLAN

SAVANNAH HARBOR REOXYGENATION WATER QUALITY MONITORING PLAN

Prepared for:



GEORGIA PORTS AUTHORITY

Prepared by:



MACTEC ENGINEERING AND CONSULTING, INC.
3200 Town Point Drive NW, Suite 100
Kennesaw, Georgia 30144

June 11, 2007

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EXECUTIVE SUMMARY

The water quality monitoring plan developed for the Savannah Reoxygenation Demonstration Project is described in this report. The Georgia Ports Authority (GPA) is to deepen the navigation channel of the Savannah Harbor to accommodate the passage of larger deep-draft ships. However, deepening the harbor has the effect of reducing the reaeration capacity of the river and thereby reducing dissolved oxygen (DO) concentrations in the deepened channel.

MACTEC Engineering and Consulting Inc. was contracted by the Georgia Ports Authority to carry out a DO mitigation demonstration project. The ReOxygenation (ReOx) project will inject DO into the harbor to mitigate the incremental DO deficit resulting from the proposed deepening.

Under this demonstration project water quality monitoring plan, the frequency and methods for instream monitoring of DO and other water quality parameters (pH, specific conductivity, temperature, salinity, and depth) have been developed.

Water quality monitoring will be conducted at three stationary points in the river (at GPA Berth 20, at the barge location, and the US Army Corps of Engineers (USACE) Dock). Water quality monitoring sondes will be deployed at 1 meter below the surface, near mid depth, and 1 meter from the bottom at each location. Redundant sondes will also be deployed as a data check and to minimize potential data loss during the project. Personnel will be deployed regularly (at a minimum 4 times per week) to replace sondes.

In addition to the stationary locations, DO and water quality measurements will be taken in the river at various depths along horizontal and vertical transects. There will be five horizontal transects (at Berth 20, upstream of the Talmadge Bridge, at the barge location, at the convention center, and at the USACE Dock). Sampling will be performed centered on high or low slack tides (tides will vary during the project). The vertical transect will be along the center of the navigation channel and will include 13 locations extending from Berth 20 to the USACE Dock.

1 INTRODUCTION

This water quality monitoring plan for the Savannah Harbor ReOxygenation Demonstration Project (ReOx project), describes the methods that will be used to monitor dissolved oxygen (DO) and other water quality parameters (pH, specific conductivity, temperature, salinity, and water depth) for the demonstration. This effort is being conducted to aid GPA in assessing the oxygen addition mitigation alternative for the proposed Savannah Harbor deepening project. The deepening project will increase the depth of the harbor, allowing passage to the port of larger deep-draft container ships. Deepening of the harbor will result in reduced reoxygenation capacity for the river. The ReOx project mitigates for this lost reoxygenation capacity, and may ultimately lead to permanent ReOx system installations along the deepened harbor channel.

This water quality monitoring plan describes specific responsibilities, equipment requirements, operating procedures; and data quality objectives for water quality monitoring during the ReOx demonstration project.

2 SURFACE WATER MONITORING

2.1 Water Quality Monitoring Program

Water quality monitoring is to be conducted at select locations within the Savannah Harbor ReOx project area (Figure 1), to assess instream conditions before, during, and one week after the reoxygenation project demonstration period. The parameters to be monitored in the field include dissolved oxygen (DO), pH, conductivity, temperature, salinity, and water depth.

The pH, conductivity, and DO instrumentation will be calibrated prior to sondes deployment for the continuous monitoring, and twice-daily (at a minimum) for the weekly monitoring events. Continuous monitor sondes calibration will be checked (at least once a week), and calibration for weekly events will occur before use and at the end of the day. Instrument calibration and maintenance will be conducted in accordance with the manufacturer's instructions and the procedures specified in this monitoring plan. Additional calibration checks may be performed as site conditions dictate. All calibration data will be recorded and filed with the project field records.

2.1.1 Continuous Monitoring Schedule and Events

Three weeks prior to start up of the ReOx system, during the demonstration period, and continuing for one week after the shutdown of the ReOx system, in situ water quality monitoring will be conducted using YSI 6920 multi-parameter recording sondes. Fourteen (14) continuous monitoring sondes will be deployed to monitor water quality in the field. The sondes will continuously record water quality data at shallow, mid-, and deep river channel depths at the following temporary locations: upstream from the ReOx system; at the ReOx barge location; and downstream from the ReOx system (Figure 2). Duplicate sondes will be deployed at each location and depth to reduce the potential for data gaps resulting from instrument problems. Two additional monitoring stations will be setup at the ReOx system discharge, to measure the concentrations of DO injected into the river.

2.1.2 Continuous Monitoring Procedures

Water quality data will be automatically recorded at quarter-hour intervals for the locations shown in Figure 2. Field personnel will be deployed two (2) or more times per week to download

data from the sondes, verify the sondes are working properly, and provide maintenance. The sondes will be changed out and recalibrated on average twice every week. The reference standards for field instrument calibration are described in Appendix A of this plan. If there is evidence of fouling on the sondes or significant drift in the data, then the sondes will be changed out more often. To allow for uninterrupted data monitoring, scheduling for the change out and recalibration of the sondes will be such that a continuous monitoring sonde and its associated duplicate should not be changed at the same time during a particular station visit.

The YSI 6920 sondes must be calibrated and certified by the manufacturer or authorized representative prior to initial field deployment. Additional calibration of the sondes will be in accordance with the manufacturer's specification and the guidelines that are outlined for instrument calibration in this monitoring plan.

2.1.3 Supplemental Weekly Monitoring Schedule and Events

Each week, field personnel will collect supplemental water quality data "snapshots" using the river grid system defined in the EPA/USACE Savannah Harbor Water Quality Model (Tetra-Tech, 2005) that falls within the ReOx demonstration project area. Dissolved oxygen, pH, water depth, conductivity and salinity profiles will be taken to allow for spatial evaluation of water quality between the fixed continuous monitoring locations. This will also allow data to be collected at the bottom of the navigation channel where DO is typically lowest.

Hand held YSI 6290 multi-parameter sondes will be used to monitor water quality parameters. Five (5) select river transect locations (Figure 3) will be sampled on a weekly basis, beginning three (3) weeks before the ReOx system is turned on and continuing until one week after the ReOx system is shut down. A total of fourteen (14) points will be sampled within each transect cross section as follows:

Table 1

**Supplemental Weekly Monitoring
Schedule at Transect Locations
Savannah Harbor ReOxygenation
Water Quality Monitoring Plan**

Location Within Transect	Sampling Depth (ft)
Left and Right Overbank –outside of navigation channel	3 ft below surface 3 ft above bottom
Left and Right –within navigation channel	3 ft below surface depth mid-depth 3 ft above bottom
Center of navigation channel	3 ft below surface 1/3 of total depth 2/3 of total depth 3 ft above bottom
ft- feet	Prepared By: VUO 05/27/07 Checked By: MET 05/28/07

In addition, thirteen (13) longitudinal (Figure 4) sampling locations will be monitored weekly using the hand held YSI 6920 sondes. These mid-channel DO measurements will be taken at four (4) select depths: 3 ft below water surface; 1/3 of total depth; 2/3 of total depth; and 3 ft above bottom.

These weekly monitoring events will be timed to coincide with local slack tide conditions (low or height).

2.1.4 Weekly Monitoring Sampling Procedures

For the weekly water quality parameters monitoring, the standards for field instruments calibration, are explained in Appendix A of this document. A minimum of ten percent (10%) of field duplicate samples should be collected at the sampling locations to meet the measure of precision necessary to maintain and follow the quality control protocols for this water quality monitoring. Discrete quality assurance (QA) DO samples will be collected using Kemmerer or Van Dorn type water samplers (Figure 5). Samples will be fixed in the field and returned to the field laboratory for DO analysis.

3 DATA QUALITY OBJECTIVES

The data quality objective for the ReOx project is to arrive at a level of sufficient and credible data that supports a reasonable level of certainty that the monitoring results are correct. The quality controls for the ReOx project are limited to assessing the precision, representativeness, comparability, and accuracy of the monitored parameter values.

3.1 PRECISION

Precision is a measure of how reproducible the data collected are between duplicate samples. It determines the consistency of repeated samples that are tested. Precision measurements are obtained by the field team taking independent duplicate measurements for parameters recorded.

To evaluate the precision of field measurements for the ReOx project, duplicate measurements will be taken at the same time and place for the continuous monitoring points and ten percent (10%) of the weekly monitoring points. The relative percent difference between duplicate measurements will show how precise the data are for the parameters sampled.

3.2 ACCURACY

This is a measure of confidence that the data collected in the field reflect the true value of a given parameter. In this field monitoring, accuracy is primarily a function of proper instrument calibration. Over time, some instruments tend to drift away from their initial calibration. Different types of instruments are affected by drift to different degrees.

In order to check that the sondes are not drifting too far from calibration, periodic accuracy checks will be performed by checking and recalibrating the sondes at the frequencies specified in section two (2) of this plan, and observing the instrument reading of known reference standards. The ranges of expected values for DO, pH, conductivity, temperature, salinity, and water depths are shown in Table 2.

3.3 REPRESENTATIVENESS

Sampling sites and procedures used in this study have been designed so that the resulting data are representative of the conditions within the local study area. Systematic sampling has been designed in such a way that samples will be taken at different depths at five locations across the

river channel for five transects along the reach of the study area (Figure 3). These transects correspond to river grid boundaries that were used in previous Savannah River Modeling study (Tetra-Tech, 2005). In addition, thirteen (13) longitudinal sampling locations (Figure 4) have been selected for mid-channel DO measurements.

3.4 COMPLETENESS

The completeness of data quality controls relies on how many samples need to be taken to be able to use the information collected. Percent completeness is the number of planned measurements judged valid divided by the total number of measurements taken multiplied by 100. For example, should the field team take the required parameters at each of the five transects for the weekly monitoring stations plus at least 10% duplicate sample at each station the completeness factor will have been met.

3.5 COMPARABILITY

The data to be gathered by the field team extends over a planned period of about 13 weeks. The ReOx demonstration data will be compared with historic continuous monitoring data from the Savannah River Modeling study (Tetra-Tech, 2005). The ReOx demonstration project data will also be compared with concurrent monitoring data expected to be available from a recently installed USGS continuous monitoring station located at the U.S. Army Corps of Engineers dock (the downstream limit of the ReOx project area).

4 DATA MANAGEMENT AND QUALITY CONTROL

Field sampling personnel will be responsible for monitoring all the parameters at the required sampling frequency and locations specified in this plan. The following section provides a list of equipment that will be needed to conduct the field work outlined in this monitoring plan.

4.1 DATA LOGS AND FIELD NOTES

Monitoring data recorded on the YSI 6920 series logger from the continuous monitoring sites will be downloaded to field laptop computers at every sampling location visit. Scheduled monitoring data will also be downloaded to the field computer at the end of each day of sampling. Other data collected by other field equipments (e.g. GPS, Geo Collector, etc.) will be downloaded to the field computer regularly. All data downloaded to the field laptop computers will be backed up to other digital media (DVDs, memory sticks, etc.) at the end of every field sampling.

Field notes will be taken for all sampling sites and recorded in a bound field notebook. It is important that all observations be recorded while at the sampling site to reduce confusion of conditions or unusual events at different sites. Information recorded includes: identification of the monitoring site; date and time of sampling; identity of the sampler(s); results of field analyses; description of the weather, including percent cloud cover and air temperature; description of the site appearance; and any unusual conditions observed. The sampling team will also record information on precipitation that occurred in the days preceding each sampling event, which will be obtained from the nearest rain gage.

4.2 DATA ANALYSIS

A spreadsheet will be used to compile the data in the computer. The data will be analyzed by the project leader, and others. The results of the data will be compiled in the final project report.

Throughout the course of the ReOx demonstration data collection, data will be routinely screened for trends and suspect data. Screening will include calculation of the DO deficit and percent of DO saturation as ongoing data quality and consistency indicators.

5 EQUIPMENTS

The YSI 6920 global change sondes will be utilized during the measurement of all field parameters.

5.1 EQUIPMENT NEEDS

The equipments needed to monitor water quality for Savannah Harbor Study according to this plan are listed below:

- YSI 6920 Sondes
- Field Cable
- Laptop Computer
- 6095B MS-8/DB-9 Adapter
- Appropriate calibration standards
- GPS
- Life Jackets
- Bluecharts
- Thermometer
- 500-mL glass container
- Deionizer (maximum conductivity of 1 $\mu\text{S}/\text{cm}$)
- Cleaning equipment
- Hobby knife or scalpel
- Fine screw driver
- Extra AA-size alkaline batteries
- Field notebooks
- Beaker, 2,000 mL, glass or Teflon™
- Bottles for biological oxygen demand (BOD) analysis, glass stoppered, 300 mL
- Stirrer, magnetic
- Stirring bars, Teflon™ coated
- Cylinder, graduated, 250 mL
- Flask, Erlenmeyer, 250 mL
- Buret, 25-mL capacity with 0.05-mL graduations and Teflon™ stopcock
- Buret, support stand
- Buret, clamp, double
- Alkaline iodide-azide reagent
- Manganous sulfate reagent
- Sulfamic acid granules
- Sodium thiosulfate, 0.025 *N* titrant
- Starch indicator solution
- Clippers, for opening reagent pillows
- Appropriate safety gloves, glasses, and apron
- Waste disposal container
- White background sheet
- Bottle, squeeze dispenser, for deionized water
- Kemmerer or Van Dorn type sampler

5.2 FIELD INSTRUMENTS SPECIFICATION

The specification for the YSI 6920 Instrument is listed in the Table 2 below:

Table 2

**Field Instruments Specification
Savannah Harbor ReOxygenation
Water Quality Monitoring Plan**

PARAMETER	INSTRUMENT	RANGE	ACCURACY
Dissolved Oxygen	YSI 6920	0 to 50 mg/L	± 0.2 mg/L
pH	YSI 6920	0 to 14 units	± 0.2
Conductivity	YSI 6920	0 to 100 mS/cm	± 0.5 of reading + 0.001mS/cm
Temperature	YSI 6920	-5 to +50°C	$\pm 0.15^{\circ}\text{C}$
Salinity	YSI 6920	0 to 70 ppt	± 0.01 of reading or 0.1 ppt, whichever is greater
Water Depths	YSI 6920	0 to 200 ft	± 0.4 ft

mg/L – milligrams per liter

mS/cm – millisiemens per centimeter

 $^{\circ}\text{C}$ – degrees Celsius

ppt – part per thousand

ft – feet

5.3 ROUTINE MAINTENANCE

All equipment that will be used in the field to obtain water quality measurements will be maintained. At the beginning and end of each sampling day, equipment must be inspected for damage, or faulty parts and any problems reported to the project leader. The project leader will be responsible for all equipment, its repair status, and the ordering of parts. An equipment inventory will be maintained. Table 3 will serve as the field equipment maintenance record sheet.

Field Equipment Maintenance Record Sheet
Savannah Harbor ReOxygenation
Water Quality Monitoring Plan

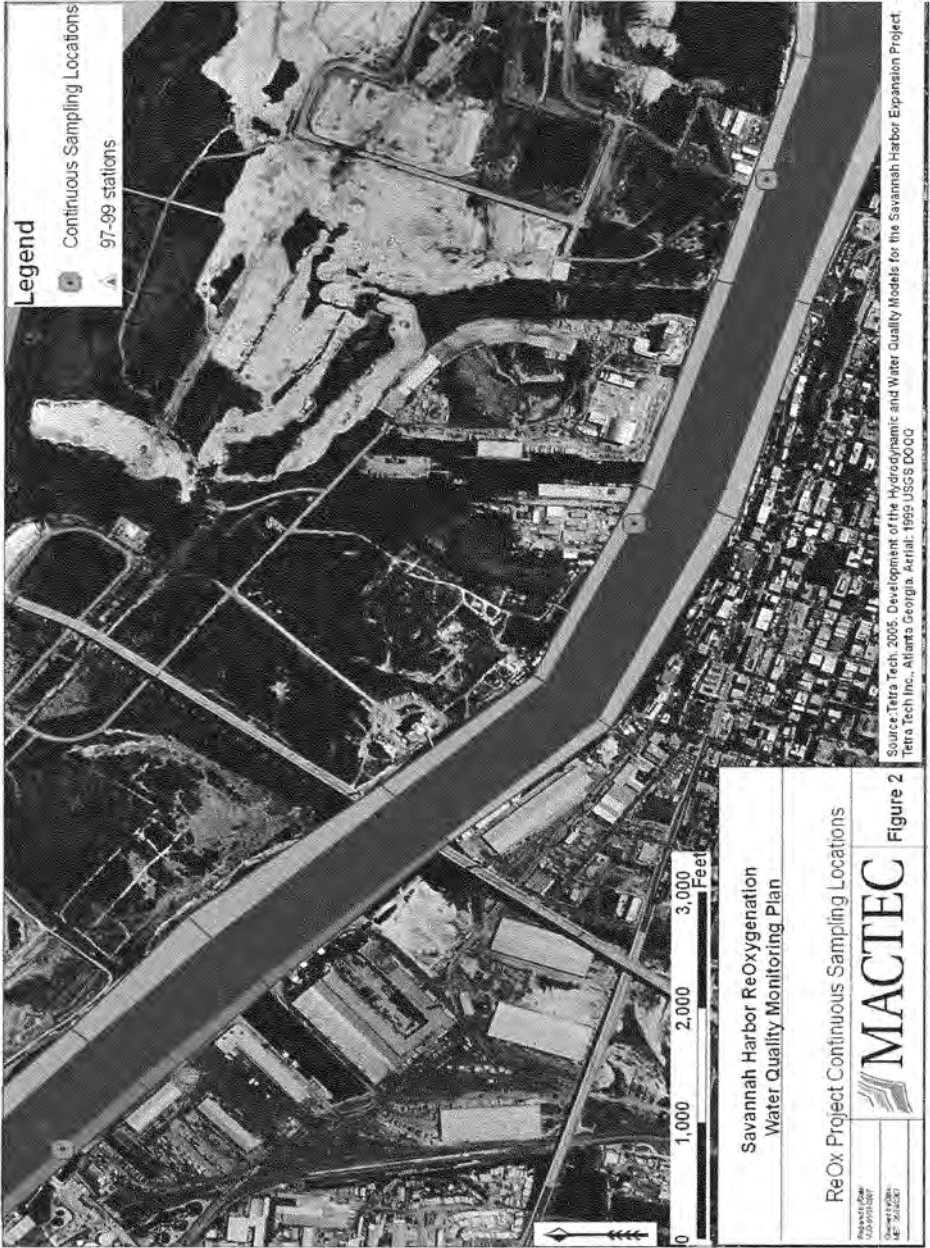
[illegible]

6 REFERENCES

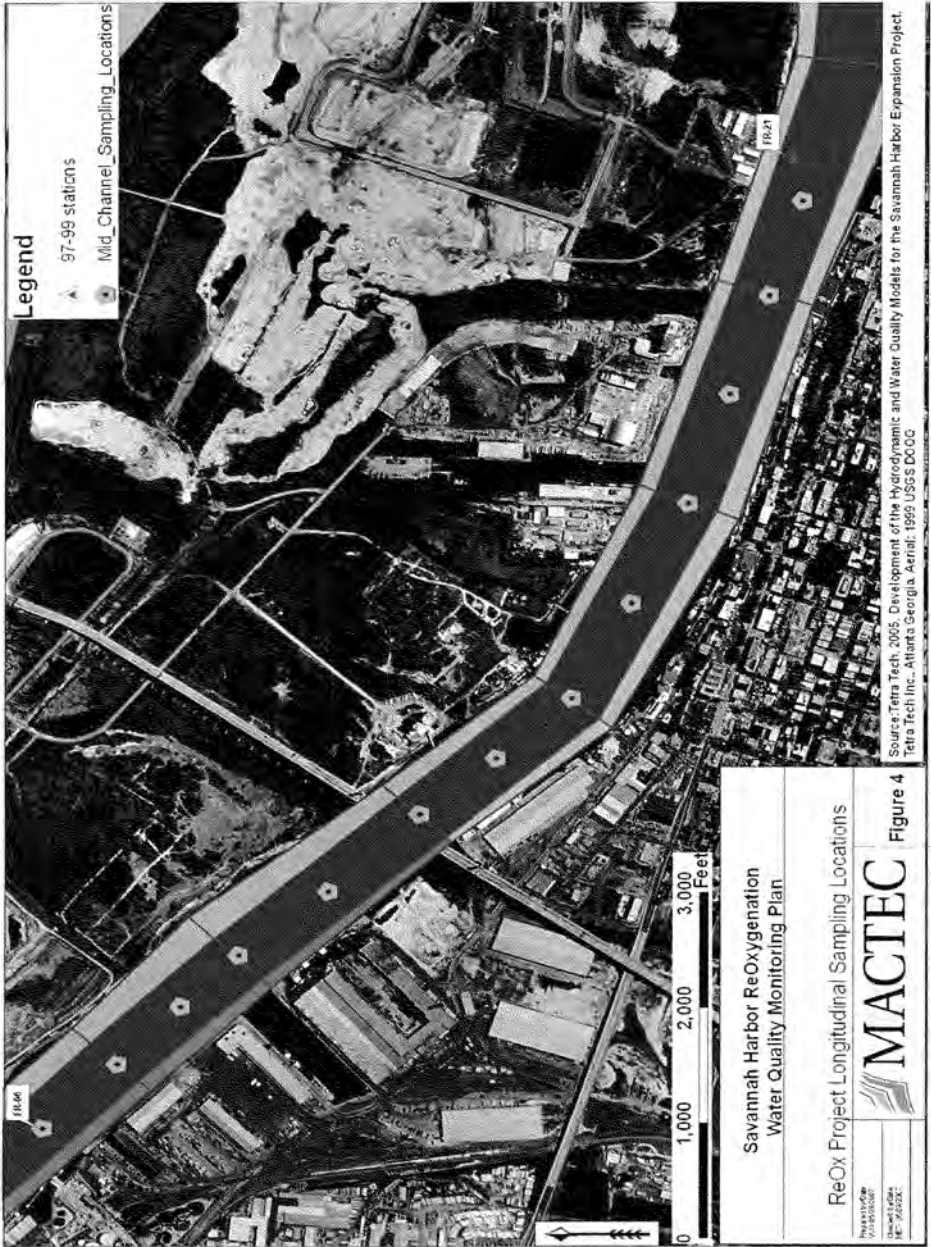
Tetra Tech. 2005. *Development of the Hydrodynamic and Water Quality Models for the Savannah Harbor Expansion Project*. Tetra Tech Inc., Atlanta Georgia.



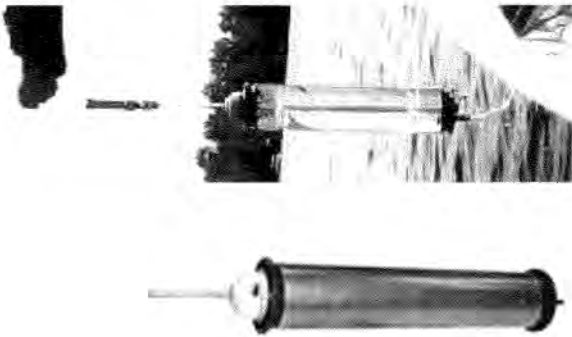








Typical samplers that will be used for collecting dissolved oxygen discrete quality assurance samples during weekly river transects.



Kemmerer Type Samplers

Van Dorn Type Samplers

Georgia Ports Authority
Savannah Harbor ReOx Project
Savannah, Georgia



Dissolved Oxygen Water Samplers

MACTEC Project Number: 6110070004

Figure 5

APPENDIX A

Calibration: The detailed procedure for the calibration of field instruments used to measure water quality parameters are outlined below:

DO: The DO probe will be calibrated the Winkler titration approach as outlined below:

Measure Dissolve Oxygen on at least two subsamples, for quality control. Results of two iodometric titrations should agree within 0.1 mg/L. If they do not agree, repeat the titration on a third subsample.

Follow steps step 1 and continue to the end to perform the iodometric titration in duplicate.

1. Fill a 2,000-mL beaker with deionized water that is near DO saturation. The water temperature should be close to the ambient (field or laboratory) temperature.
2. Prepare the DO instrument for operation according to the manufacturer's instructions.
3. Place the DO sensor in a beaker of distilled water. With a magnetic stirrer, maintain a velocity of at least 1 ft/s past the DO sensor.
4. Monitor the DO concentrations of the deionized water with the DO instrument and record the value after the readings have stabilized.
5. Carefully fill two biochemical oxygen demand (BOD) bottles with deionized water from the beaker, taking care to avoid introducing any air bubbles, and overflowing the bottles adequately to remove any trapped air bubbles.
6. Determine the DO concentration of the water in each BOD bottle, as follows:
 - a. Add one each of the following dry reagent pillow packets:
 - Alkaline iodide-azide (white powder).
 - Manganous sulfate (pinkish-colored powder).
 - b. Recap the bottle. **Do not allow air bubbles to be trapped in the bottle.**
 - c. Invert the bottle 25 times or more to completely dissolve the reagents.
 - An orange-brown flocculent indicates the presence of DO.
 - Allow the flocculent to settle halfway down the bottle (approximately 5 minutes).
 - Invert the bottle 25 times again; let the flocculent settle again until the upper half of the solution is clear.
 - d. Add one reagent pillow of sulfamic acid.
 - e. Recap the bottle without introducing air or air bubbles. Invert the bottle 25 times until all of the flocculent and granules are dissolved, leaving a yellow color.

- f. Fill a clean 25-mL burette with 0.025 *N (Normal)* sodium thiosulfate titrant. Remove any air bubbles from the delivery tube beneath the stopcock and zero the meniscus.
- g. Use a clean, graduated cylinder to measure 200 mL of the sample and pour the sample into a clean, wide-mouth Erlenmeyer flask.
- h. Place the flask on a magnetic stirrer. Add a clean Teflon™ stirring bar and stir the sample at a moderate rate **without aerating the sample**.
- i. Add increments of sodium thiosulfate titrant until the color turns pale straw-yellow.
- j. Add 1 to 2 mL of starch indicator solution. (This causes the sample to turn dark blue.)
- k. Very slowly add more sodium thiosulfate titrant until the sample just turns clear. (A white background behind the bottle will help you see the color change.)
- l. Record the volume of sodium thiosulfate titrant used, in milliliters.
 - For a 200-mL sample, the volume of titrant added is directly proportional to the amount of DO in milligrams per liter.
 - To calculate DO for a sample volume greater or less than 200 mL,

$$DO(mg/L) = \left(\frac{200}{\text{Sample Volume}} \right) \times \text{titrant added, in mL}$$

- m. Record the DO value. Rinse the equipment with deionized water.
- n. **Quality control**—The titration values for the duplicate samples should agree within 0.1 mg/L. If they do not, repeat the titration on a third sample.

7. Recheck the field instrument for proper functioning, following the manufacturer's instructions. Adjust the calibration control until the DO instrument system reads the DO concentration determined from the iodometric measurement.

NOTE: Be very careful when doing DO analyses. The reagents are corrosive, so keep them away from your skin and clothes. Wear safety goggles and wash your hands when you are done.

Temperature: Perform calibration according to manufacturer's suggestion, and compare results from two or more different temperature sensors taken at the same time and location.

pH: Perform calibration according to manufacturer's direction. Use of two buffers (pH 7 and 10) for calibration is recommended.

Specific Conductivity: Perform calibration according to manufacturer's direction. At least two standards should be used in specific conductivity calibration. One standard will serve as the approximate sample conductivity and the second standard as a calibration check.

Salinity: Perform calibration according to procedures outlined in manufacturers manual.

Water depth: Perform calibration according to procedures outlined in manufacturers manual.

Field Measurement: The detailed procedure that will be used to obtain the temperature, salinity, conductivity, pH, and DO at the sampling locations are outlined below.

- At each station, turn the meter on and place the probe into the water column;
- Allow sufficient time for the probe to stabilize before sampling the parameters;
- Record the reading;
- For the weekly field sampling, check the calibration of the instruments at the end of the day;
- Rinse the probe with distilled water;
- Turn off the instrument and handle the probe carefully so as not to damage it while in the field;
- Recheck the standard of the instrument at the end of each sampling and record the reading;
- Collect at least 10% of the samples from the weekly field monitoring locations and compare the results with the corresponding parameter on data logs.
- At least 10% of the DO measured each week should be compared to DO measurements using the Winkler method for samples collected from corresponding locations.

APPENDIX C

USACE Water Quality Monitoring Data, 2007

APPENDIX C

USACE Water Quality Monitoring Data, 2007

The USACE Water Quality Monitoring Data as provided by the USACE, Savannah District is provided here in tabular format. This data is also available on the Project DVD (Appendix A).

[illegible]

12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475
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3.56	1	Booth	The dredge was located in the center of the navigation channel, so that Center was fairly good level and down river.
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3.75	1	Bottom	The dredge was located in the center of the navigation channel, so that Carrier vessel traffic BQZ kept up and down frayed
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of the navigation channels, are built			
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94	94	94	94
95	95	95	95
96	96	96	96
97	97	97	97
98	98	98	98
99	99	99	99
100	100	100	100

Depth	Bottom
0-1 ft	Silt
1-2 ft	Mud
2-3 ft	Silt
3-4 ft	Gravel

Appendix C
USACE Storage Water Quality Monitoring Data

Date	Time	Direction	Time	Stage	Device	Location	Channel	Location	Lat (N)	Long (W)	Time	Temp (°C)	Salinity (ppt)	Dissolved Solids (mg/L)	pH	Acidity (meq/L)	DO (%)	DO (mg/L)	Flow (cfs)	Notes	Remarks
02/07/07	06:00	Outgoing	13:20	4.3	S1045	#11705	20.1486	Upstream (Peak)	31.1486	22.1320	13:15	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	22.1320	13:15	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	22.1320	13:15	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	22.1320	13:15	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	22.1320	13:15	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	22.1320	13:15	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	22.1320	13:15	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	22.1320	13:15	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	22.1320	13:15	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	22.1320	13:15	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
05/05/07	06:00	Outgoing	17:17	4.3	S1045	#11714	22.1332	Upstream (Peak)	31.1486	22.1332	17:10	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	22.1332	17:10	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	22.1332	17:10	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	22.1332	17:10	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	22.1332	17:10	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	22.1332	17:10	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	22.1332	17:10	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	22.1332	17:10	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	22.1332	17:10	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	22.1332	17:10	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
07/05/07	06:00	Outgoing	18:00	5.0	S1045	#11800	20.1340	Upstream (Peak)	31.1486	20.1340	17:55	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	20.1340	17:55	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	20.1340	17:55	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	20.1340	17:55	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	20.1340	17:55	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	20.1340	17:55	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	20.1340	17:55	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	20.1340	17:55	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	20.1340	17:55	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	20.1340	17:55	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
09/05/07	06:00	Incoming	12:10	8.1	S1045	#11800	20.1340	Upstream (Peak)	31.1486	20.1340	12:05	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	20.1340	12:05	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	20.1340	12:05	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	20.1340	12:05	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	20.1340	12:05	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	20.1340	12:05	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	20.1340	12:05	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	20.1340	12:05	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	20.1340	12:05	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0
								Upstream (Peak)	31.1486	20.1340	12:05	20.0	0.0	1.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0

November 15, 2007

Thames Valley Bioscience Research Project
MAGTEC Engineering and Consulting, Inc.
Project 0104-07-0004

Appendix C
USACE Bridge Water Quality Monitoring Data

Date	Time	Station	Depth (m)	Temp (°C)	Salinity (ppt)	pH	DO (mg/L)	Site	Notes	Remarks							
04/20/2007	16:21	8.8	1004000	81.4501	23.1900	Upstream (North)	81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
04/20/2007	16:21	8.8	1004000	81.4501	23.1900	Downstream (South)	81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
04/20/2007	16:21	8.8	1004000	81.4501	23.1900	Upstream (North)	81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
04/20/2007	16:21	8.8	1004000	81.4501	23.1900	Downstream (South)	81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
04/20/2007	16:21	8.8	1004000	81.4501	23.1900	Upstream (North)	81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
04/20/2007	16:21	8.8	1004000	81.4501	23.1900	Downstream (South)	81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	
						81.4501	23.1900	1.0	18.5	1.0	7.2	0.0	0.0	Station	Station	Station	

Station: USACE Bridge Water Quality Monitoring Data, 2007

USACE Dredge Water Quality Monitoring Data
Appendix C

Date	Time (MST)		Dredge Station	Dredge Lat (N)	Dredge Long (W)	Location (with the dredge)	Channel Profile	Lat (N)	Long (W)	Temp (°C)	No. Gird (#Girders)	Salinity (ppt)	Depth (ft)	pH	Turbidity (NTU)	DO (mg/L)	Silt #	Notes	Comments
	Offset	Time																	
8/15/07	morning	14:30	B14-15	31.13974	-82.13271	Dredge #1 (14-15)	C14-15	31.13974	-82.13271	28.48	30.00	33.33	4.00	6.8	2.0	4.0	1	A. 14-15	C. 14-15
								31.13974	-82.13271	28.48	30.00	33.33	4.00	6.8	2.0	4.0	1		
								31.13974	-82.13271	28.48	30.00	33.33	4.00	6.8	2.0	4.0	1		
								31.13974	-82.13271	28.48	30.00	33.33	4.00	6.8	2.0	4.0	1		
								31.13974	-82.13271	28.48	30.00	33.33	4.00	6.8	2.0	4.0	1		
								31.13974	-82.13271	28.48	30.00	33.33	4.00	6.8	2.0	4.0	1		
								31.13974	-82.13271	28.48	30.00	33.33	4.00	6.8	2.0	4.0	1		
								31.13974	-82.13271	28.48	30.00	33.33	4.00	6.8	2.0	4.0	1		
								31.13974	-82.13271	28.48	30.00	33.33	4.00	6.8	2.0	4.0	1		
								31.13974	-82.13271	28.48	30.00	33.33	4.00	6.8	2.0	4.0	1		
8/15/07	morning	14:30	B14-15	31.13974	-82.13271	Dredge #2 (14-15)	C14-15	31.13974	-82.13271	28.48	30.00	33.33	4.00	6.8	2.0	4.0	1	A. 14-15	C. 14-15
								31.13974	-82.13271	28.48	30.00	33.33	4.00	6.8	2.0	4.0	1		
								31.13974	-82.13271	28.48	30.00	33.33	4.00	6.8	2.0	4.0	1		
								31.13974	-82.13271	28.48	30.00	33.33	4.00	6.8	2.0	4.0	1		
								31.13974	-82.13271	28.48	30.00	33.33	4.00	6.8	2.0	4.0	1		
								31.13974	-82.13271	28.48	30.00	33.33	4.00	6.8	2.0	4.0	1		
								31.13974	-82.13271	28.48	30.00	33.33	4.00	6.8	2.0	4.0	1		
								31.13974	-82.13271	28.48	30.00	33.33	4.00	6.8	2.0	4.0	1		
								31.13974	-82.13271	28.48	30.00	33.33	4.00	6.8	2.0	4.0	1		
								31.13974	-82.13271	28.48	30.00	33.33	4.00	6.8	2.0	4.0	1		
8/15/07	morning	14:30	B14-15	31.13974	-82.13271	Dredge #3 (14-15)	C14-15	31.13974	-82.13271	28.48	30.00	33.33	4.00	6.8	2.0	4.0	1	A. 14-15	C. 14-15
								31.13974	-82.13271	28.48	30.00	33.33	4.00	6.8	2.0	4.0	1		
								31.13974	-82.13271	28.48	30.00	33.33	4.00	6.8	2.0	4.0	1		
								31.13974	-82.13271	28.48	30.00	33.33	4.00	6.8	2.0	4.0	1		
								31.13974	-82.13271	28.48	30.00	33.33	4.00	6.8	2.0	4.0	1		
								31.13974	-82.13271	28.48	30.00	33.33	4.00	6.8	2.0	4.0	1		
								31.13974	-82.13271	28.48	30.00	33.33	4.00	6.8	2.0	4.0	1		
								31.13974	-82.13271	28.48	30.00	33.33	4.00	6.8	2.0	4.0	1		
								31.13974	-82.13271	28.48	30.00	33.33	4.00	6.8	2.0	4.0	1		
								31.13974	-82.13271	28.48	30.00	33.33	4.00	6.8	2.0	4.0	1		

November 13, 2007

Removal Water Flowmeter, Downstream Project
 AMETEC Engineering and Consulting, Inc.
 Project #1507-004

Appendix C USACE Design Water Quality Monitoring Data

Date	Time/Start to End/Stop	Design Station	Design Loc. (N)	Location, 1000 feet from Design Loc. (N)	Channel Position	Loc. (N)	Lat. (N)	Temp (°C)	Depth (feet)	pH	Salinity (ppt/‰)	D.O. (mg/L)	Size	Noise	Parameter	Comments			
7/15/2007	Outgoing 13:04 - 4:3	81-1200	81-1200	32-1194	Center	81-1202	32-115	10.46	28.95	10.87	5.29	33.74	1.62	38.5	44.5	2.32	1	Bottom	The design was located in the center of the navigation channel, no pilot channel. Center was taken 500 feet up and down river.
					Down-Current (Downstream)	81-1205	32-1160	10.46	28.95	10.87	5.29	33.74	1.62	38.5	44.5	2.32	1	Bottom	
					Up-Current (Upstream)	81-1200	32-1167	10.46	28.95	10.87	5.29	33.74	1.62	38.5	44.5	2.32	1	Bottom	The design was located in the center of the navigation channel, no pilot channel. Center was taken 500 feet up and down river.
7/16/2007	Outgoing 14:41 - 4:54	81-1200	81-1200	32-1129	Center	81-1202	32-115	10.46	28.95	10.87	5.29	33.74	1.62	38.5	44.5	2.32	1	Bottom	The design was located in the center of the navigation channel, no pilot channel. Center was taken 500 feet up and down river.
					Down-Current (Downstream)	81-1205	32-1160	10.46	28.95	10.87	5.29	33.74	1.62	38.5	44.5	2.32	1	Bottom	
					Up-Current (Upstream)	81-1200	32-1167	10.46	28.95	10.87	5.29	33.74	1.62	38.5	44.5	2.32	1	Bottom	The design was located in the center of the navigation channel, no pilot channel. Center was taken 500 feet up and down river.
7/16/2007	Outgoing 17:14 - 4:1	85-4500	81-1204	32-1132	Center	81-1202	32-115	10.46	28.95	10.87	5.29	33.74	1.62	38.5	44.5	2.32	1	Bottom	The design was located in the center of the navigation channel, no pilot channel. Center was taken 500 feet up and down river.
					Down-Current (Downstream)	81-1205	32-1160	10.46	28.95	10.87	5.29	33.74	1.62	38.5	44.5	2.32	1	Bottom	
					Up-Current (Upstream)	81-1200	32-1167	10.46	28.95	10.87	5.29	33.74	1.62	38.5	44.5	2.32	1	Bottom	The design was located in the center of the navigation channel, no pilot channel. Center was taken 500 feet up and down river.
7/17/2007	Outgoing 17:50 - 0:2	81-1200	81-1204	32-1136	Center	81-1202	32-115	10.46	28.95	10.87	5.29	33.74	1.62	38.5	44.5	2.32	1	Bottom	The design was located in the center of the navigation channel, no pilot channel. Center was taken 500 feet up and down river.
					Down-Current (Downstream)	81-1205	32-1160	10.46	28.95	10.87	5.29	33.74	1.62	38.5	44.5	2.32	1	Bottom	
					Up-Current (Upstream)	81-1200	32-1167	10.46	28.95	10.87	5.29	33.74	1.62	38.5	44.5	2.32	1	Bottom	The design was located in the center of the navigation channel, no pilot channel. Center was taken 500 feet up and down river.
7/18/2007	Outgoing 18:37 - 0:7	84-020	81-1202	32-1124	Center	81-1202	32-115	10.46	28.95	10.87	5.29	33.74	1.62	38.5	44.5	2.32	1	Bottom	The design was located in the center of the navigation channel, no pilot channel. Center was taken 500 feet up and down river.
					Down-Current (Downstream)	81-1205	32-1160	10.46	28.95	10.87	5.29	33.74	1.62	38.5	44.5	2.32	1	Bottom	
					Up-Current (Upstream)	81-1200	32-1167	10.46	28.95	10.87	5.29	33.74	1.62	38.5	44.5	2.32	1	Bottom	The design was located in the center of the navigation channel, no pilot channel. Center was taken 500 feet up and down river.
7/18/2007	Incoming 12:16 - 7:4	80-480	81-1205	32-1104	Center	81-1202	32-115	10.46	28.95	10.87	5.29	33.74	1.62	38.5	44.5	2.32	1	Bottom	The design was located in the center of the navigation channel, no pilot channel. Center was taken 500 feet up and down river.
					Down-Current (Downstream)	81-1205	32-1160	10.46	28.95	10.87	5.29	33.74	1.62	38.5	44.5	2.32	1	Bottom	
					Up-Current (Upstream)	81-1200	32-1167	10.46	28.95	10.87	5.29	33.74	1.62	38.5	44.5	2.32	1	Bottom	The design was located in the center of the navigation channel, no pilot channel. Center was taken 500 feet up and down river.
7/18/2007	Incoming 14:04 - 7:4	50-800	81-1204	32-1116	Center	81-1202	32-115	10.46	28.95	10.87	5.29	33.74	1.62	38.5	44.5	2.32	1	Bottom	The design was located in the center of the navigation channel, no pilot channel. Center was taken 500 feet up and down river.
					Down-Current (Downstream)	81-1205	32-1160	10.46	28.95	10.87	5.29	33.74	1.62	38.5	44.5	2.32	1	Bottom	
					Up-Current (Upstream)	81-1200	32-1167	10.46	28.95	10.87	5.29	33.74	1.62	38.5	44.5	2.32	1	Bottom	The design was located in the center of the navigation channel, no pilot channel. Center was taken 500 feet up and down river.
7/22/2007	Incoming 18:23 - 7:8	84-400	81-1204	32-1054	Center	81-1202	32-115	10.46	28.95	10.87	5.29	33.74	1.62	38.5	44.5	2.32	1	Bottom	The design was located in the center of the navigation channel, no pilot channel. Center was taken 500 feet up and down river.
					Down-Current (Downstream)	81-1205	32-1160	10.46	28.95	10.87	5.29	33.74	1.62	38.5	44.5	2.32	1	Bottom	
					Up-Current (Upstream)	81-1200	32-1167	10.46	28.95	10.87	5.29	33.74	1.62	38.5	44.5	2.32	1	Bottom	The design was located in the center of the navigation channel, no pilot channel. Center was taken 500 feet up and down river.

Source: USACE Design Water Quality Measurements, 2007

Appendix C
USACE Bridges Water Quality Monitoring Data[illegible]

APPENDIX D

Field References (Solubility of Oxygen in Water and Local Tides Charts)

Table 6.2-6. Solubility of oxygen in water at various temperatures and pressures
 [From R.F. Weiss (1970). Temp °C, temperature in degrees Celsius; atmospheric pressures from 695 to 600 millimeters mercury begin after 40°C]

Temp °C	Atmospheric pressure, in millimeters of mercury																			
	795	790	785	780	775	770	765	760	755	750	745	740	735	730	725	720	715	710	705	700
0.0	15.3	15.2	15.1	15.0	14.9	14.8	14.7	14.6	14.5	14.4	14.3	14.2	14.1	14.0	13.9	13.8	13.7	13.6	13.5	13.4
0.5	15.1	15.0	14.9	14.8	14.7	14.6	14.5	14.4	14.3	14.2	14.1	14.0	13.9	13.8	13.7	13.6	13.5	13.4	13.3	13.2
1.0	14.9	14.8	14.7	14.6	14.5	14.4	14.3	14.2	14.1	14.0	13.9	13.8	13.7	13.6	13.5	13.4	13.3	13.2	13.1	13.0
1.5	14.8	14.7	14.6	14.5	14.4	14.3	14.2	14.1	14.0	13.9	13.8	13.7	13.6	13.5	13.4	13.3	13.2	13.1	13.0	12.9
2.0	14.6	14.5	14.4	14.3	14.2	14.1	14.0	13.9	13.8	13.7	13.6	13.5	13.4	13.3	13.2	13.1	13.0	12.9	12.8	12.7
2.5	14.4	14.2	14.1	14.0	13.9	13.8	13.7	13.6	13.5	13.4	13.3	13.2	13.1	13.0	12.9	12.8	12.7	12.6	12.5	12.4
3.0	14.2	14.0	13.9	13.8	13.7	13.6	13.5	13.4	13.3	13.2	13.1	13.0	12.9	12.8	12.7	12.6	12.5	12.4	12.3	12.2
3.5	13.9	13.8	13.7	13.6	13.5	13.4	13.3	13.2	13.1	13.0	12.9	12.8	12.7	12.6	12.5	12.4	12.3	12.2	12.1	12.0
4.0	13.7	13.6	13.5	13.4	13.3	13.2	13.1	13.0	12.9	12.8	12.7	12.6	12.5	12.4	12.3	12.2	12.1	12.0	11.9	11.8
4.5	13.5	13.4	13.3	13.2	13.1	13.0	12.9	12.8	12.7	12.6	12.5	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.6
5.0	13.3	13.2	13.1	13.0	12.9	12.8	12.7	12.6	12.5	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4
5.5	13.2	13.1	13.0	12.9	12.8	12.7	12.6	12.5	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3
6.0	13.0	12.9	12.8	12.7	12.6	12.5	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1
6.5	12.8	12.7	12.6	12.5	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.0	10.9
7.0	12.7	12.6	12.5	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.8
7.5	12.5	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.7	10.6
8.0	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.7	10.6	10.5
8.5	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.3
9.0	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.3	10.2
9.5	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.3	10.2	10.1	10.0
10.0	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.3	10.2	10.1	10.0	9.9
10.5	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.3	10.2	10.1	10.0	9.9	9.8
11.0	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.3	10.2	10.1	10.0	9.9	9.8	9.7	9.6
11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.3	10.2	10.1	10.0	9.9	9.8	9.7	9.6	9.5
12.0	11.3	11.2	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.3	10.2	10.1	10.0	9.9	9.8	9.7	9.6	9.5	9.4
12.5	11.1	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.3	10.2	10.1	10.0	9.9	9.8	9.7	9.6	9.5	9.4	9.3
13.0	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.3	10.2	10.1	10.0	9.9	9.8	9.7	9.6	9.5	9.4	9.3	9.2	9.1
13.5	10.9	10.8	10.7	10.6	10.5	10.4	10.3	10.2	10.1	10.0	9.9	9.8	9.7	9.6	9.5	9.4	9.3	9.2	9.1	9.0
14.0	10.8	10.7	10.6	10.5	10.4	10.3	10.2	10.1	10.0	9.9	9.8	9.7	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9
14.5	10.6	10.5	10.4	10.3	10.2	10.1	10.0	9.9	9.8	9.7	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8	8.7

Table 6.2-6. Solubility of oxygen in water at various temperatures and pressures—Continued

Temp °C	Atmospheric pressure, in millimeters of mercury																			
	795	790	785	780	775	770	765	760	755	750	745	740	735	730	725	720	715	710	705	700
15.0	10.5	10.5	10.4	10.3	10.3	10.2	10.1	10.1	10.0	9.9	9.9	9.8	9.7	9.7	9.6	9.5	9.5	9.4	9.3	9.3
15.5	10.4	10.4	10.3	10.2	10.2	10.1	10.0	10.0	9.9	9.8	9.8	9.7	9.6	9.6	9.5	9.4	9.4	9.3	9.2	9.2
16.0	10.3	10.3	10.2	10.1	10.1	10.0	9.9	9.8	9.8	9.7	9.7	9.6	9.5	9.5	9.4	9.3	9.3	9.2	9.1	9.1
16.5	10.2	10.1	10.1	10.0	9.9	9.8	9.8	9.7	9.7	9.6	9.5	9.4	9.4	9.3	9.3	9.2	9.1	9.0	8.9	8.9
17.0	10.1	10.0	10.0	9.9	9.8	9.8	9.7	9.6	9.6	9.5	9.4	9.4	9.3	9.3	9.2	9.1	9.1	9.0	8.9	8.9
17.5	10.0	9.9	9.9	9.8	9.7	9.7	9.6	9.5	9.5	9.4	9.3	9.3	9.2	9.2	9.1	9.0	8.9	8.8	8.7	8.7
18.0	9.9	9.8	9.8	9.7	9.6	9.6	9.5	9.4	9.4	9.3	9.2	9.2	9.1	9.1	9.0	8.9	8.8	8.7	8.6	8.6
18.5	9.8	9.7	9.7	9.6	9.5	9.5	9.4	9.3	9.3	9.2	9.1	9.1	9.0	9.0	8.9	8.8	8.7	8.6	8.5	8.5
19.0	9.7	9.6	9.6	9.5	9.4	9.4	9.3	9.2	9.2	9.1	9.1	9.0	8.9	8.9	8.8	8.7	8.6	8.5	8.4	8.4
19.5	9.6	9.5	9.5	9.4	9.3	9.3	9.2	9.2	9.1	9.0	9.0	8.9	8.8	8.8	8.7	8.6	8.5	8.4	8.3	8.3
20.0	9.5	9.4	9.4	9.3	9.2	9.2	9.1	9.0	8.9	8.9	8.8	8.8	8.7	8.7	8.6	8.5	8.4	8.3	8.2	8.2
20.5	9.4	9.3	9.3	9.2	9.1	9.1	9.0	8.9	8.9	8.8	8.7	8.7	8.6	8.6	8.5	8.4	8.3	8.2	8.1	8.1
21.0	9.3	9.2	9.2	9.1	9.0	8.9	8.9	8.8	8.8	8.7	8.6	8.6	8.5	8.5	8.4	8.3	8.2	8.1	8.0	8.0
21.5	9.2	9.1	9.1	9.0	8.9	8.8	8.8	8.7	8.7	8.6	8.5	8.5	8.4	8.4	8.3	8.2	8.1	8.0	7.9	7.9
22.0	9.1	9.0	9.0	8.9	8.8	8.7	8.7	8.6	8.5	8.5	8.4	8.3	8.3	8.2	8.2	8.1	8.0	7.9	7.8	7.8
22.5	9.0	8.9	8.8	8.8	8.7	8.7	8.6	8.5	8.5	8.4	8.3	8.3	8.2	8.1	8.1	8.0	7.9	7.8	7.7	7.7
23.0	8.9	8.8	8.8	8.7	8.6	8.6	8.5	8.4	8.4	8.3	8.3	8.2	8.1	8.1	8.0	7.9	7.8	7.7	7.6	7.6
23.5	8.8	8.7	8.7	8.6	8.5	8.5	8.4	8.3	8.3	8.2	8.2	8.1	8.0	8.0	7.9	7.8	7.7	7.6	7.5	7.5
24.0	8.7	8.7	8.6	8.6	8.5	8.5	8.4	8.3	8.3	8.2	8.2	8.1	8.0	7.9	7.9	7.8	7.7	7.6	7.5	7.5
24.5	8.7	8.7	8.6	8.5	8.5	8.4	8.4	8.3	8.3	8.2	8.1	8.1	8.0	8.0	7.9	7.8	7.7	7.6	7.5	7.5
25.0	8.6	8.6	8.5	8.5	8.4	8.3	8.3	8.2	8.2	8.1	8.1	8.0	7.9	7.9	7.8	7.8	7.7	7.6	7.5	7.5
25.5	8.5	8.5	8.4	8.4	8.3	8.3	8.2	8.2	8.1	8.1	8.0	7.9	7.9	7.8	7.8	7.7	7.6	7.5	7.4	7.4
26.0	8.5	8.4	8.4	8.3	8.3	8.2	8.1	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.7	7.6	7.5	7.4	7.4	7.4
26.5	8.4	8.3	8.3	8.2	8.2	8.1	8.1	8.0	8.0	7.9	7.8	7.8	7.7	7.7	7.6	7.5	7.4	7.3	7.3	7.3
27.0	8.3	8.3	8.2	8.2	8.1	8.0	8.0	7.9	7.9	7.8	7.7	7.7	7.6	7.6	7.5	7.4	7.3	7.2	7.2	7.2
27.5	8.2	8.2	8.1	8.1	8.0	7.9	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.5	7.4	7.4	7.3	7.2	7.1	7.1
28.0	8.1	8.1	8.0	8.0	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.2	7.1	7.0	7.0
28.5	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.5	7.4	7.4	7.3	7.2	7.1	7.0	6.9	6.9
29.0	8.0	8.0	7.9	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.5	7.4	7.4	7.3	7.2	7.1	7.0	6.9	6.8	6.8
29.5	8.0	7.9	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.5	7.4	7.4	7.3	7.2	7.1	7.0	6.9	6.8	6.7	6.7

Table 6.2-6. Solubility of oxygen in water at various temperatures and pressures—Continued

Temp °C	Atmospheric pressure, in millimeters of mercury																			
	795	790	785	780	775	770	765	760	755	750	745	740	735	730	725	720	715	710	705	700
30.0	7.9	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.3	7.2	7.2	7.1	7.1	7.0	7.0	6.9
30.5	7.8	7.7	7.7	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8
31.0	7.8	7.7	7.7	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.7
31.5	7.7	7.6	7.6	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.7	6.7
32.0	7.6	7.5	7.5	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6
32.5	7.5	7.4	7.4	7.3	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.4
33.0	7.5	7.4	7.4	7.3	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.8	6.8	6.7	6.6	6.6	6.5	6.5	6.4	6.4
33.5	7.4	7.3	7.3	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.7	6.7	6.6	6.5	6.5	6.4	6.4	6.3	6.3
34.0	7.3	7.2	7.2	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.7	6.6	6.6	6.5	6.4	6.4	6.3	6.3	6.2	6.2
34.5	7.2	7.1	7.1	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.5	6.5	6.4	6.3	6.3	6.2	6.2	6.1	6.1
35.0	7.1	7.0	7.0	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0
35.5	7.0	6.9	6.9	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9
36.0	6.9	6.8	6.8	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8
36.5	6.8	6.7	6.7	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7
37.0	6.7	6.6	6.6	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6
37.5	6.6	6.5	6.5	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5
38.0	6.5	6.4	6.4	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4
38.5	6.4	6.3	6.3	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4	5.3
39.0	6.3	6.2	6.2	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.6	5.6	5.5	5.5	5.4	5.4	5.3	5.3	5.2
39.5	6.2	6.1	6.1	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.5	5.5	5.4	5.4	5.3	5.3	5.2	5.2	5.1
40.0	6.1	6.0	6.0	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.4	5.4	5.3	5.3	5.2	5.2	5.1	5.1	5.0

Table 6.2-6. Solubility of oxygen in water at various temperatures and pressures—Continued

Temp °C	Atmospheric pressure, in millimeters of mercury																		
	698	690	685	680	675	670	665	660	655	650	645	640	635	630	625	620	615	610	600
0.0	13.3	13.2	13.1	13.0	12.9	12.8	12.6	12.5	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.5
0.5	13.1	13.0	12.9	12.8	12.7	12.6	12.5	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3
1.0	13.0	12.8	12.8	12.7	12.6	12.5	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.2
1.5	12.8	12.7	12.6	12.5	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.0
2.0	12.6	12.5	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.8
2.5	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.7	10.6
3.0	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.7	10.6	10.5
3.5	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.3
4.0	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.3	10.2
4.5	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.3	10.2	10.1	10.0
5.0	11.6	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.3	10.2	10.1	10.0	9.9	9.8
5.5	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.3	10.2	10.1	10.0	9.9	9.8	9.7
6.0	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.3	10.2	10.1	10.0	9.9	9.8	9.7	9.6
6.5	11.2	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.3	10.2	10.1	10.0	9.9	9.8	9.7	9.6	9.5	9.4
7.0	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.3	10.2	10.1	10.0	9.9	9.8	9.7	9.6	9.5	9.4	9.3
7.5	10.9	10.8	10.7	10.6	10.5	10.4	10.3	10.2	10.1	10.0	9.9	9.8	9.7	9.6	9.5	9.4	9.3	9.2	9.1
8.0	10.8	10.7	10.6	10.5	10.4	10.3	10.2	10.1	10.0	9.9	9.8	9.7	9.6	9.5	9.4	9.3	9.2	9.1	9.0
8.5	10.7	10.6	10.5	10.4	10.3	10.2	10.1	10.0	9.9	9.8	9.7	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9
9.0	10.5	10.4	10.3	10.2	10.1	10.0	9.9	9.8	9.7	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8	8.7
9.5	10.4	10.3	10.2	10.1	10.0	9.9	9.8	9.7	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8	8.7	8.6
10.0	10.3	10.2	10.1	10.0	9.9	9.8	9.7	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8	8.7	8.6	8.5
10.5	10.2	10.1	10.0	9.9	9.8	9.7	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8	8.7	8.6	8.5	8.4
11.0	10.1	10.0	9.9	9.8	9.7	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8	8.7	8.6	8.5	8.4	8.3
11.5	9.9	9.8	9.7	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8	8.7	8.6	8.5	8.4	8.3	8.2	8.1
12.0	9.8	9.7	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8	8.7	8.6	8.5	8.4	8.3	8.2	8.1	8.0
12.5	9.7	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8	8.7	8.6	8.5	8.4	8.3	8.2	8.1	8.0	7.9
13.0	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8	8.7	8.6	8.5	8.4	8.3	8.2	8.1	8.0	7.9	7.8
13.5	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8	8.7	8.6	8.5	8.4	8.3	8.2	8.1	8.0	7.9	7.8	7.7
14.0	9.4	9.3	9.2	9.1	9.0	8.9	8.8	8.7	8.6	8.5	8.4	8.3	8.2	8.1	8.0	7.9	7.8	7.7	7.6
14.5	9.3	9.2	9.1	9.0	8.9	8.8	8.7	8.6	8.5	8.4	8.3	8.2	8.1	8.0	7.9	7.8	7.7	7.6	7.5

Table 6.2-6. Solubility of oxygen in water at various temperatures and pressures—Continued

Temp °C	Atmospheric pressure, in millimeters of mercury																		
	595	590	585	580	575	570	565	560	555	550	545	540	535	530	525	520	515	510	500
15.0	9.2	9.1	9.1	9.0	8.9	8.8	8.7	8.6	8.5	8.4	8.3	8.2	8.1	8.0	7.9	7.8	7.7	7.6	7.5
15.5	9.1	9.0	8.9	8.8	8.7	8.6	8.5	8.4	8.3	8.2	8.1	8.0	7.9	7.8	7.7	7.6	7.5	7.4	7.3
16.0	9.0	8.9	8.8	8.7	8.6	8.5	8.4	8.3	8.2	8.1	8.0	7.9	7.8	7.7	7.6	7.5	7.4	7.3	7.2
16.5	8.9	8.8	8.7	8.6	8.5	8.4	8.3	8.2	8.1	8.0	7.9	7.8	7.7	7.6	7.5	7.4	7.3	7.2	7.1
17.0	8.8	8.7	8.6	8.5	8.4	8.3	8.2	8.1	8.0	7.9	7.8	7.7	7.6	7.5	7.4	7.3	7.2	7.1	7.0
17.5	8.7	8.6	8.5	8.4	8.3	8.2	8.1	8.0	7.9	7.8	7.7	7.6	7.5	7.4	7.3	7.2	7.1	7.0	6.9
18.0	8.6	8.5	8.4	8.3	8.2	8.1	8.0	7.9	7.8	7.7	7.6	7.5	7.4	7.3	7.2	7.1	7.0	6.9	6.8
18.5	8.5	8.4	8.3	8.2	8.1	8.0	7.9	7.8	7.7	7.6	7.5	7.4	7.3	7.2	7.1	7.0	6.9	6.8	6.7
19.0	8.4	8.3	8.2	8.1	8.0	7.9	7.8	7.7	7.6	7.5	7.4	7.3	7.2	7.1	7.0	6.9	6.8	6.7	6.6
19.5	8.3	8.2	8.1	8.0	7.9	7.8	7.7	7.6	7.5	7.4	7.3	7.2	7.1	7.0	6.9	6.8	6.7	6.6	6.5
20.0	8.2	8.1	8.0	7.9	7.8	7.7	7.6	7.5	7.4	7.3	7.2	7.1	7.0	6.9	6.8	6.7	6.6	6.5	6.4
20.5	8.1	8.0	7.9	7.8	7.7	7.6	7.5	7.4	7.3	7.2	7.1	7.0	6.9	6.8	6.7	6.6	6.5	6.4	6.3
21.0	8.0	7.9	7.8	7.7	7.6	7.5	7.4	7.3	7.2	7.1	7.0	6.9	6.8	6.7	6.6	6.5	6.4	6.3	6.2
21.5	7.9	7.8	7.7	7.6	7.5	7.4	7.3	7.2	7.1	7.0	6.9	6.8	6.7	6.6	6.5	6.4	6.3	6.2	6.1
22.0	7.8	7.7	7.6	7.5	7.4	7.3	7.2	7.1	7.0	6.9	6.8	6.7	6.6	6.5	6.4	6.3	6.2	6.1	6.0
22.5	7.7	7.6	7.5	7.4	7.3	7.2	7.1	7.0	6.9	6.8	6.7	6.6	6.5	6.4	6.3	6.2	6.1	6.0	5.9
23.0	7.6	7.5	7.4	7.3	7.2	7.1	7.0	6.9	6.8	6.7	6.6	6.5	6.4	6.3	6.2	6.1	6.0	5.9	5.8
23.5	7.5	7.4	7.3	7.2	7.1	7.0	6.9	6.8	6.7	6.6	6.5	6.4	6.3	6.2	6.1	6.0	5.9	5.8	5.7
24.0	7.4	7.3	7.2	7.1	7.0	6.9	6.8	6.7	6.6	6.5	6.4	6.3	6.2	6.1	6.0	5.9	5.8	5.7	5.6
24.5	7.3	7.2	7.1	7.0	6.9	6.8	6.7	6.6	6.5	6.4	6.3	6.2	6.1	6.0	5.9	5.8	5.7	5.6	5.5
25.0	7.2	7.1	7.0	6.9	6.8	6.7	6.6	6.5	6.4	6.3	6.2	6.1	6.0	5.9	5.8	5.7	5.6	5.5	5.4
25.5	7.1	7.0	6.9	6.8	6.7	6.6	6.5	6.4	6.3	6.2	6.1	6.0	5.9	5.8	5.7	5.6	5.5	5.4	5.3
26.0	7.0	6.9	6.8	6.7	6.6	6.5	6.4	6.3	6.2	6.1	6.0	5.9	5.8	5.7	5.6	5.5	5.4	5.3	5.2
26.5	6.9	6.8	6.7	6.6	6.5	6.4	6.3	6.2	6.1	6.0	5.9	5.8	5.7	5.6	5.5	5.4	5.3	5.2	5.1
27.0	6.8	6.7	6.6	6.5	6.4	6.3	6.2	6.1	6.0	5.9	5.8	5.7	5.6	5.5	5.4	5.3	5.2	5.1	5.0
27.5	6.7	6.6	6.5	6.4	6.3	6.2	6.1	6.0	5.9	5.8	5.7	5.6	5.5	5.4	5.3	5.2	5.1	5.0	4.9
28.0	6.6	6.5	6.4	6.3	6.2	6.1	6.0	5.9	5.8	5.7	5.6	5.5	5.4	5.3	5.2	5.1	5.0	4.9	4.8
28.5	6.5	6.4	6.3	6.2	6.1	6.0	5.9	5.8	5.7	5.6	5.5	5.4	5.3	5.2	5.1	5.0	4.9	4.8	4.7
29.0	6.4	6.3	6.2	6.1	6.0	5.9	5.8	5.7	5.6	5.5	5.4	5.3	5.2	5.1	5.0	4.9	4.8	4.7	4.6
29.5	6.3	6.2	6.1	6.0	5.9	5.8	5.7	5.6	5.5	5.4	5.3	5.2	5.1	5.0	4.9	4.8	4.7	4.6	4.5

Table 6.2-6. Solubility of oxygen in water at various temperatures and pressures—Continued

Temp °C	Atmospheric pressure, in millimeters of mercury																			
	695	690	685	680	675	670	665	660	655	650	645	640	635	630	625	620	615	610	605	600
30.0	6.9	6.8	6.7	6.6	6.7	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9
30.5	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8
31.0	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8
31.5	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7
32.0	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7
32.5	6.6	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6
33.0	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.5
33.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5
34.0	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5
34.5	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4
35.0	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4
35.5	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4	5.3	5.3
36.0	6.2	6.1	6.1	6.0	6.0	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4	5.3	5.3	5.2	5.2
36.5	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4	5.3	5.3	5.2	5.2
37.0	6.1	6.0	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4	5.3	5.3	5.2	5.2
37.5	6.0	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4	5.3	5.3	5.2	5.2	5.2
38.0	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4	5.3	5.3	5.2	5.2	5.2	5.1
38.5	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4	5.3	5.3	5.2	5.2	5.1	5.1	5.1
39.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4	5.3	5.3	5.2	5.2	5.1	5.1	5.0	5.0
39.5	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4	5.3	5.3	5.2	5.2	5.1	5.1	5.0	5.0	5.0
40.0	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4	5.3	5.3	5.2	5.2	5.1	5.1	5.0	5.0	5.0	5.0

Georgia, Savannah
N 32° 05' 44" W 81° 05'

July 2007

Tide Tables and Charts available at FreeTideTables.com

Date	Day	High Tide	High Tide	High Tide	Low Tide	Low Tide	Sunrise	Sunset	Moonrise	Moonsset	Phase			
1	Su	941am	7.3	1008pm	8.7	420am	0.1	414pm	0.1	622am	835pm	554pm	706am	
2	Mo	1021am	7.4	1047pm	8.7	502am	-0.1	458pm	0.0	622am	835pm	1033pm	811am	
3	Tu	1106am	7.6	1129pm	8.6	544am	-0.2	543pm	0.0	622am	834pm	1107pm	917am	
4	We	1153am	7.7			625am	-0.3	629pm	0.1	623am	834pm	1138pm	1023am	
5	Th	1218am	8.4	1248pm	7.9	709am	-0.3	720pm	0.3	623am	834pm		1128am	
6	Fr	1133am	8.2	147pm	8.1	755am	-0.3	817pm	0.6	624am	834pm	1208am	1232pm	
7	Sa	211am	7.9	248pm	8.3	847am	-0.2	921pm	0.8	624am	834pm	1237am		3rd
8	Su	308am	7.7	344pm	8.6	945am	-0.2	1030pm	0.9	625am	834pm	109am	246pm	
9	Mo	406am	7.5	443pm	8.7	1045am	-0.2	1137pm	0.8	625am	834pm	144am	356pm	
10	Tu	506am	7.3	545pm	8.8	1146am	-0.2			626am	833pm	224am	508pm	
11	We	610am	7.2	649pm	8.9	1241am	0.7	1246pm	-0.3	626am	833pm	312am	617pm	
12	Th	715am	7.2	751pm	9.0	141am	0.5	144pm	-0.3	627am	833pm	409am	722pm	
13	Fr	816am	7.3	847pm	9.0	238am	0.3	241pm	-0.4	627am	832pm	512am	818pm	
14	Sa	912am	7.4	936pm	9.0	331am	0.1	335pm	-0.4	628am	832pm	620am	905pm	New
15	Su	1003am	7.5	1022pm	8.8	420am	-0.1	425pm	-0.3	629am	832pm	727am	943pm	
16	Mo	1051am	7.5	1104pm	8.6	505am	-0.1	512pm	-0.1	629am	831pm	832am	1016pm	
17	Tu	1139am	7.5	1147pm	8.3	546am	0.0	555pm	0.2	630am	831pm	933am	1044pm	
18	We	1228pm	7.4			624am	0.2	637pm	0.6	630am	830pm	1031am	1110pm	
19	Th	1303am	7.9	116pm	7.4	700am	0.4	720pm	1.0	631am	830pm	1127am	1135pm	
20	Fr	114am	7.6	203pm	7.4	737am	0.7	804pm	1.3	632am	829pm	1222pm		
21	Sa	200am	7.4	249pm	7.4	815am	0.9	854pm	1.6	632am	829pm	118pm	1200am	
22	Su	246am	7.2	334pm	7.5	857am	1.0	949pm	1.7	633am	828pm	214pm	1227am	1st
23	Mo	333am	7.1	420pm	7.6	949am	1.1	1047pm	1.7	633am	828pm	311pm	1256am	
24	Tu	421am	7.0	508pm	7.7	1039am	1.1	1143pm	1.6	634am	827pm	410pm	130am	
25	We	511am	6.9	601pm	7.9	1134am	1.0			635am	827pm	510pm	209am	
26	Th	605am	6.9	655pm	8.1	1237am	1.3	1229pm	0.8	635am	826pm	607pm	256am	
27	Fr	659am	7.1	746pm	8.4	129am	1.0	123pm	0.6	636am	825pm	701pm	350am	
28	Sa	750am	7.3	832pm	8.6	220am	0.7	216pm	0.4	637am	825pm	748pm	451am	
29	Su	838am	7.5	913pm	8.9	309am	0.3	307pm	0.1	637am	824pm	830pm	557am	
30	Mo	922am	7.6	952pm	9.0	355am	0.0	357pm	-0.1	638am	823pm	907pm	704am	Full
31	Tu	1004am	8.0	1032pm	8.9	439am	-0.3	444pm	-0.2	639am	822pm	940pm	812am	

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Georgia, Savannah, Fort Jackson
N 32° 05' / W 81° 02'

August 2007

Tide Tables and Charts available at FreeTideTables.com

Date	Day	High Tide	High Tide	Low Tide	Low Tide	Sunrise	Sunset	Moonrise	Moonset	Phase				
1	We	1044am	7.8	1110pm	8.3	520am	-0.5	530pm	-0.2	639am	822pm	1010pm	918am	
2	Th	1133am	8.0	1159pm	8.0	602am	-0.6	618pm	0.0	640am	821pm	1040pm	1024am	
3	Fr	1225pm	8.1			646am	-0.5	708pm	0.3	641am	820pm	1111pm	1131am	
4	Sa	1252am	7.7	125pm	8.1	732am	-0.4	804pm	0.7	641am	819pm	1145pm	1238pm	
5	Su	150am	7.4	226pm	8.2	824am	-0.2	907pm	0.9	642am	818pm		148pm	3rd
6	Mo	250am	7.1	327pm	8.2	922am	0.0	1015pm	1.0	643am	817pm	1223am		
7	Tu	350am	6.9	428pm	8.2	1026am	0.1	1122pm	1.0	643am	816pm	108am	407pm	
8	We	452am	6.8	531pm	8.3	1129am	0.1			644am	816pm	201am	513pm	
9	Th	556am	6.9	635pm	8.3	1225am	0.9	1230pm	0.1	645am	815pm	300am	610pm	
10	Fr	701am	7.0	734pm	8.4	123am	0.7	128pm	0.0	645am	814pm	406am	659pm	
11	Sa	800am	7.2	827pm	8.4	217am	0.5	223pm	-0.1	646am	813pm	512am	740pm	
12	Su	852am	7.4	912pm	8.4	307am	0.3	315pm	-0.1	647am	812pm	617am	815pm	
13	Mo	938am	7.6	952pm	8.4	383am	0.1	403pm	-0.1	647am	811pm	720am	845pm	New
14	Tu	1020am	7.6	1029pm	8.2	434am	0.1	447pm	0.1	648am	810pm	819am	911pm	
15	We	1100am	7.5	1104pm	7.9	512am	0.2	527pm	0.4	649am	809pm	916am	937pm	
16	Th	1138am	7.4	1141pm	7.6	546am	0.4	606pm	0.7	649am	808pm	1012am	1002pm	
17	Fr	1218pm	7.3			618am	0.6	643pm	1.0	650am	806pm	1107am	1028pm	
18	Sa	1220am	7.3	100pm	7.2	649am	0.9	722pm	1.4	651am	805pm	1203pm	1056pm	
19	Su	103am	7.0	145pm	7.1	721am	1.0	805pm	1.7	651am	804pm	100pm	1127pm	
20	Mo	151am	6.8	234pm	7.1	759am	1.1	856pm	1.9	652am	803pm	158pm		
21	Tu	241am	6.7	325pm	7.2	846am	1.3	956pm	1.9	652am	802pm	257pm	1204am	1st
22	We	333am	6.7	418pm	7.4	945am	1.3	1101pm	1.8	653am	801pm	355pm	1247am	
23	Th	427am	6.7	514pm	7.6	1050am	1.2			654am	800pm	449pm	137am	
24	Fr	524am	6.8	613pm	7.8	1200am	1.5	1154am	1.0	654am	759pm	539pm	235am	
25	Sa	622am	7.0	709pm	8.2	1255am	1.1	1254pm	0.8	655am	757pm	624pm	338am	
26	Su	718am	7.3	800pm	8.4	147am	0.7	150pm	0.4	656am	756pm	703pm	445am	
27	Mo	809am	7.8	845pm	8.7	237am	0.3	245pm	0.1	656am	755pm	737pm	553am	
28	Tu	856am	8.2	927pm	8.7	325am	-0.2	337pm	-0.2	657am	754pm	810pm	701am	Full
29	We	941am	8.4	1009pm	8.7	411am	-0.5	426pm	-0.3	658am	753pm	840pm	809am	
30	Th	1026am	8.7	1052pm	8.4	455am	-0.7	516pm	-0.3	658am	751pm	912pm	917am	
31	Fr	1114am	8.7	1139pm	8.1	539am	-0.7	605pm	0.0	659am	750pm	945pm	1026am	

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September 2007

Georgia, Savannah, Fort Jackson
N 32° 05' W 81° 02'

Tide Tables and Charts available at FreeTideTables.com

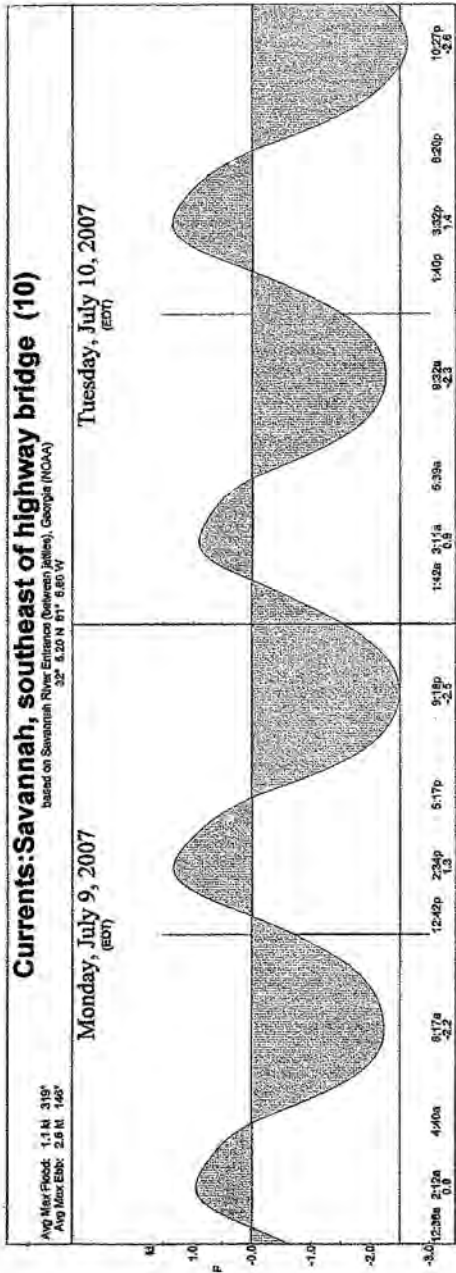
Date	Day	High Tide	High Tide	Low Tide	Low Tide	Sunrise	Sunset	Moonrise	Moonsset	Phase
1	Sa	1207pm 8.7		624am -0.5	656pm 0.4	659am	749pm	1023pm	1137am	
2	Su	1234am 7.6	107pm 8.4	711am -0.2	751pm 0.9	700am	746pm	1106pm	1249pm	
3	Mo	136am 7.3	212pm 8.3	804am 0.2	833pm 1.2	701am	746pm	1156pm	200pm	
4	Tu	241am 7.0	317pm 8.2	904am 0.5	1005pm 1.3	701am	745pm		307pm	3rd
5	We	344am 7.0	420pm 8.2	1010am 0.6	1107pm 1.3	702am	744pm	1254am		
6	Th	447am 7.0	522pm 8.2	1115am 0.6		702am	742pm	157am	457pm	
7	Fr	550am 7.2	622pm 8.3	1208am 1.1	1216pm 0.5	703am	741pm	303am	540pm	
8	Sa	650am 7.4	716pm 8.4	102am 0.9	1122pm 0.3	704am	740pm	407am	616pm	
9	Su	744am 7.7	804pm 8.4	153am 0.6	204pm 0.2	704am	739pm	510am	646pm	
10	Mo	822am 8.0	846pm 8.6	239am 0.4	253pm 0.2	705am	737pm	610am	714pm	
11	Tu	914am 8.1	923pm 8.4	322am 0.3	339pm 0.2	706am	736pm	707am	739pm	New
12	We	952am 8.2	957pm 8.3	401am 0.3	421pm 0.4	706am	735pm	803am	804pm	
13	Th	1025am 8.1	1029pm 8.0	437am 0.5	506pm 0.6	707am	733pm	856am	830pm	
14	Fr	1056am 7.9	1101pm 7.7	509am 0.6	536pm 0.9	707am	732pm	954am	857pm	
15	Sa	1127am 7.8	1135pm 7.4	538am 0.9	611pm 1.2	708am	731pm	1050am	927pm	
16	Su	1201pm 7.6		606am 1.0	647pm 1.5	709am	729pm	1148am	1001pm	
17	Mo	1214am 7.1	1243pm 7.4	637am 1.1	726pm 1.8	709am	728pm	1246pm	1041pm	
18	Tu	101am 6.9	135pm 7.4	713am 1.3	814pm 2.0	710am	727pm	144pm	1128pm	
19	We	154am 6.8	233pm 7.4	800am 1.4	914pm 2.1	710am	725pm	239pm		1st
20	Th	252am 6.8	333pm 7.5	900am 1.5	1020pm 1.9	711am	724pm	330pm	1221am	
21	Fr	350am 6.9	433pm 7.8	1012am 1.4	1123pm 1.6	712am	723pm	415pm	121am	
22	Sa	450am 7.1	534pm 8.0	1123am 1.2		712am	721pm	456pm	225am	
23	Su	550am 7.5	633pm 8.3	1220am 1.1	1227pm 0.9	713am	720pm	532pm	331am	
24	Mo	649am 8.0	728pm 8.6	114am 0.7	127pm 0.5	714am	719pm	605pm	439am	
25	Tu	743am 8.4	817pm 8.7	205am 0.2	224pm 0.1	714am	717pm	637pm	547am	
26	We	833am 8.9	903pm 8.7	254am -0.2	319pm -0.1	715am	716pm	708pm	655am	Full
27	Th	920am 9.2	947pm 8.7	342am -0.5	411pm -0.3	715am	715pm	742pm	806am	
28	Fr	1006am 9.3	1032pm 8.4	429am -0.7	501pm -0.2	716am	713pm	819pm	918am	
29	Sa	1055am 9.2	1121pm 8.0	516am -0.6	551pm 0.1	717am	712pm	901pm	1032am	
30	Su	1148am 9.0		602am -0.4	642pm 0.5	717am	711pm	951pm	1146am	

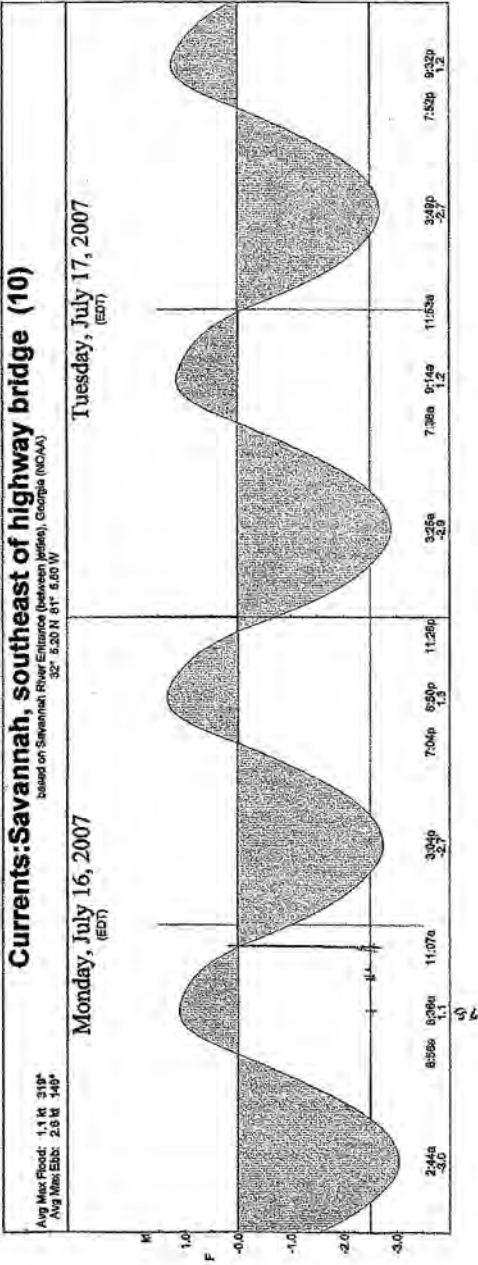
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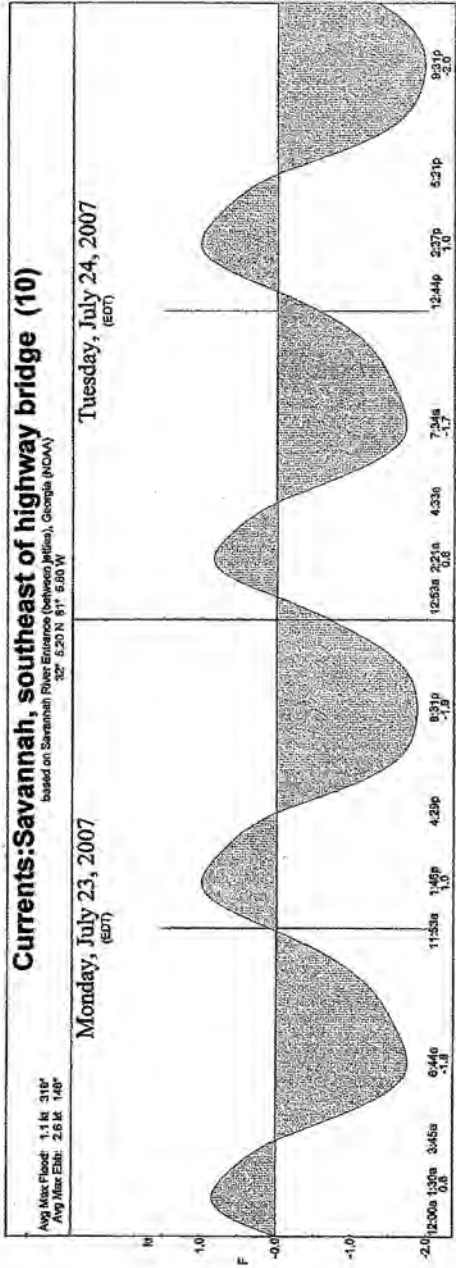
Currents: Savannah, southeast of highway bridge (10)

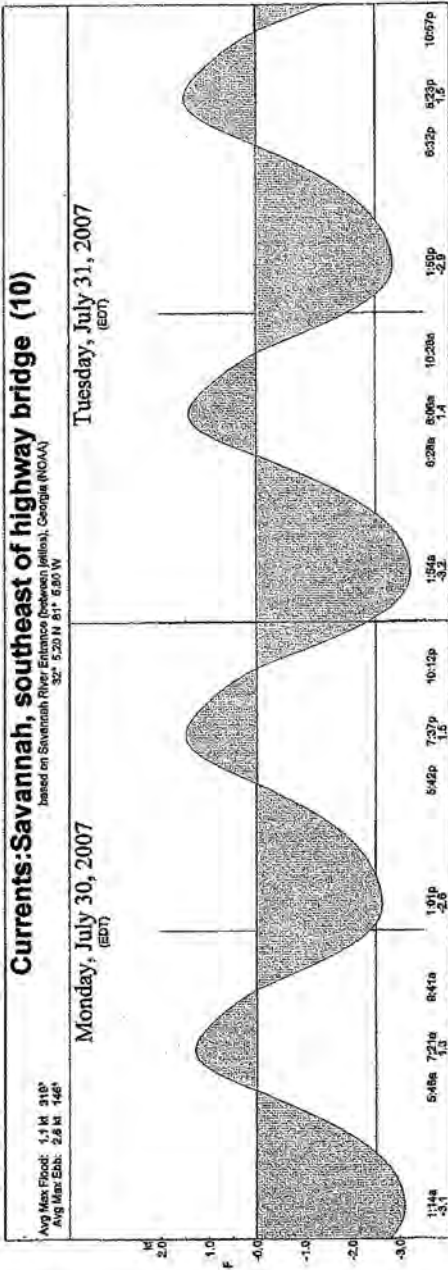
based on Savannah River Entrance (between jetties), Georgia (NOAA)
32° 5.20 N 81° 5.80 W

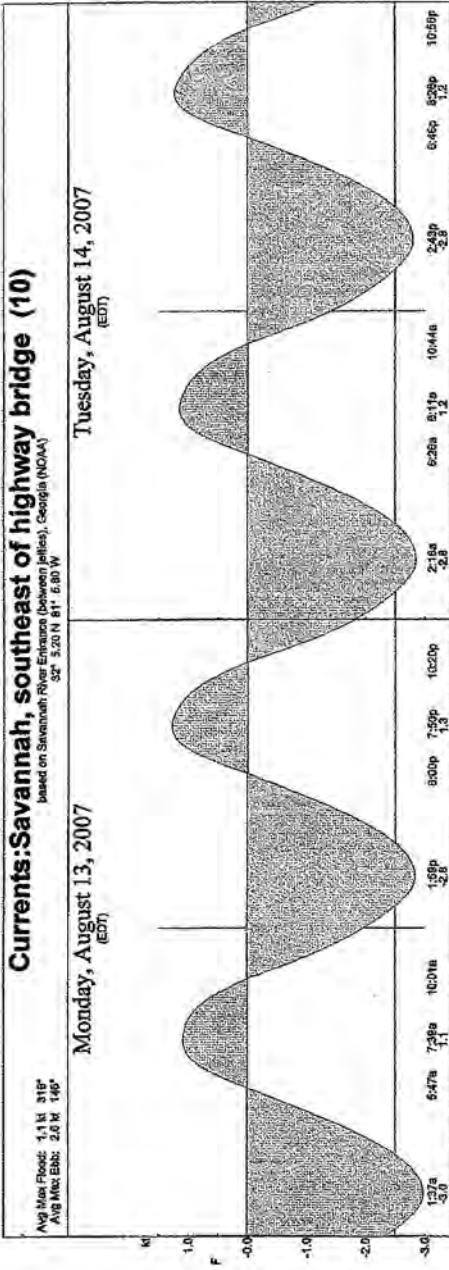
July, 2007										August, 2007										September, 2007										
1	6:16a	1:44a	2:9E	16	2:44a	3:0E	1	2:38a	3:3E	16	3:24a	2:4E	1	12:07a	3:37a	3:1E	16	12:11a	3:20a	1:8E										
Su	10:05a	1:15p	2:3E	Mo	11:07a	3:04a	2:7E	We	7:10a	8:45a	1:5E	Th	7:38a	8:17a	1:2E	Sa	8:08a	8:55a	1:4E	Su	8:13a	8:56a	1:0E							
(EDT)	6:01p	7:37p	1:4E	(EDT)	7:04p	8:34p	1:3E	(EDT)	7:22p	9:08p	1:5E	(EDT)	8:11p	9:42p	1:1E	(EDT)	8:49p	10:25p	1:3E	(EDT)	9:00p	10:20p	0:5E							
2	2:23a	3:0E	17	3:23a	2:9E	2	3:17a	3:2E	17	12:12a	3:22a	2:2E	2	12:55a	4:27a	3:9E	17	12:49a	3:57a	1:8E										
Mo	8:58a	8:31a	1:2E	Tu	7:36a	8:14a	1:2E	Th	7:52a	8:34a	1:5E	Fr	8:13a	8:53a	1:1E	Su	8:00a	10:49a	1:5E	Mo	8:51a	10:38a	1:0E							
(EDT)	10:02a	2:07p	2:4E	(EDT)	7:32p	8:32p	1:2E	(EDT)	8:14p	9:57p	1:4E	(EDT)	8:59p	10:22p	1:0E	(EDT)	9:47p	11:20p	1:1E	(EDT)	9:48p	11:16p	0:8E							
3	3:02a	3:0E	18	12:07a	4:00a	2:7E	3	12:32a	4:02a	3:0E	18	12:48a	4:02a	2:0E	3	1:54a	5:20a	2:8E	18	1:33a	4:36a	1:7E								
Tu	7:41a	8:31a	2:5E	We	12:37a	4:30a	2:6E	Fr	12:55a	4:30a	3:0E	Sa	12:15a	4:54a	2:0E	Mo	1:32a	5:02a	2:9E	Tu	1:27a	4:45a	1:8E							
(EDT)	11:40a	2:50p	2:4E	(EDT)	8:39p	10:14p	1:1E	(EDT)	9:08p	10:49p	1:3E	(EDT)	9:38p	11:05p	0:8E	(EDT)	10:53p		2:6E	(EDT)	10:44p									
4	12:08a	3:43a	3:0E	19	12:47a	4:30a	2:4E	4	12:4a	4:50a	2:9E	19	1:29a	4:25a	1:8E	19	12:4a	4:50a	0:8E	19	12:4a	4:50a	0:7E							
We	10:02a	10:48a	1:3E	Th	12:07a	12:40a	1:0E	Fr	12:55a	4:30a	3:0E	Sa	12:15a	4:54a	2:0E	Mo	1:32a	5:02a	2:9E	Tu	1:27a	4:45a	1:8E							
(EDT)	8:30p	10:17p	1:3E	(EDT)	9:27p	11:00p	1:0E	(EDT)	10:07p	11:44p	1:1E	(EDT)	10:24p	11:54a	0:6E	(EDT)	8:49p	7:30p	2:4E	(EDT)	3:18p	6:32p	1:8E							
5	12:57a	4:27a	2:9E	20	1:29a	4:54a	2:2E	5	2:19a	8:42a	2:8E	20	2:13a	5:16a	1:8E	20	12:03a	1:35a	2:3E	20	3:24a	5:11a	0:7E							
Th	12:07a	11:41a	1:3E	Fr	2:04a	8:30a	2:2E	Sa	12:55a	4:30a	2:9E	Mo	1:32a	5:02a	1:7E	We	12:03a	1:35a	2:3E	Th	12:07a	12:27a	0:5E							
(EDT)	9:27p	11:11p	1:2E	(EDT)	10:16p	11:46p	0:9E	(EDT)	11:12p		2:8E	(EDT)	11:13p		1:7E	(EDT)	4:52p	6:55p	2:5E	(EDT)	4:16p	7:46p	1:9E							
6	1:50a	5:14a	2:7E	21	2:12a	8:22a	2:0E	6	12:46a	1:0E	21	12:46a	1:0E	21	1:08a	2:51a	0:8E	21	12:43a	2:50a	0:7E									
Fr	8:55a	11:41a	1:3E	Sa	10:16a	12:40a	1:0E	Mo	1:32a	5:02a	1:7E	Tu	1:27a	4:45a	1:8E	Th	12:03a	1:35a	2:3E	Fr	12:07a	12:27a	0:5E							
(EDT)	10:28p	12:33p	2:6E	(EDT)	11:37p	1:34p	2:0E	(EDT)	3:39p	7:49p	2:4E	(EDT)	3:52p	7:12p	1:7E	(EDT)	5:44p	9:18p	2:7E	(EDT)	5:10p	8:01p	2:1E							
7	12:08a	1:1E	22	12:33a	0:8E	7	12:21a	1:51a	0:9E	22	12:17a	1:33a	0:8E	7	2:10a	4:05a	0:9E	22	1:35a	3:04a	0:8E									
Sa	10:47a	12:37a	1:3E	Su	11:03a	12:54a	1:0E	Tu	12:55a	2:18a	1:3E	Th	12:03a	1:35a	2:3E	Fr	12:03a	1:35a	2:3E	Sa	12:07a	12:27a	0:5E							
(EDT)	8:15p	9:49p	2:5E	(EDT)	3:39p	7:29p	1:3E	(EDT)	5:00p	9:11p	2:4E	(EDT)	4:49p	8:42p	1:4E	(EDT)	6:51p	10:52p	2:8E	(EDT)	6:04p	9:24p	2:4E							
8	1:11a	1:0E	23	12:00a	1:30a	0:8E	8	1:28a	2:58a	0:8E	23	1:14a	2:32a	0:8E	8	3:03a	5:08a	0:9E	23	2:23a	3:58a	1:1E								
Su	11:44a	1:35p	1:3E	Mo	1:45a	6:44a	1:2E	We	1:28a	2:58a	0:8E	Th	1:14a	2:32a	0:8E	Mo	3:03a	5:08a	0:9E	23	2:23a	3:58a	1:1E							
(EDT)	4:14p	7:52p	2:4E	(EDT)	4:26p	8:31p	1:9E	(EDT)	6:11p	10:17p	2:6E	(EDT)	5:40p	9:49p	2:1E	(EDT)	7:43p	11:40p	2:9E	(EDT)	6:59p	10:40p	2:7E							
SLACK TRUCK MAIL																														
9	12:33a	1:1E	24	12:53a	2:11a	0:8E	9	2:30a	4:05a	0:8E	24	2:08a	3:33a	0:8E	9	3:50a	5:59a	1:0E	24	3:08a	4:46a	1:3E								
Mo	12:43a	1:1E	24	12:53a	2:11a	0:8E	9	2:30a	4:05a	0:8E	24	2:08a	3:33a	0:8E	9	3:50a	5:59a	1:0E	24	3:08a	4:46a	1:3E								
(EDT)	5:17p	9:16p	2:6E	(EDT)	6:21p	8:31p	2:0E	(EDT)	7:12p	11:14p	2:8E	(EDT)	6:52p	10:34p	2:4E	(EDT)	8:29p		1:2E	(EDT)	7:45p	11:24p	2:0E							
10	1:42a	3:11a	0:8E	25	1:48a	3:11a	0:8E	10	3:27a	5:13a	0:8E	25	2:57a	4:25a	1:0E	10	4:33a	6:36a	1:1E	25	3:52a	5:34a	1:4E							
Tu	5:30a	8:32a	2:3E	We	5:24a	8:28a	1:7E	Fr	7:39a	11:27a	2:8E	Sa	2:47a	4:43a	1:8E	Mo	4:33a	6:36a	1:1E	25	3:52a	5:34a	1:4E							
(EDT)	10:02p	10:27p	2:6E	(EDT)	6:14p	10:20p	2:1E	(EDT)	8:06p		2:8E	(EDT)	7:25p	11:18p	2:7E	(EDT)	8:12p		1:2E	(EDT)	8:24p									
11	2:41a	4:11a	0:8E	26	2:37a	4:02a	0:8E	11	4:18a	6:15a	0:9E	26	3:44a	5:17a	1:1E	11	5:13a	7:07a	1:1E	26	4:37a	6:22a	1:6E							
We	2:37a	4:11a	0:8E	26	2:37a	4:02a	0:8E	11	4:18a	6:15a	0:9E	26	3:44a	5:17a	1:1E	11	5:13a	7:07a	1:1E	26	4:37a	6:22a	1:6E							
(EDT)	7:22p	11:29p	2:8E	(EDT)	7:35p	11:09p	2:4E	(EDT)	8:58p		2:8E	(EDT)	8:14p	11:58p	3:0E	(EDT)	9:01p		1:2E	(EDT)	9:05p	10:52p	1:5E							
12	3:41a	5:12a	0:8E	27	3:28a	4:54a	0:8E	12	5:05a	7:03a	1:0E	27	4:28a	6:06a	1:3E	12	5:18a	7:33a	1:2E	27	5:59a	7:10a	1:7E							
Th	7:37a	11:28a	2:5E	Fr	7:11a	10:28a	2:0E	Su	8:14a	11:10a	2:5E	Mo	4:32a	6:26p	1:5E	We	5:18a	7:33a	1:2E	Th	5:59a	7:10a	1:7E							
(EDT)	8:26p		1:4E	(EDT)	7:54p	11:32p	2:8E	(EDT)	8:39p		1:3E	(EDT)	9:01p		1:5E	(EDT)	10:26p		1:2E	(EDT)	10:08p									
13	12:21a	2:9E	28	4:16a	6:45a	1:0E	13	1:37a	3:0E	28	12:41a	3:2E	13	5:12a	6:33a	1:3E	28	6:27a	8:00a	1:2E	28	6:08a	7:57a	1:9E						
Fr	4:39a	6:13a	0:9E	Sa	4:02a	6:00p	1:2E	Mo	5:47a	7:39a	1:1E	Tu	5:12a	6:33a	1:3E	Th	6:27a	8:00a	1:2E	Fr	6:08a	7:57a	1:9E							
(EDT)	4:28p	8:27p	1:4E	(EDT)	8:42p		1:2E	(EDT)	6:00p	7:50p	1:3E	(EDT)	5:47a	7:39a	1:1E	(EDT)	7:02a	8:35p	1:1E	(EDT)	6:45p	8:28p	1:6E							
14	5:27a	1:25a	3:0E	29	5:03a	6:53a	1:1E	Tu	5:47a	7:39a	1:1E	29	5:55a	7:39a	1:6E	14	7:03a	8:42a	1:1E	29	6:55a	8:44a	1:6E							
Sa	5:27a	1:25a	3:0E	29	5:03a	6:53a	1:1E	Tu	5:47a	7:39a	1:1E	29	5:55a	7:39a	1:6E	14	7:03a	8:42a	1:1E	29	6:55a	8:44a	1:6E							
(EDT)	8:22p	7:20p	1:4E	(EDT)	4:52p	6:48p	1:4E	(EDT)	8:40p	10:28p	1:2E	(EDT)	8:16p	8:02p	1:6E	(EDT)	7:42p	9:10p	1:1E	(EDT)	7:38p	9:16p	1:4E							
15	6:16a	2:00a	3:1E	30	5:46a	7:37a	1:5E	15	7:02a	2:55a	2:0E	30	6:37a	8:22a	1:7E	15	7:37a	9:17a	1:7E	30	7:45a	9:24a	1:7E							
Su	10:18a	2:18p	2:7E	Mo	8:41a	10:10a	2:6E	We	11:23a	3:40a	2:7E	Th	10:48a	2:30a	3:4E	Sa	15:01a	3:46a	2:2E	Su	12:14a	3:52a	3:0E							
(EDT)	8:18p	8:07p	1:4E	(EDT)	10:12p		1:5E	(EDT)	7:28p	8:04p	1:2E	(EDT)	11:19p		1:5E	(EDT)	8:18p	8:47p	1:0E	(EDT)	8:31p	10:53p	1:2E							
16	6:16a	2:00a	3:1E	31	8:28a	9:06a	1:4E	16	7:22a	3:10a	3:4E	16	7:22a	3:10a	3:4E	16	7:22a	3:10a	3:4E	16	7:22a	3:10a	3:4E							
Su	10:18a	2:18p	2:7E	Mo	8:41a	10:10a	2:6E	We	11:23a	3:40a	2:7E	Th	10:48a	2:30a	3:4E	Sa	15:01a	3:46a	2:2E	Su	12:14a	3:52a	3:0E							
(EDT)	8:18p	8:07p	1:4E	(EDT)	10:12p		1:5E	(EDT)	7:28p</																					

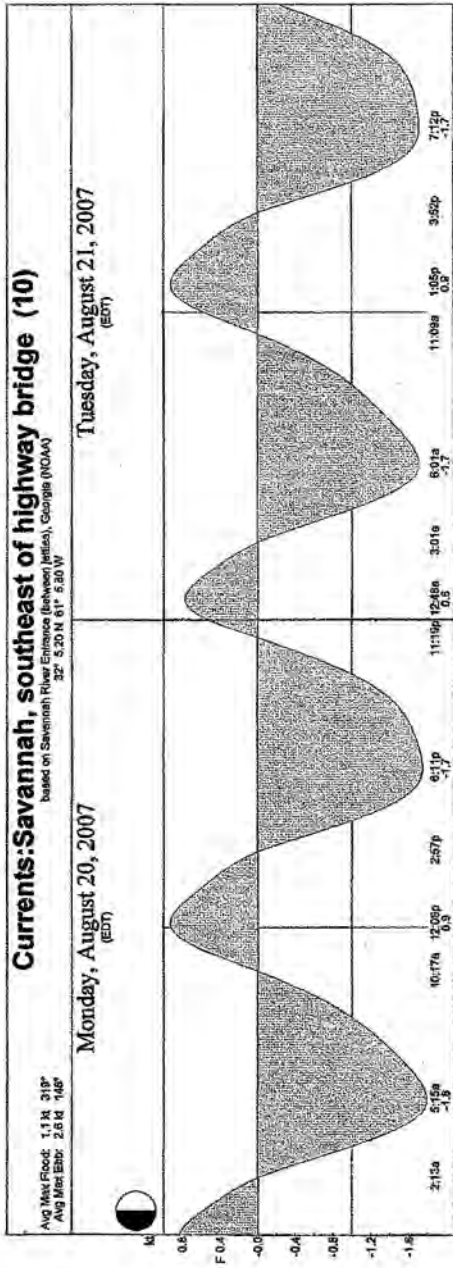


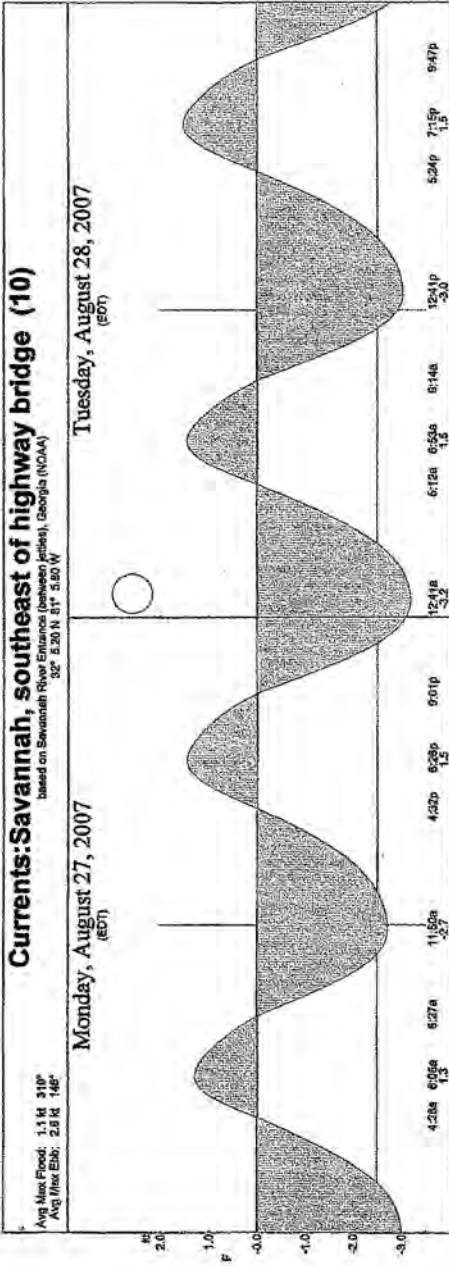


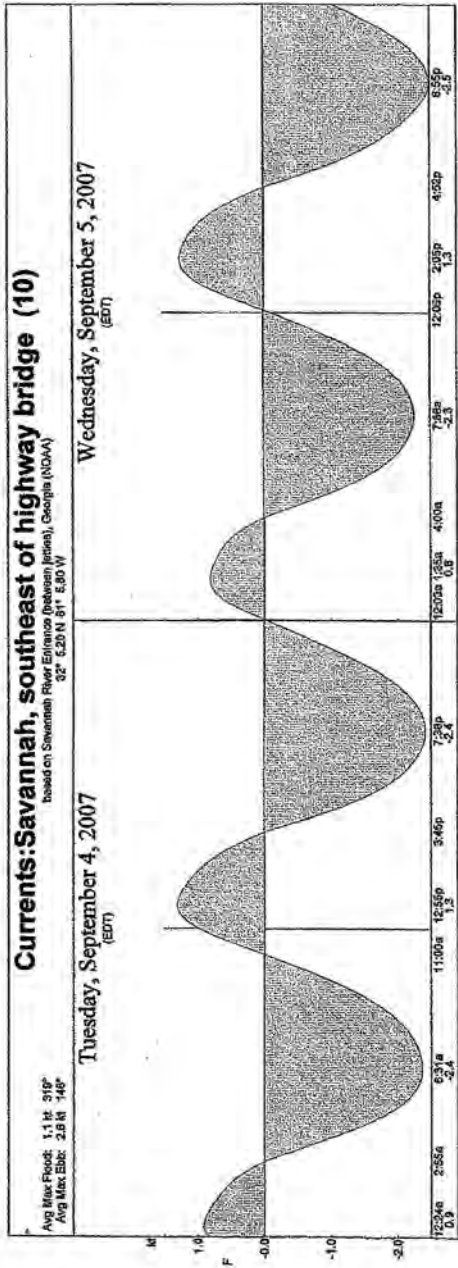


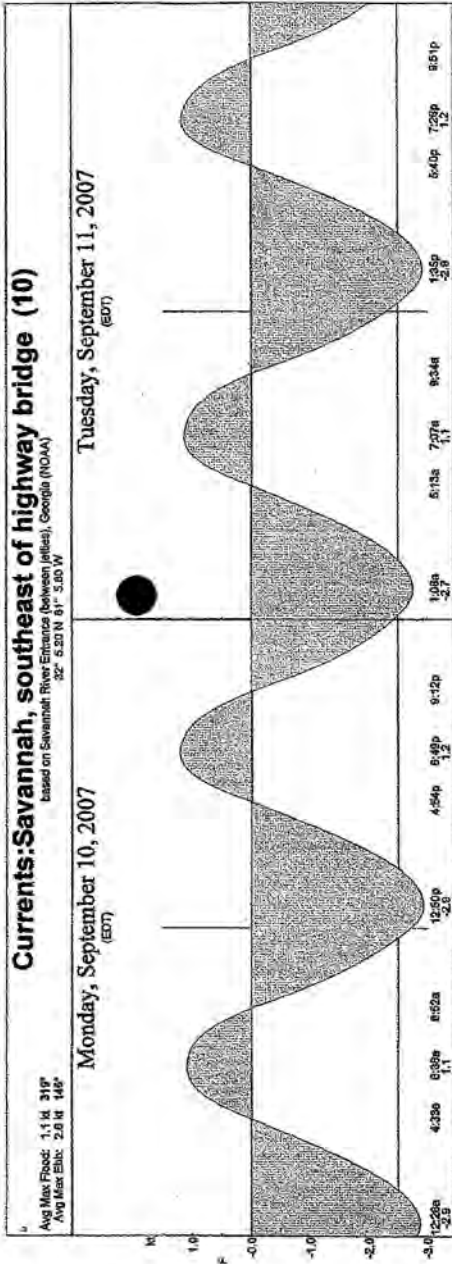












FOR CONTINUATION OF HOUSE DOCUMENT 112-153

**SAVANNAH HARBOR EXPANSION PROJECT
CHATMAN CO., GEORGIA & JASPER CO., S. CAROLINA:
FINAL GENERAL RE-EVALUATION REPORT AND
ENVIRONMENTAL IMPACT STATEMENT**

SEE PART 8