FINAL FEASIBILITY REPORT AND INTEGRATED ENVIRONMENTAL ASSESSMENT

MAIN REPORT

LYNNHAVEN RIVER BASIN ECOSYSTEM RESTORATION

VIRGINIA BEACH, VIRGINIA

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

July 2013

EXECUTIVE SUMMARY

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

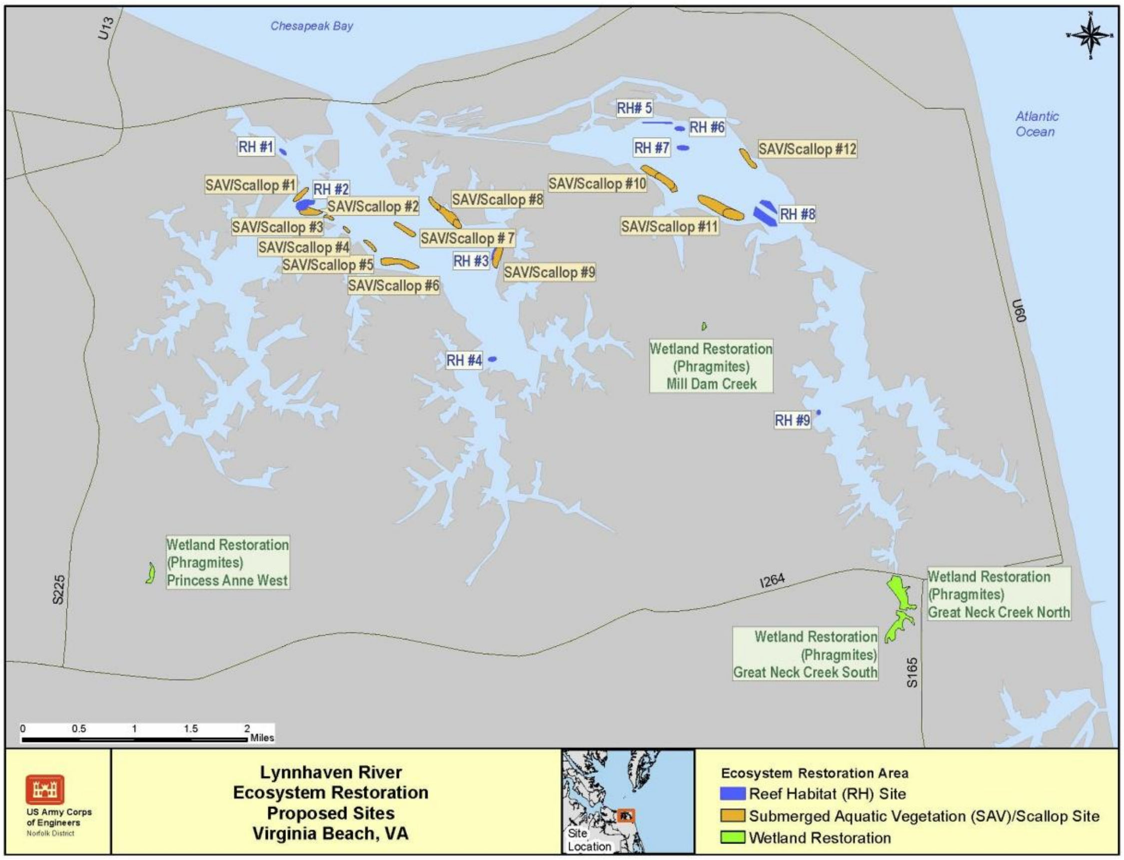
The study team, comprised of the non-Federal sponsor, the City of Virginia Beach, and representatives of Federal, State, and local governments, identified cost-effective and environmentally and technically sound alternatives to restore the ecosystem within the Lynnhaven River Basin. The process integrated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

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

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

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

Figure i. LYNNHAVEN RIVER BASIN RECOMMENDED PLAN



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

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

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

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

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

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

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

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

RECOMMENDATIONS

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

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

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

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

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

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

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

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

LYNNHAVEN RIVER BASIN ECOSYSTEM RESTORATION
VIRGINIA BEACH, VIRGINIA
FEASABILITY REPORT AND INTEGRATED
ENVIRONMENTAL ASSESSMENT

TABLE OF CONTENTS

TABLE OF CONTENTS
(Cont'd)

TABLE OF CONTENTS
(Cont'd)

LIST OF TABLES

LIST OF TABLES
(Cont'd)

LIST OF TABLES
(Cont'd)

LIST OF FIGURES

LIST OF FIGURES
(Cont'd)

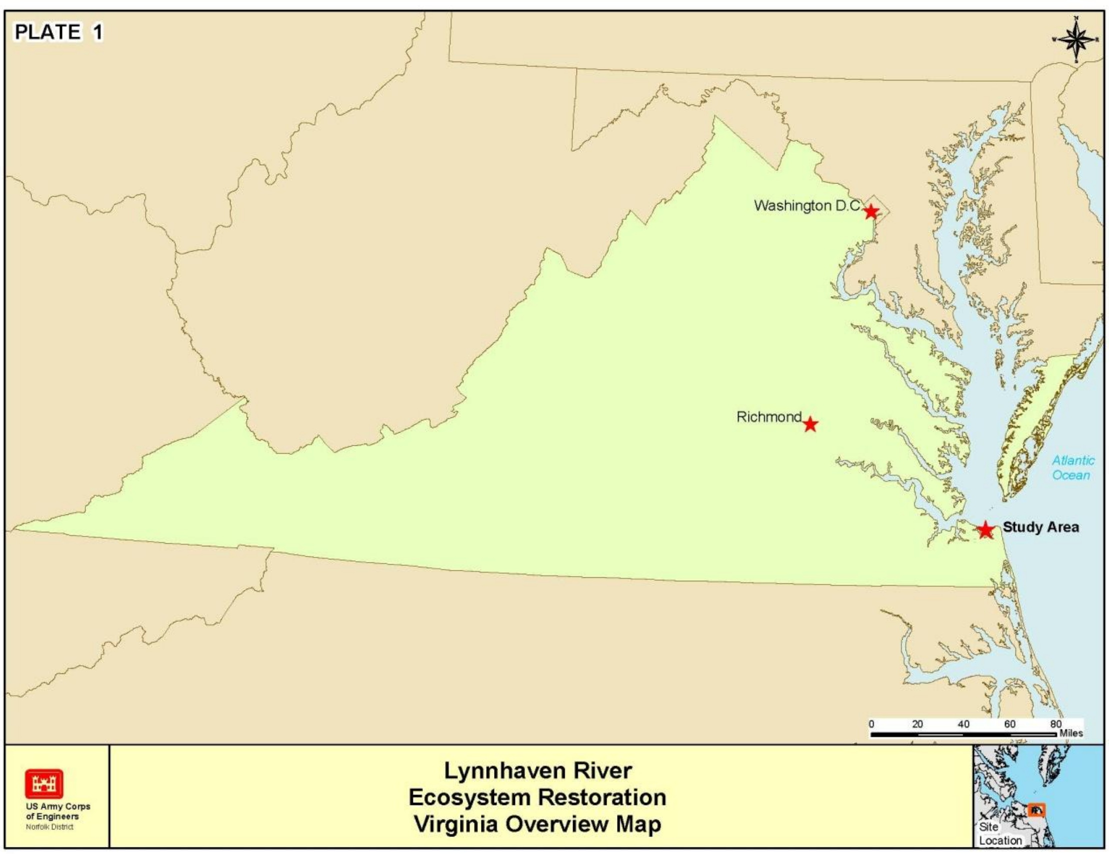
LIST OF FIGURES
(Cont'd)

LIST OF APPENDICES

1.0 INTRODUCTION

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

Figure 1. PROJECT LOCATION



1.1 Study Authority

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

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

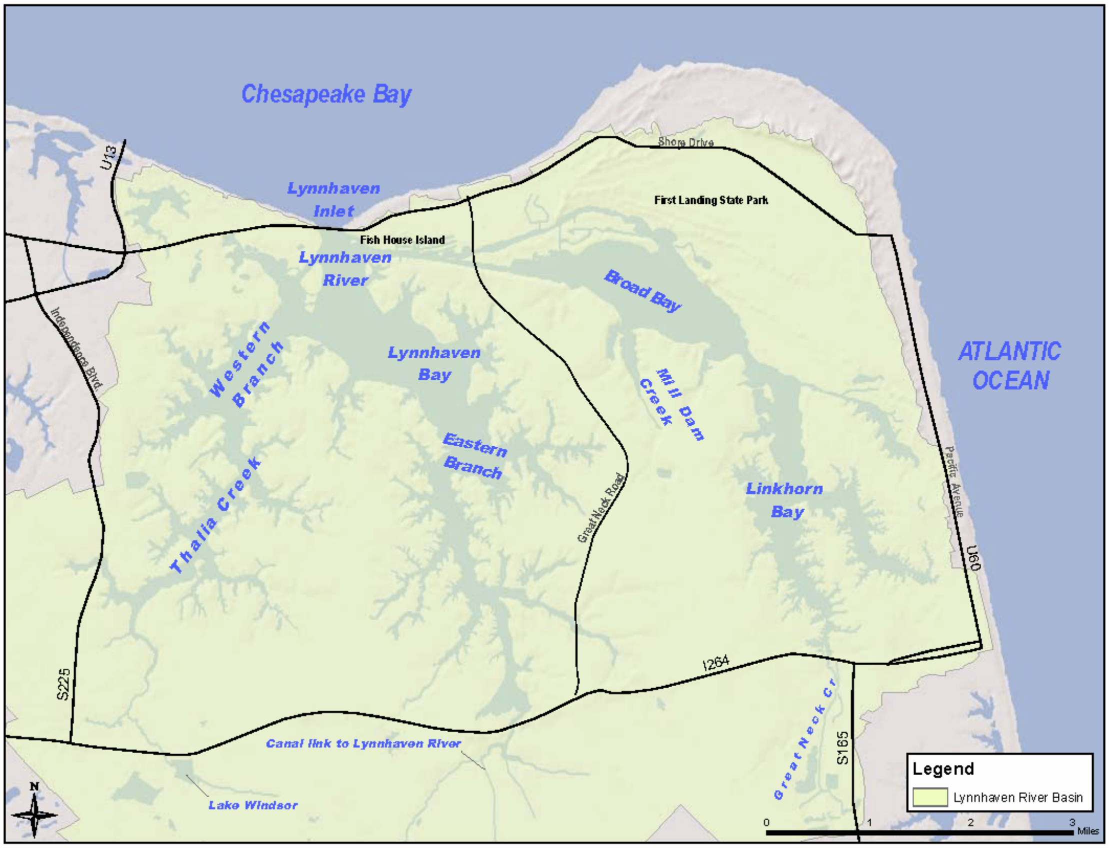
1.2 Study Purpose and Scope

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

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

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

Figure 2. LYNNHAVEN RIVER BASIN



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

1.3 Significance of the Ecosystem

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

1.4 Study Sponsors, Participants, and Coordination

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

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

1.5 Reconnaissance Phase Recommendations

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

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

1.6 Feasibility Study Purpose and Objectives

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

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

1.7 Studies and Reports

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

1.8 Existing Water Projects

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

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

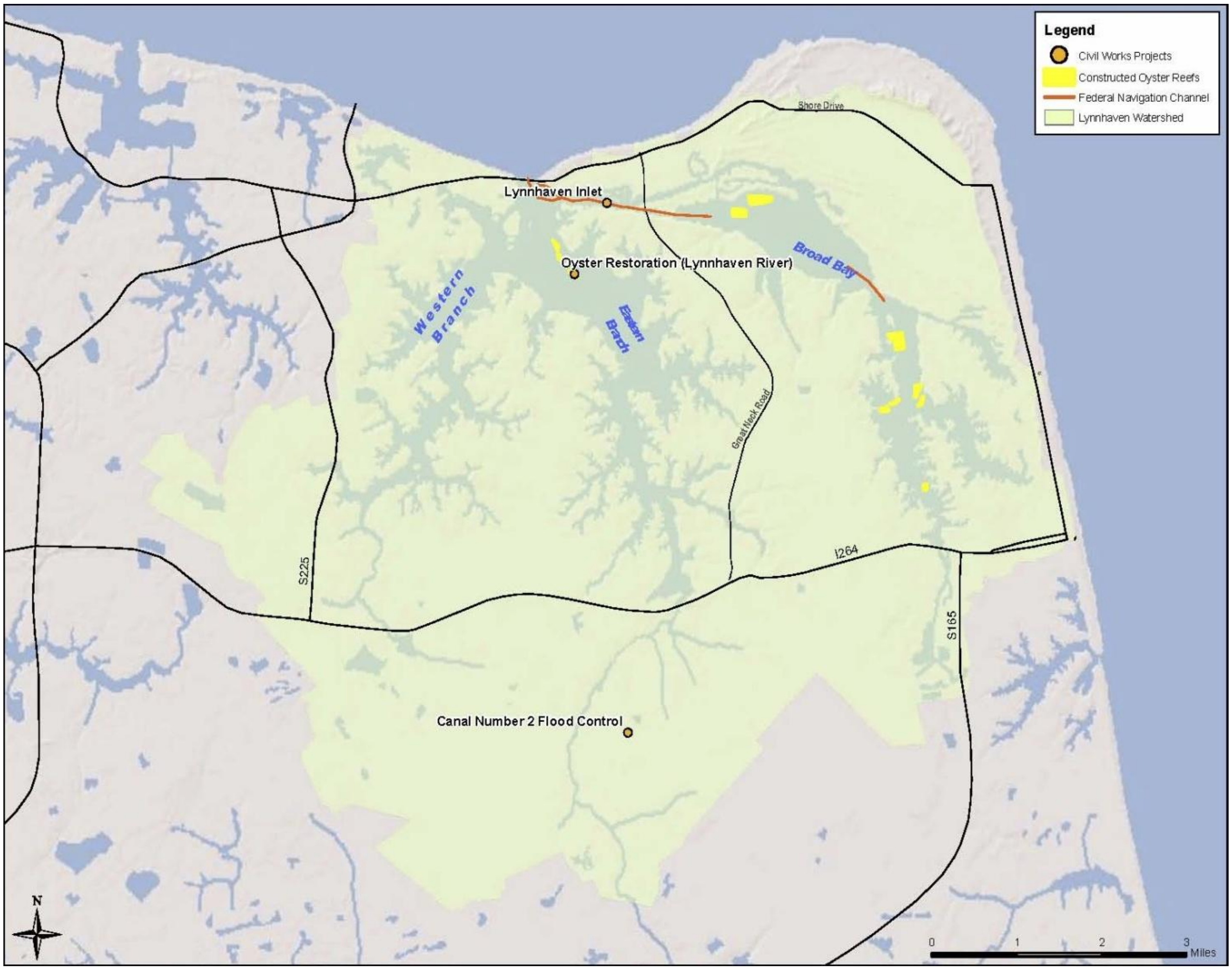
Figure 3. LYNNHAVEN INLET

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

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

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

Figure 4. EXISTING WATER PROJECTS



2.0 EXISTING CONDITIONS

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

2.1 Study Area

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

2.2 Environmental Resources

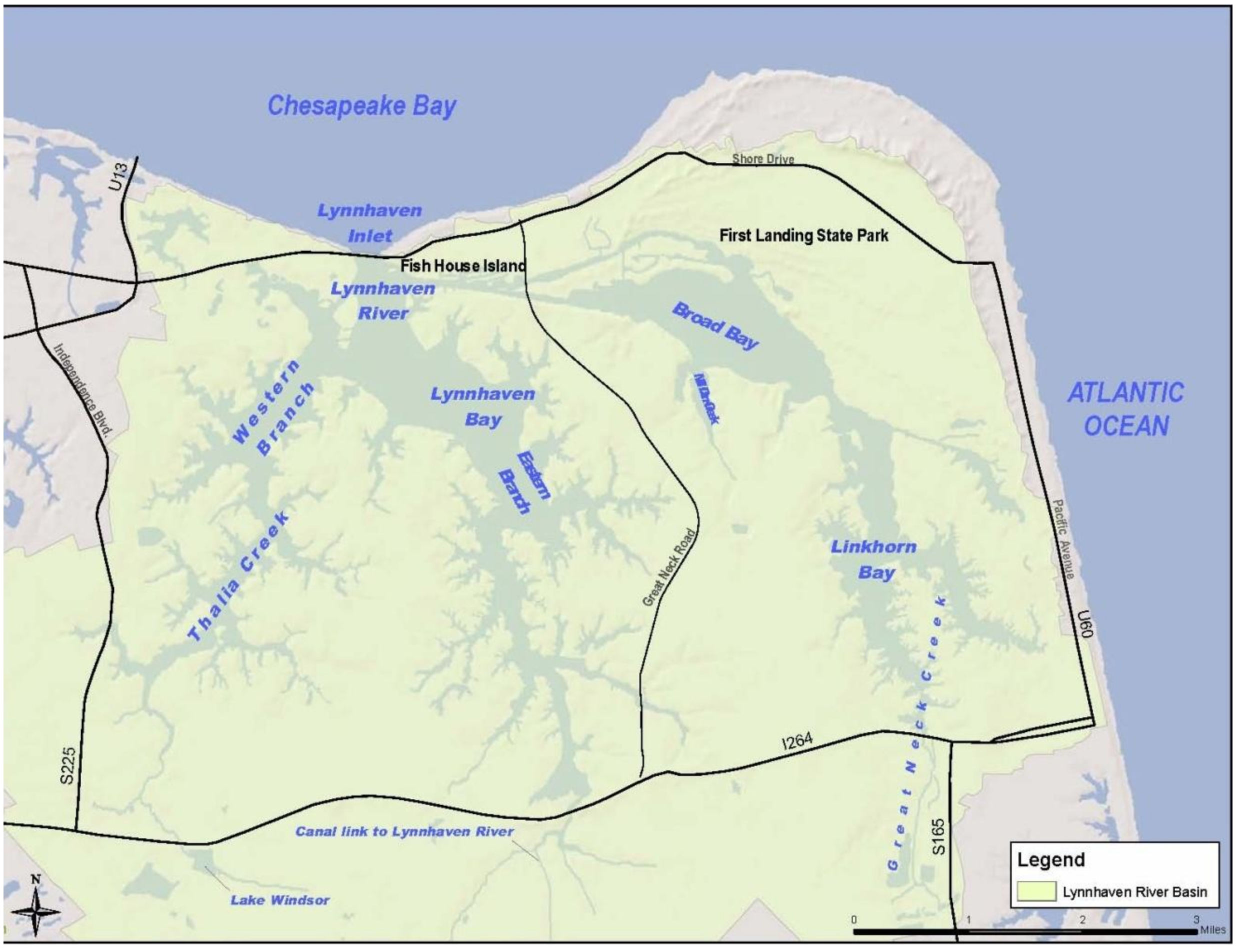
The following section of the report details the physical and biological resources of the Lynnhaven River Basin. The river comprises over 5,000 acres of surface waters (VDEQ, 1999). The Lynnhaven River's major tributaries are London Bridge Creek (Eastern Branch), Wolfsnare Creek (Eastern Branch), Great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

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

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

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

Figure 5. MAJOR TRIBUTARIES AND DRAINAGE OF THE LYNNHAVEN RIVER



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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

2.2.8 Aquatic Fauna.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

2.3 Water Quality

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

2.4 Terrestrial Resources

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

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

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

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

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

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

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

2.5 Threatened and Endangered Species

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

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

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

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

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

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

Source: VDGIF Online Database (latitude 36°54′28.1″ and longitude 76°05′ 29.4″), 2010.

KEY - FE=Federal Endangered; FT=Federal Threatened; SE=State Endangered; ST=State Threatened; FP=Federal Proposed; FC=Federal Candidate; FS=Federal Species of Concern; SC=State Candidate; CC=Collection Concern; SS=State Special Concern DEP = Depleted status under the Marine Mammal Protection Act (*status is not listed by VDGIF).

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

2.6 Air Quality

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

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

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

2.7 Noise

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

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

Table 4. PERMISSIBLE NON-DEPARTMENT OF DEFENSE NOISE EXPOSURES

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

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

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

2.8 Socio-Economic Resources

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

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

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

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

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

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

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

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

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

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

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

Table 5. DEMOGRAPHIC INFORMATION

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

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

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

Table 6. CENSUS TRACT ENVIRONMENTAL JUSTICE DATA (2000)

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

Source: U.S. Census, 2000

2.9 Cultural Resources

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

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

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

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

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

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

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

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

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

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

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

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

2.10 Wild and Scenic Rivers

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

2.11 Hazardous, Toxic, and Radioactive Waste

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

3.0 PROBLEMS, OPPORTUNITIES, AND OBJECTIVES

3.1 Problems

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

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

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

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

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

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

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

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

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

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

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

3.2 Opportunities

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

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

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

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

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

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

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

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

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

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

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

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

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

3.3 Objectives

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

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

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

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

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

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

3.4 Constraints

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

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

4.0 FUTURE WITHOUT PROJECT CONDITION

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

4.1 Submerged Aquatic Vegetation

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

4.2 Reef Habitat

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

4.3 Bay Scallops

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

4.4 Water Quality

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

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

4.5 Tidal Wetlands

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

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

5.0 PLAN FORMULATION

5.1 Formulation and Evaluation Criteria

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

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

• Plans must represent sound, safe, and acceptable engineering solutions;

• Plans must comply with USACE regulations;

• Plans must be realistic and reflect state-of-the-art measures and analysis techniques;

• Restoration plans should be conceived in a system context, considering aquatic, wetland, and terrestrial complexes as appropriate;

• Consideration should be given to the interconnectedness and dynamics of natural systems along with human activities, which may influence the results of restoration measures; and
• The significance of restoration outputs should be recognized in terms of institutional, public, and technical importance.

5.1.2 <u>Economic Criteria</u>. Plans for restoring ecological resources are based on both monetary and nonmonetary benefits (base year is 2014 and the Federal discount rate is 4.125%); and
• Cost-effective analysis must show that an alternative plan's output cannot be produced more cost effectively by another alternative.
• Incremental analysis must show that a cost-effective alternative plan's output cannot be produced at a lower incremental cost per unit of output.

5.1.3 <u>Social Criteria</u>. Consideration should be given to public health, safety, and social well-being, including possibly loss of life;
• Plans should minimize the displacement of people, businesses, and the livelihood of residents in the project area;
• Plans should minimize the disruption of normal, anticipated local, and regional growth and effects on local community patterns; and
• Plans should preserve, and where practical, enhance the social, cultural, educational, aesthetic, and historical values of the study area.

5.1.4 <u>Environmental Criteria</u>. Plans cannot have an unreasonably negative impact on environmental resources;
• National Environmental Policy Act documentation must be fully coordinated;
• Water quality standards must be maintained during construction activities in accordance with water quality certification requirements;
• Plans should avoid the destruction or disruption of natural and manmade resources, aesthetic and cultural values, community cohesion, and the availability of public facilities and services;

• Ecosystem restoration plans should be designed to avoid the need for fish and wildlife mitigation;

• Ecosystem restoration plans should be designed to be self-sustaining. If maintenance is necessary, it should be minimal; and

• Plan will be developed in a manner that is consistent with the USACE' Environmental Operating Principles (EOP).

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

5.2 Plan Formulation Process

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

The plan formulation process requires six essential steps as follows.

• Step 1: Identifying problems and opportunities;

• Step 2: Inventorying and forecasting conditions;

• Step 3: Formulating alternative plans;

• Step 4: Evaluating alternative plans;

• Step 5: Comparing alternative plans; and

• Step 6: Selecting an Ecosystem Restoration Plan.

5.3 Identification of Management Measures

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

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

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

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

Figure 6. POTENTIAL HARD REEF STRUCTURE

Figure 7. POTENTIAL HARD REEF STRUCTURE

Figure 8. POTENTIAL HARD REEF STRUCTURE

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

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

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

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

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

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

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

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

5.4 Identification and Screening of Sites for Each Measure

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

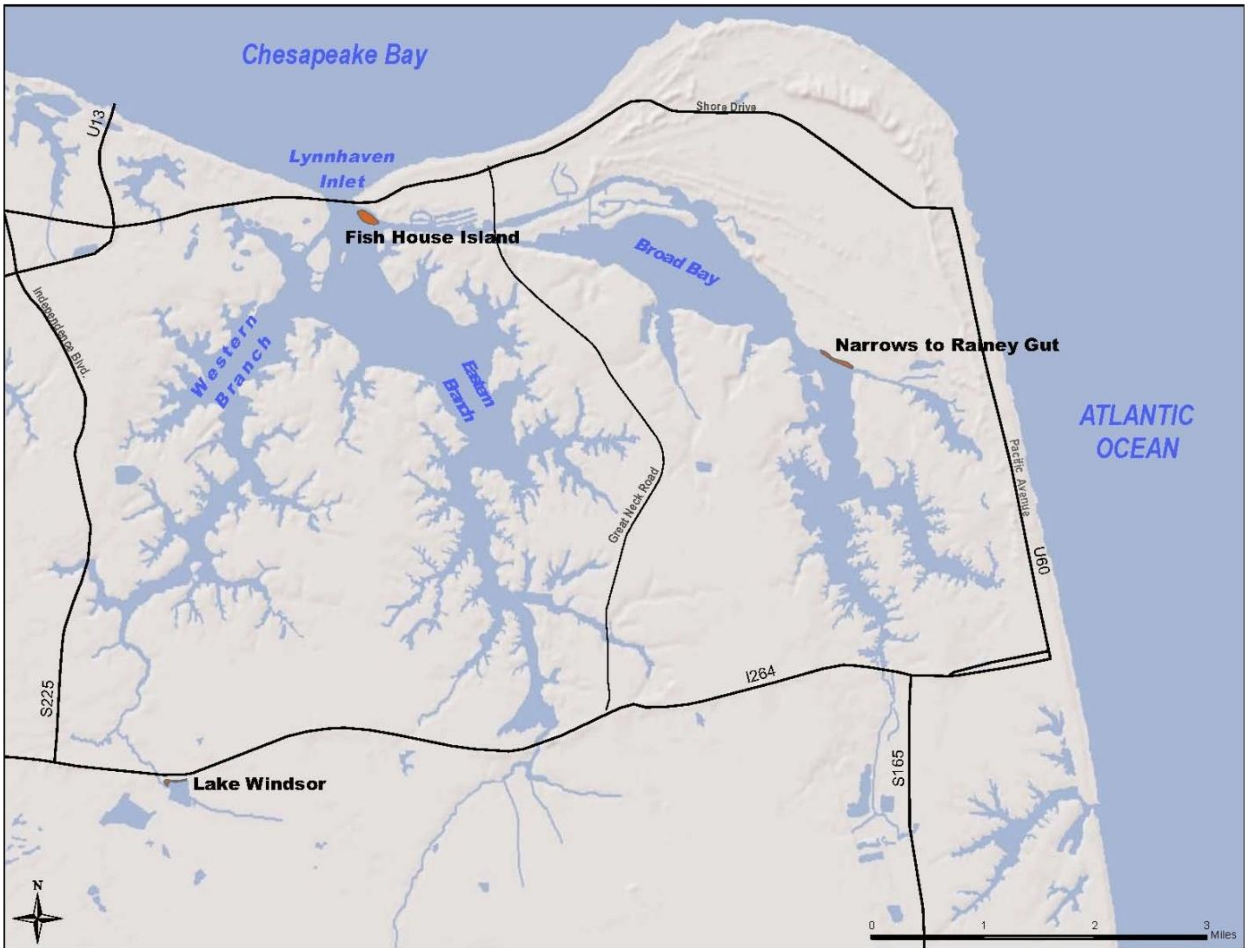
5.4.4 Benthic Habitat Restoration. Many sites were identified for the restoration of benthic habitat; however, maintenance dredging would be required to sustain the restored sites. As a result, either the environmental benefits achieved through the restoration would not be sustained over the life of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

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

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

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

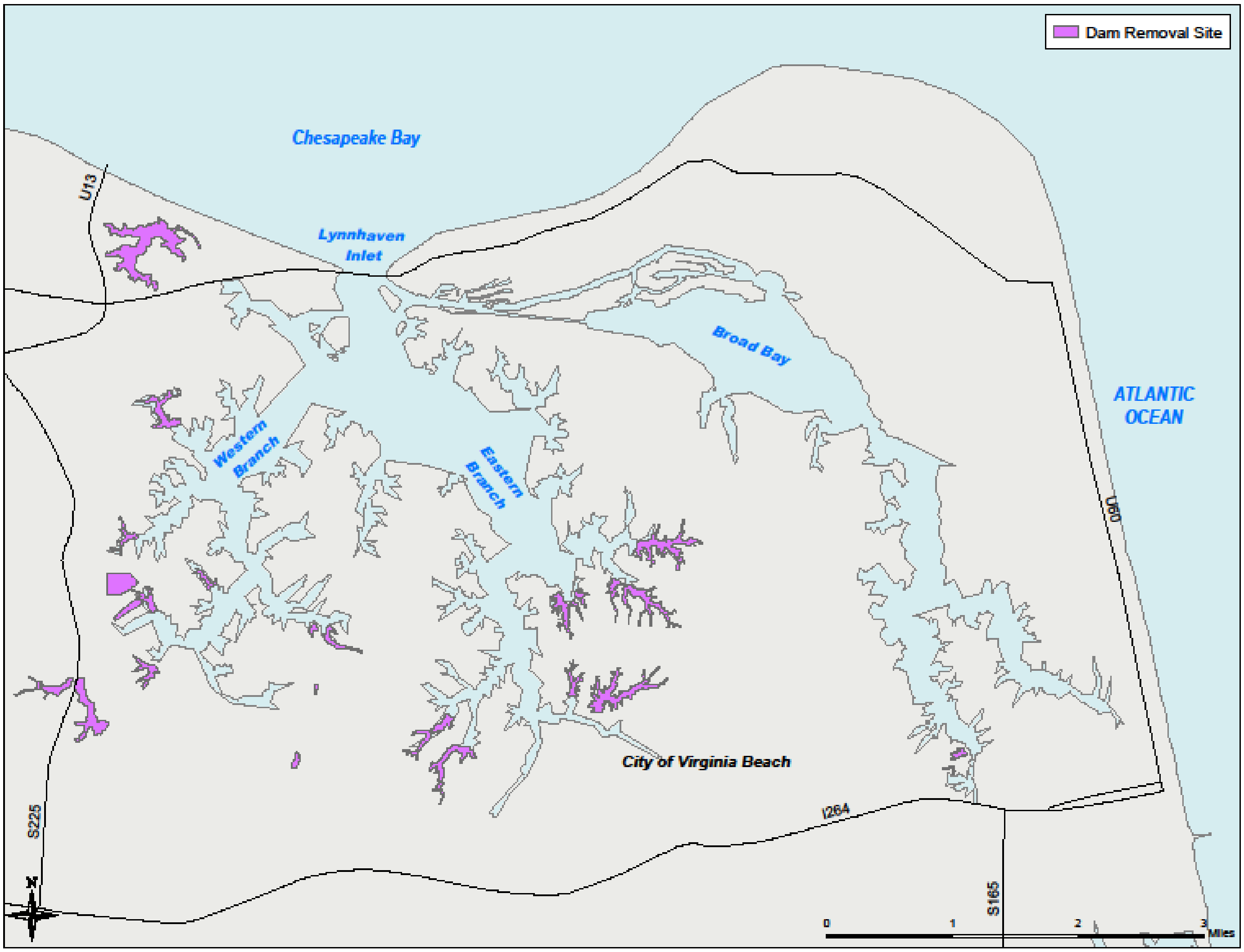
Figure 9. WETLAND CREATION SITES IN THE LYNNHAVEN RIVER BASIN



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

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

Figure 10. DAMS WITHIN THE LYNNHAVEN RIVER BASIN

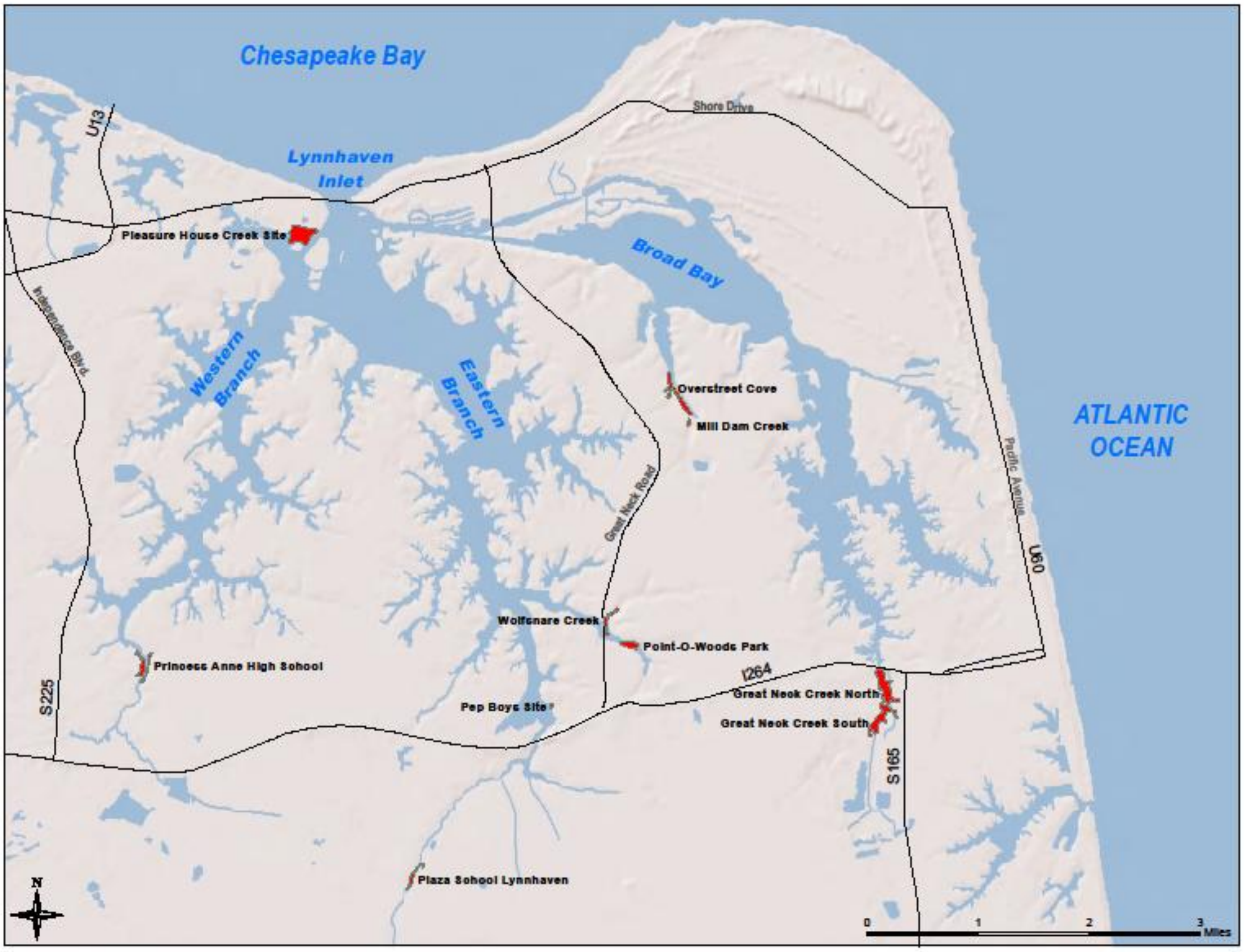


5.4.7 **Wetland Restoration/Diversification.** Ten areas have been identified by the sponsor and resource agencies for the reduction of invasive species. The sites identified are as follows: Overstreet Cove, Pleasure House Creek, Point O' Woods Park, Wolfsnare Creek, Brookwood and Plaza Elementary, the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

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

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

Figure 11. WETLAND DIVERSIFICATION SITES CONSIDERED



5.5 Formulation of Alternatives

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

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

Table 8. FINAL ARRAY OF MEASURES COMBINED INTO ALTERNATIVES

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

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

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

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

6.0 EVALUATION OF ALTERNATIVES

6.1 Costs of Construction

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Table 9. COSTS OF MEASURES

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

Table 9. COSTS OF MEASURES (Cont'd)

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

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

6.2 Description of Environmental Benefits

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

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

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

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

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

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

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

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

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

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

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

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

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

Table 10. ESTIMATED ANNUAL BENEFITS PER ACRE FOR EACH PROJECT MEASURE

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

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

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

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

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

Table 11. AVERAGE ANNUAL BENEFITS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Table 12. WETLANDS WITH PHRAGMITES ERADICATION SITES AVERAGE ANNUAL BENEFITS

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

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

7.0 COMPARISON OF ALTERNATIVE PLANS

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

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

7.1 Multivariable Analysis

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

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

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

Table 13. DESCRIPTION OF ALTERNATIVES

(See Table 18 for Wetland Restoration/Diversification)

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

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

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

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

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

Figure 12. SECONDARY PRODUCTION AND BIBI BEST BUY PLANS

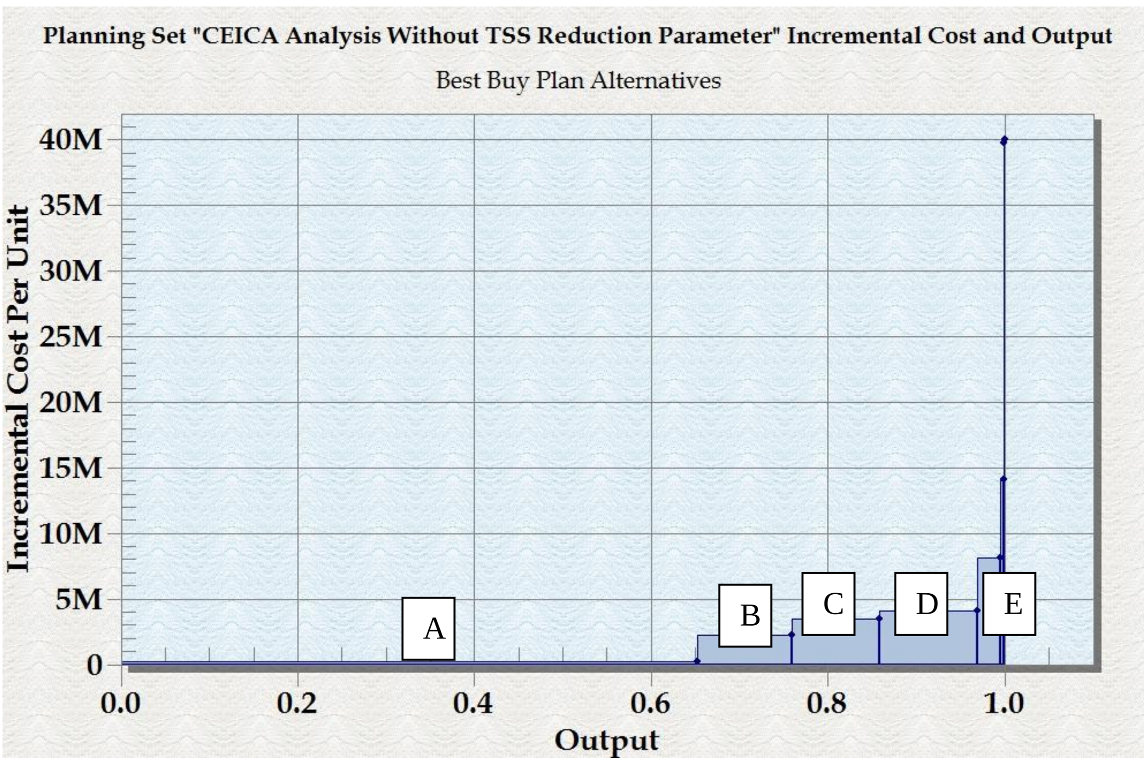


Table 15. RESULTS OF BEST BUY ANALYSIS

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

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

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

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

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

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

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

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

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

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

7.2 Wetland Restoration/Diversification Sites

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

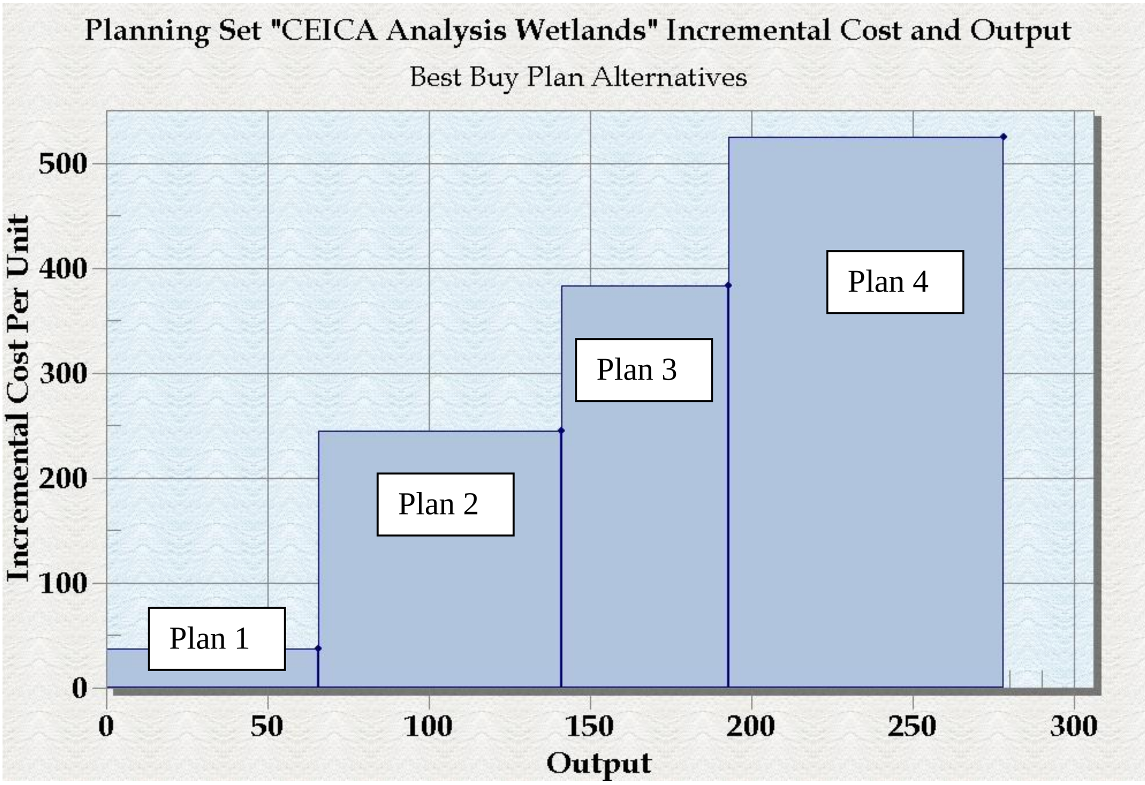
CE/ICA was conducted on just these sites. The CE/ICA for the wetland restoration sites was relatively straightforward, since only one output parameter was used to quantify the environmental benefits. Construction of each of the four sites is not considered mutually exclusive, so all possible combinations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

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

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

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

Figure 13. WETLANDS ANALYSIS BEST BUY PLANS



8.0 SELECTION OF A NATIONAL ECOSYSTEM RESTORATION PLAN

8.1 Plan Selection

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

8.2 Multivariable Analysis

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

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

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

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

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

Table 17. ALTERNATIVE PLANS CARRIED FORWARD AFTER CE/ICA

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

Figure 14. LOCATIONS OF PLAN A

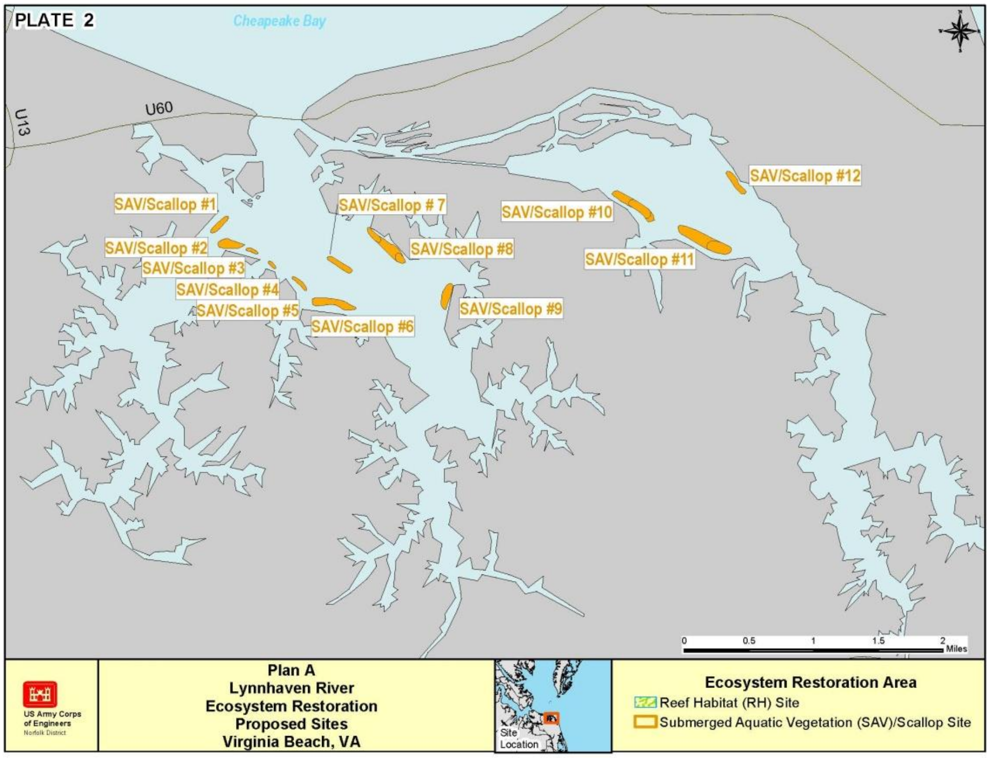


Figure 15. LOCATIONS OF PLAN B

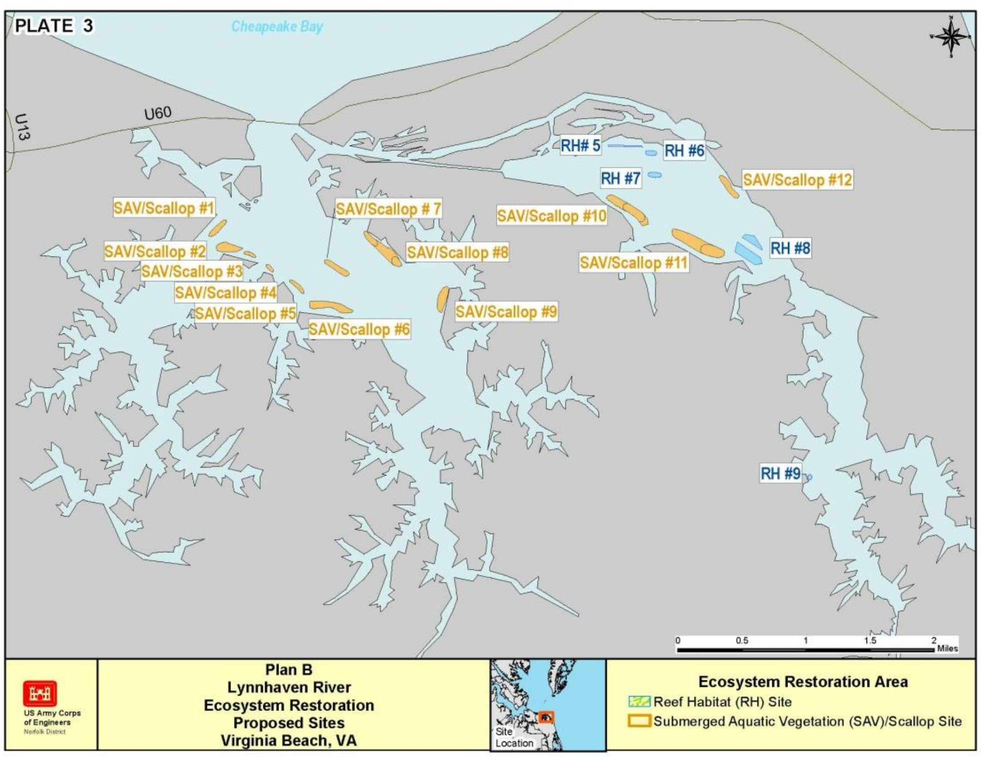


Figure 16. LOCATIONS OF PLAN C

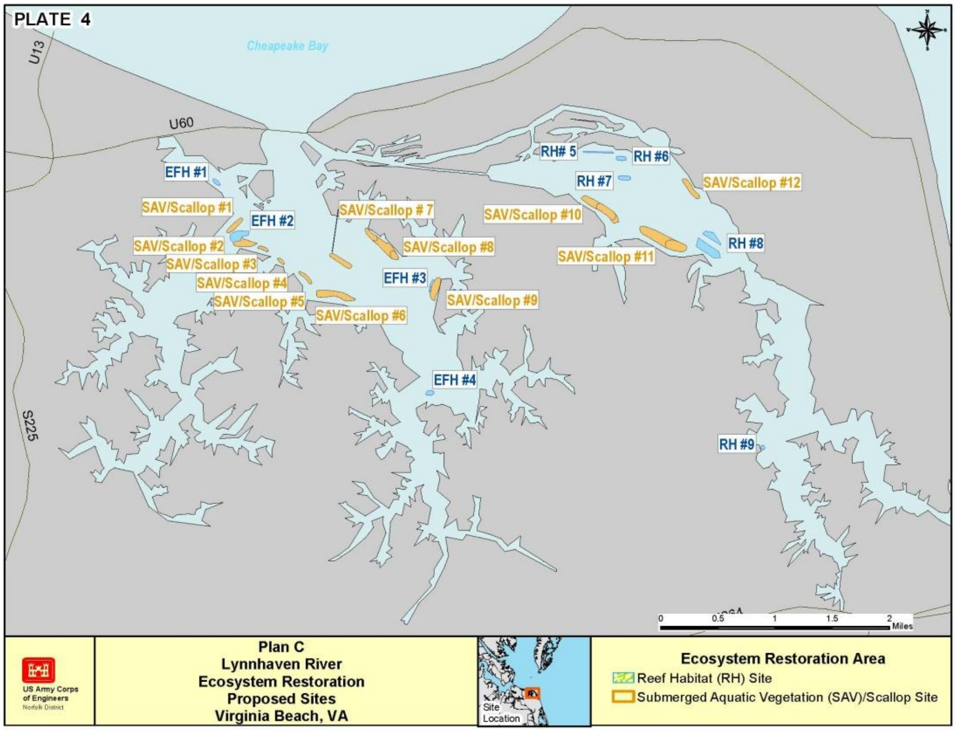


Figure 17. LOCATIONS OF PLAN D

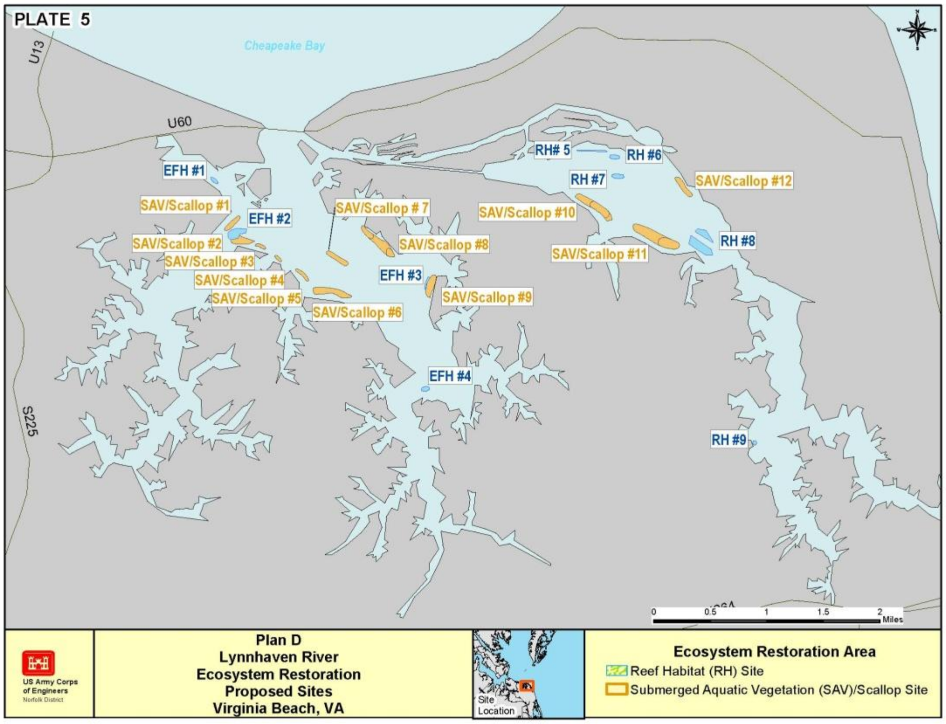
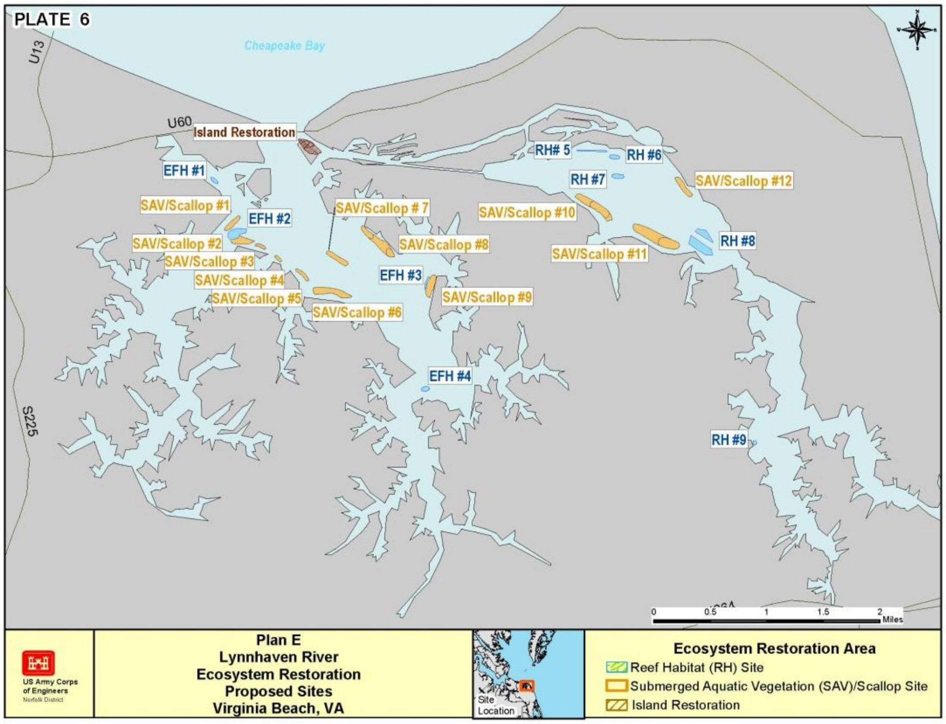


Figure 18. LOCATIONS OF PLAN E



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

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

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

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

8.3 Wetland Restoration/Diversification Sites

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

Table 18. ALTERNATIVE PLANS CARRIED FORWARD AFTER CE/ICA

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

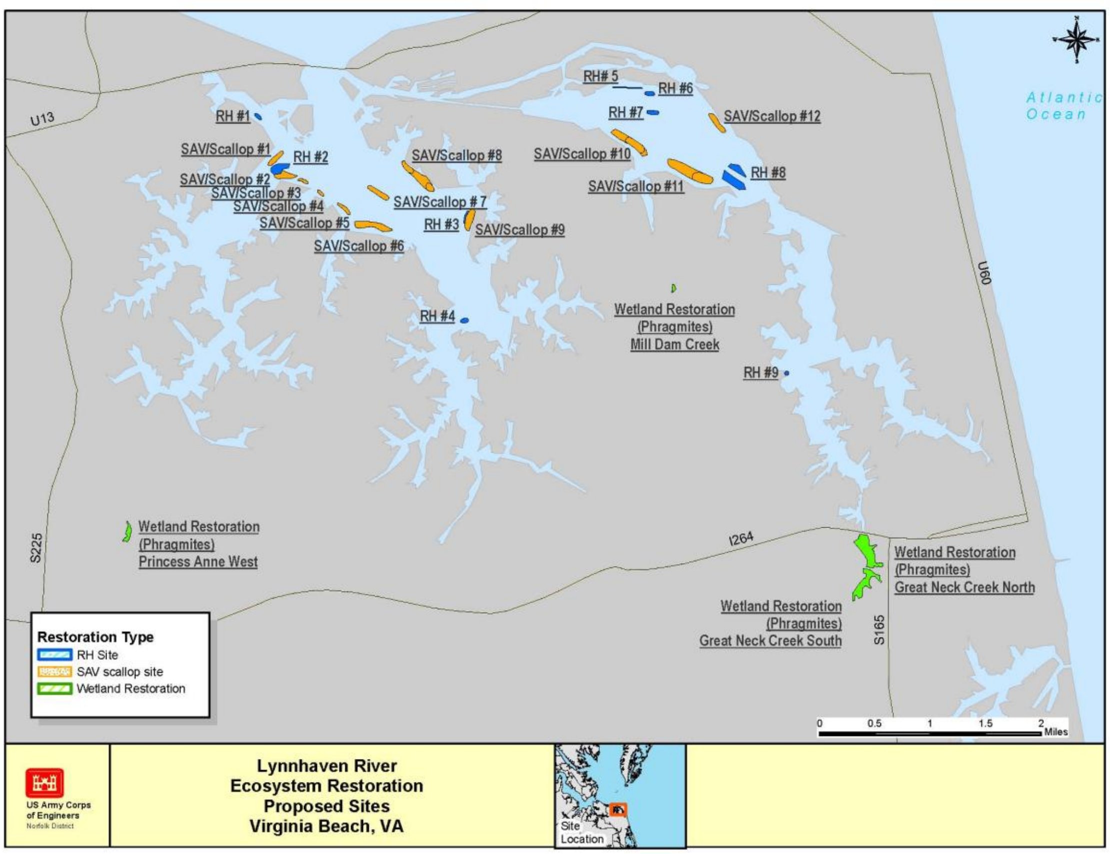
The results of the CE/ICA were analyzed to determine the plan with the best value of the plans evaluated. Of the Best Buy Plans, Alternative 4, with construction of all four wetlands with *P. australis* eradication sites, best meets the planning objectives while reasonably maximizing the environmental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

8.4 Recommended Plan

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

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

Figure 19. LOCATIONS OF THE RECOMMENDED PLAN



8.5 NER Plan Evaluation

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

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

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

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

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

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

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

8.6 NER Plan

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

9.0 PLAN DESCRIPTION

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

9.1 Project Costs

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

Table 19. TENATIVELY SELECTED PLAN PROJECT COSTS

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

9.2 Project Measures

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Figure 24. SAV AND SCALLOP SITES – MAIN STEM

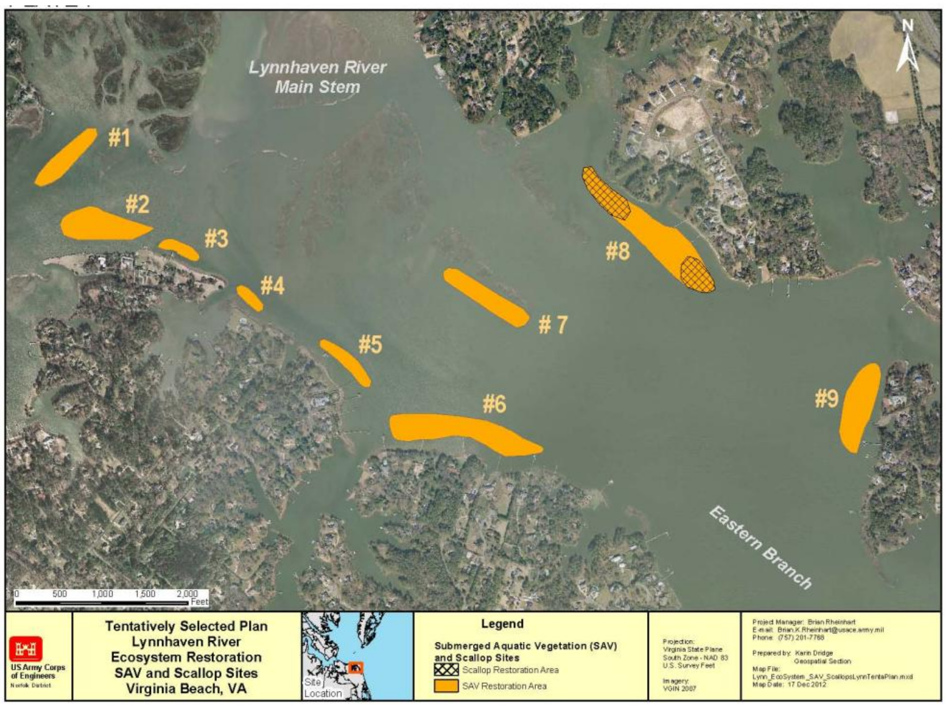
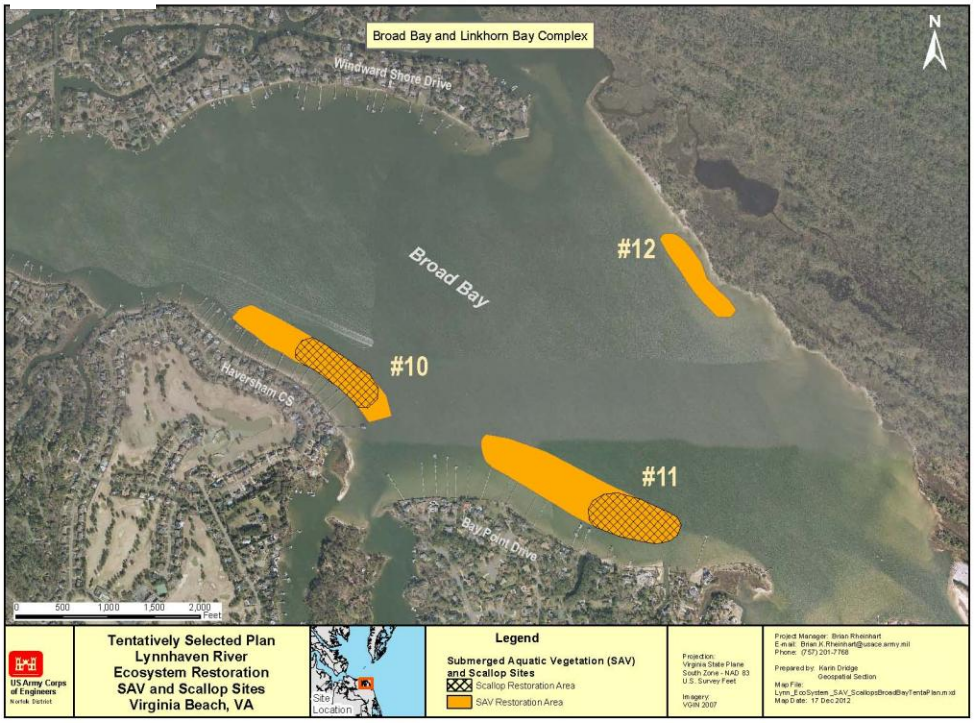


Figure 25. SAV AND SCALLOP SITES – BROAD BAY AND LINKHORN BAY



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

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

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

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

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

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

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

Figure 26. LYNNHAVEN BAY MAINSTEM REEF HABITAT SITES

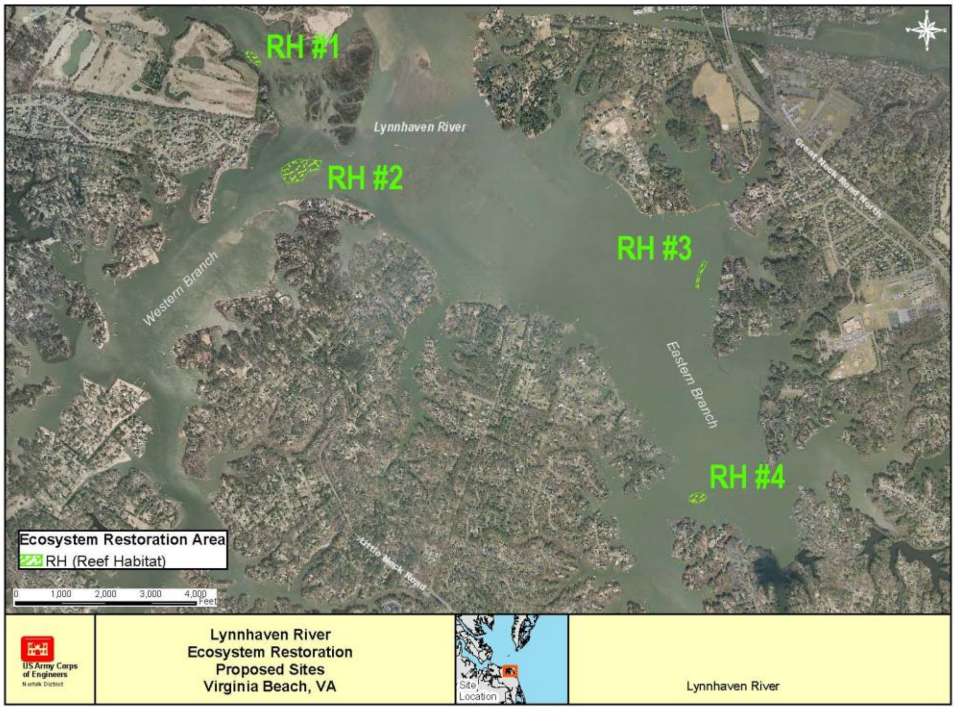
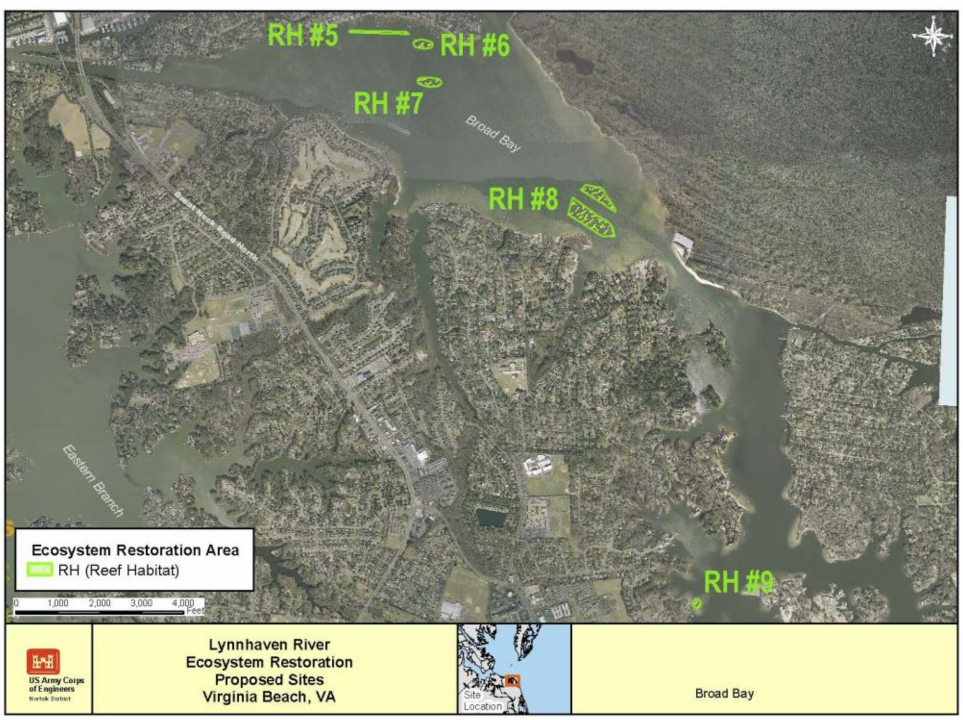


Figure 27. BROAD BAY AND LINKHORN BAY REEF HABITAT SITES



9.3 Real Estate Requirements

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

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

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

9.4 Risk and Uncertainty

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

9.4.5 Sea Level Change.

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

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

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

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

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

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

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

Table 20. SUMMARY OF PROJECT RISK AND UNCERTAINTY

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

Page Intentionally Left Blank

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

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

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

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

9.5 Monitoring and Adaptive Management

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

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

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

Table 21. Reef Secondary Production Over Time

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

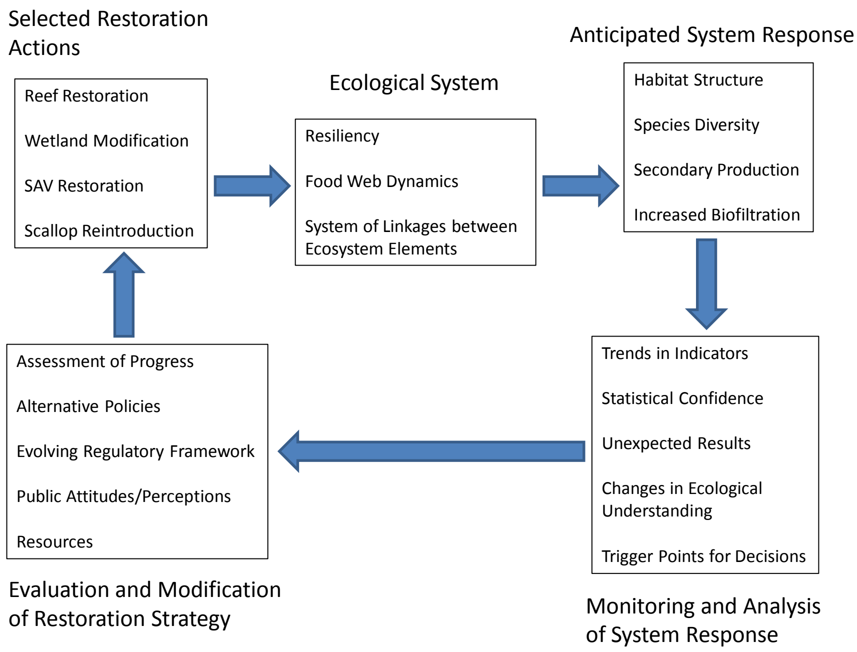
1. The presence of Phragmites australis in the constructed features that would impede the growth of native shrub plantings and would fill in tidal streams and pool,
2. Success of native plantings,
3. Integrity of features (streams, pools, islands, etc.).
4. Estimation of Secondary Production

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

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

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

Figure 28. ADAPTIVE MANAGEMENT PROCESS



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

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

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

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

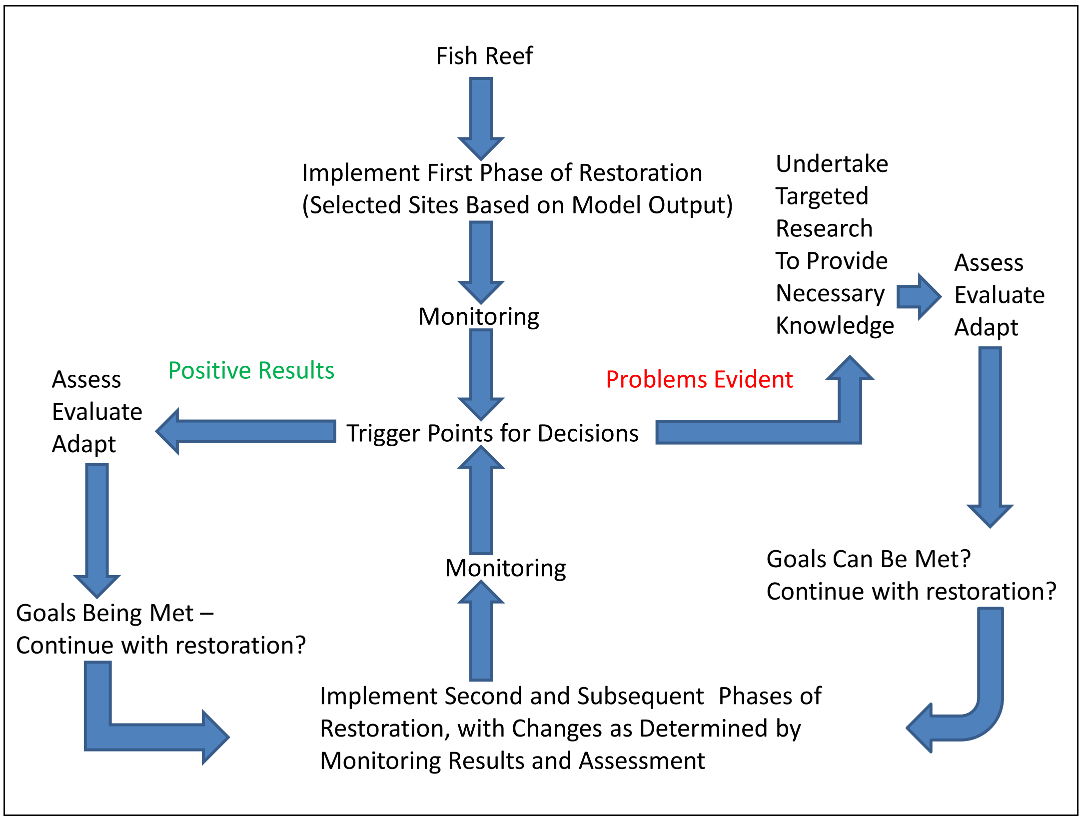
- It should aid in identifying unexpected stresses, environmental conditions, and/or ecological interactions that can affect the overall success of the project. For instance, water quality, particularly temperature, TSS and chlA, can be affected by a very wide range of factors; measuring all of which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

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

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

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

Figure 29. ADAPTIVE MANAGEMENT PROCESS FOR REEF HABITAT



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

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

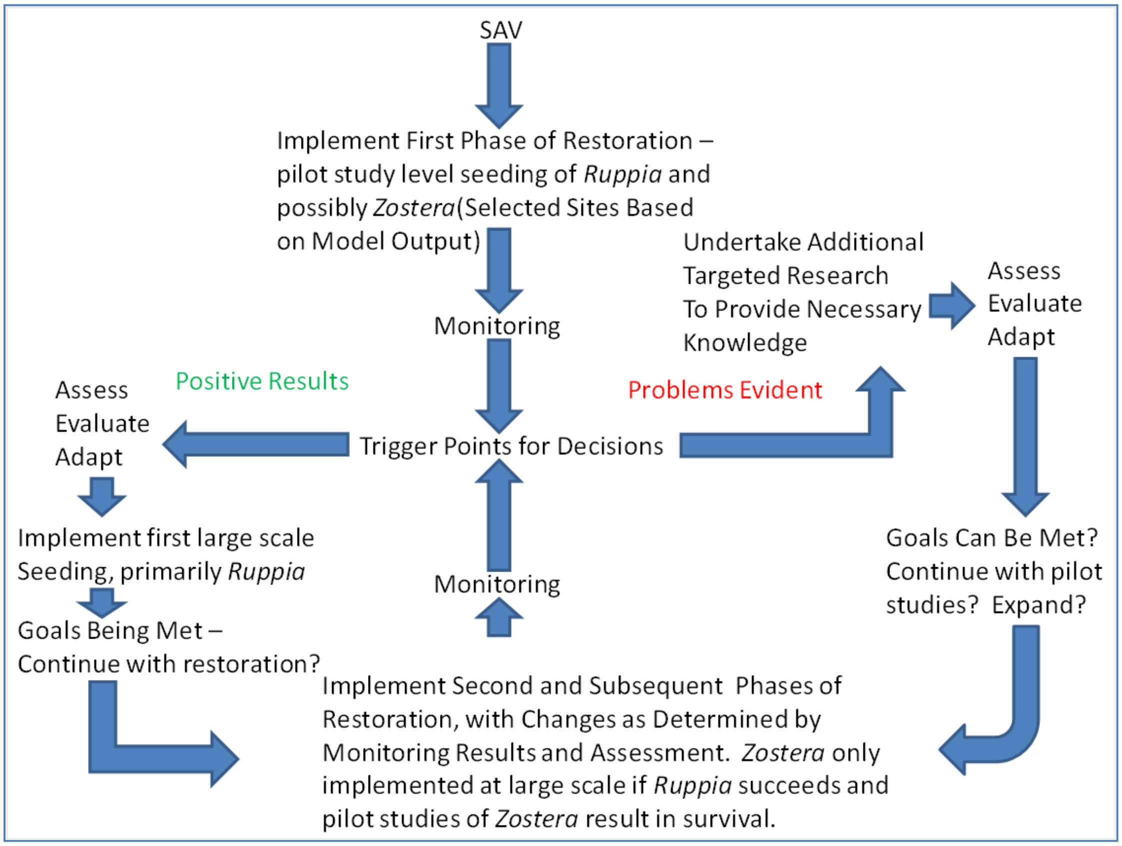
Based on the initial results, future reef placement will be considered and possibly modified in order to improve performance. Modifications could also include changing the shape, conformation and/or placement grid of the structures to improve performance as well as selecting alternative areas for placement.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

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

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

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

Figure 30: ADAPTIVE MANAGEMENT PROCESS FOR SAV



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

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

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

Table 22. SAV SECONDARY PRODUCTION OVER TIME

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

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

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

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

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

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

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

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

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

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

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

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

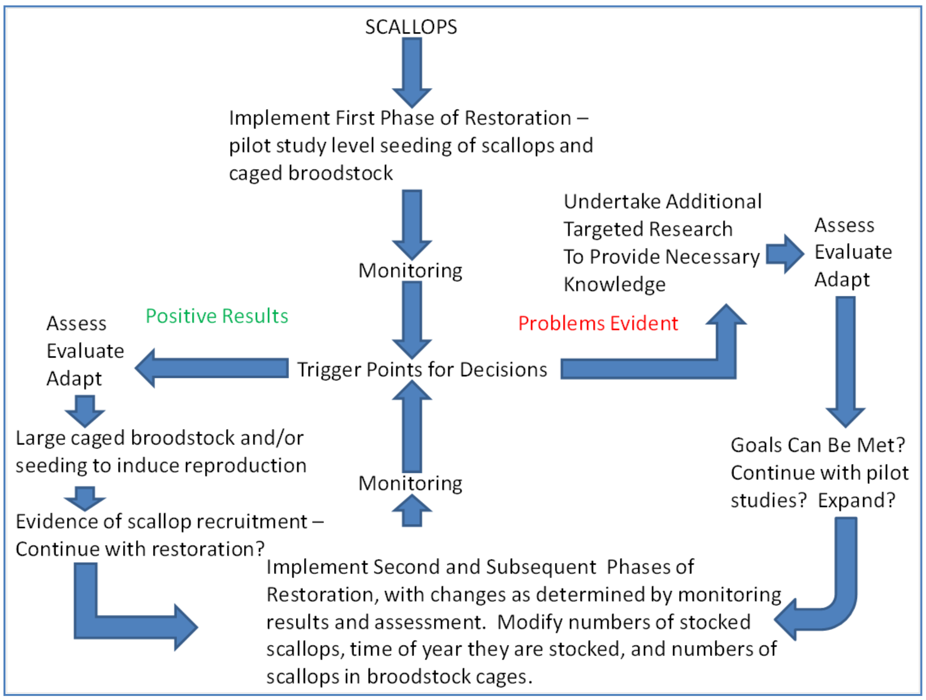
The objectives of the initial sequencing is to determine if scallops reproduce in the Lynnhaven as well as gather data on the most efficient means to restore a breeding population. It is expected that these efforts will be less and shorter in duration than those for SAV, as the Corps has already funded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

Table 23. SCALLOP SECONDARY PRODUCTION OVER TIME

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

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

Figure 31. ADAPTIVE MANAGEMENT PROCESS FOR SCALLOPS



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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The tidal creeks and streams that were constructed or widened during the original construction effort will be observed to ensure that tidal water moves freely through the channel. If the stream is occluded, the feature will be repaired to allow flow.

The shallow pools should remain open and free from vegetation. If the areas are beginning to be colonized by P. australis, herbicide will be used to remove the invasive species unless a better solution is found to maintain the open pool habitats.

The upland islands will be checked for the success of native shrub plantings and re-colonization by P. australis. If 15 percent of the plantings have died, new individuals will be planted on site to replace the dead vegetation. If it is determined that new plantings would be unsuccessful, the site should be evaluated for another solution to vegetate the upland islands. If P. australis has re-colonized the upland islands, inhibiting the success of the native plantings, herbicide will be used to eliminate the plant from the habitat features.

Diversification Sites The habitat features created at the GNS and MDC sites will be observed for colonization of P. australis. If P. australis is found on the upland islands, inhibiting the success of the native plantings, herbicide will be used to eliminate the common reed from the habitat features. The shallow pools and tidal creeks should remain open and free from vegetation. If the areas are recolonized by P. australis, herbicide will be used to remove the invasive species unless a better solution is found to maintain the open pool habitats.

The upland islands will be monitored for the success of native shrub plantings. If 15 percent of the plantings have died, new individuals will be planted on site to replace the dead vegetation. If it is determined that new plantings will be unsuccessful, the site should be evaluated for another solution to vegetate the upland islands.

The integrity of the habitat features will also be evaluated. The tidal creeks and streams that were constructed or widened during the original construction effort will be observed to ensure that tidal water flow moves freely through the channel. If streams are blocked, the feature will be repaired to allow flow. The integrity of the open pools and islands will also be observed to ensure that they are fulfilling their original purpose (i.e. increase habitat diversity at the site). If it is determined that the features are not improving the function of the site, they will be modified in order to meet project goals. Secondary production will also be assessed.

These values are closely tied to the success of the plantings, and as wetlands restoration methods are much more well-established than other portions of the plan, it is expected that if the plantings survive, these values will be achieved. The AM plan is triggered in the event of excessive casualties of the plantings, which directly relate to the values provided in Table 24.

Table 24. WETLANDS SECONDARY PRODUCTION OVER TIME

Wetland Secondary Production Over Time	
Year	Secondary Production (kg/acre/year)
0*	12.1
1	24.2
2	48.4
3	96.8
4	157.3
5	242

9.5.6.2 *Wetland Restoration and Diversification Associated Costs* - It is foreseen the certain adaptive management actions, such as the application of herbicide and the replacement of native plantings, will occur annually. Larger actions, such as the restoration the integrity of habitat features, requiring the physical alteration of the site will be planned every 5 years. The monitoring and adaptive management program will take place over a 10-year period.

The adaptive management costs associated with the wetland sites is $93,755.

9.5.7 Adaptive Management Determination and Closeout. The monitoring program and pre and post construction surveys would be utilized to determine if any adaptive management is needed and what kind to proceed with. This determination would be made by the project delivery team made up of personnel from the Corps of Engineers and the City of Virginia Beach. Costs for the AM decision process have been included in monitoring cost estimates. AM measures will be implemented at any time over the first 10 years post construction by the USACE. After that, if AM is required, it will be the responsibility of the local sponsor, the city of Virginia Beach.

9.6 Additional Ecological Improvements Resulting from the Recommended Plan

The recommended plan will provide many other environmental improvements to the Lynnhaven River System in addition to secondary production and diversity, the two environmental benefit parameters used to quantitatively justify the project.

9.6.1 Alteration of Stable State. In ecology, alternative stable state theory asserts that changes in ecosystem conditions can result in an abrupt shift to the state of the ecosystem, creating a new state that can be stable and persistent (Scheffer et al., 2001; Lewontin, 1969). Such ecologically stable states are also resilient. Ecosystem resilience is the capacity of an ecosystem to tolerate environmental disturbance without collapsing into a qualitatively different state (positive or negative) that is controlled by a different set of processes. Thus, stable states can tolerate additional impacts and can be difficult to alter by restoration attempts (Suding et al, 2004). The likelihood of significantly altering the stable state of the system is greater with a large scale and diversified project, such as the one recommended in this report.

Environmental conditions in the Lynnhaven River started to become impaired around the turn of the 20th century. During the 1970's, river conditions seemed to stabilize in an alternative stable state, one degraded from the original condition but persistent and difficult to change (Beisner et al., 2003). This degraded condition has been a fairly stable ecological state that has persisted for years. That condition was due to the reduction in the population density of primary filter feeders, in this case oysters, as well as negative shifts in underlying environmental drivers such as increases in TSS, nitrogen, and phosphorus related to accelerated human habitation and development of the Lynnhaven River Basin. Increases in nitrogen and phosphorus drove primary productivity up, in this case phytoplankton, thus increasing chlorophyll *a* levels throughout the river (as well as Chesapeake Bay in general).

The current Lynnhaven River condition represents a complex situation with both biotic (living) and abiotic (non-living) factors are influencing the system together. For the Lynnhaven River, this has resulted in extensive loss of natural biota, including near total losses of oyster reef habitat, structure dependent fish, SAV, and benthic diatoms as well as the extirpation of Bay Scallops (which likely happened in the 1930's if not earlier), with little likelihood for natural recovery. Species diversity has been negatively compromised and remains so with little hope for improvement without significant increases in diversity habitat. Abiotically, high levels of TSS and nitrogen compounds have become the normal state for water throughout the river. The ecological feedback resulting from altered abiotic factors and loss of reef and SAV habitat will continue to inhibit the recovery to a healthier, ecologically stable state unless large scale environmental manipulation is successful. Such manipulations can be human or environmentally induced.

The Lynnhaven Ecosystem Restoration Study assessed a wide variety of options and a Recommended Plan was identified. This large-scale manipulation of the river system involves restoration of degraded wetlands and manipulation of wetlands to increase vegetative and concomitant animal species diversity in the near shore environment. Aquatic restoration efforts include restoration of SAV beds, a re-introduction of Bay Scallops within the SAV beds, and replacement of lost 3-D subtidal oyster reefs with high-relief fish reefs which will function as both oyster reefs and fish reefs once they are colonized by oysters and their related epifauna. All of the proposed restoration activities will be done at scales large enough to potentially influence conditions in the Lynnhaven River Basin, which is needed in order to achieve a return to an alternative stable state more representative of an earlier, more pristine ecology. The Recommended Plan will attempt to restore the river to a state dominated by reef-building filter feeding bivalves, SAV beds, scallops, native wetlands, and benthic diatoms in contrast to one currently characterized by waters with high levels of TSS and eutrophic conditions with high levels of phytoplankton and low levels of secondary production.

9.6.2 <u>Total Suspended Solids</u>. Another environmental parameter that will be improved by implementation of the Lynnhaven restoration project is the reduction of TSS levels in river. TSS is a common measure used to estimate negative human-induced impacts to aquatic ecosystems. Quantities of TSS higher than pre-development levels produce a number of negative environmental impacts. TSS reduces gas exchange, increasing the chances for anoxia in tidal estuaries (Abril et al., 2009). TSS reduces water clarity and its increase from human impacts, primarily resulting from agriculture and urban development in the Chesapeake Bay watershed, has greatly reduced the available habitat for SAV (Tomasko et al., 2005). SAV stabilizes bottom sediments and its loss creates a negative feedback loop where TSS tends to increase further, making it increasingly difficult for light-dependent marine life to persist, especially rooted aquatic vegetation. Additionally, TSS reduces the available habitat for other photosynthetic life such as benthic diatoms (Ulanowicz, 1992), altering the species composition along with the associated local estuarine ecosystem and food webs.

TSS also stresses filter feeding organisms, such as oysters, making them more susceptible to disease (Colosimo, 2007). This has been a major cause in their population collapse in recent decades. Additionally, when TSS is high, oyster reefs can become covered with a fine layer of silt that quickly renders the reef substrate unsuitable for oyster larval attachment. However, functional oyster reefs or other hard substrate colonized by oysters and other filter feeders can substantially reduce TSS as they filter feed. TSS typically becomes incorporated into their waste and often ends up deposited on the bottom out of the water column.

Fish species that require hard substrate for benthic egg laying cannot use silt covered habitat for reproduction. Other reef dependent species, such as naked gobies, tautog, and other finfish, suffer from this loss of habitat. Other filter feeders, such as clams and menhaden fish, are also negatively affected by high TSS levels because they must process and eliminate the excess TSS during their filter feeding (Soniat et al., 1998), which uses energy that could otherwise be used for somatic growth or reproduction.

Another negative impact associated with high levels of TSS is increased levels of *E. coli* and other pathogenic bacteria. Such organisms are not commonly found freely living in the water column, because they usually attach to small particles of suspended sediment instead (Schillinger et al., 1985). Thus, lowering TSS levels may have some beneficial effects on pathogenic bacteria levels by lowering them and thereby improving water quality.

There are numerous input factors that influence the TSS levels measured during routine monitoring in the River. However, it is estimated that the Recommended Plan will result in an average annual reduction of 928,000 kg TSS. Table 25 provides an estimate of the amount of TSS that would be removed from the Lynnhaven River Basin annually as calculated by the VIMS Hydrodynamic model.

Table 25. RESULTS OF VIMS HYDRODYNAMIC MODEL RUN WITH RECOMMENDED PLAN

	Chlorophyll A Reduction, Average Annual %	TSS Reduction, Average Annual %
Lynnhaven Bay	13%	17%
Eastern Branch	12%	38%
Western Branch	14%	36%
Broad Bay	16%	74%
Linkhorn Bay	17%	61%

9.6.3 Restoration of Lost Habitat Types. The Recommended Plan focuses on restoration of two valuable habitats, fish reefs and SAV, that once had a dominant presence in the Lynnhaven River System. Both were completely removed from the Lynnhaven River and more recently have played a very minor role ecologically. As described earlier in the report, reef habitat was lost due to the elimination of the oyster population resulting from overharvesting and disease. SAV beds were lost from the system as a result of poor water quality. Recovery of both SAV and oysters is an effective strategy to initiate significant and positive ecological change. The projected outcome is a shift to a more positive, stable ecological state stable enough to promote additional natural recovery over time.

The both habitat types function as ecosystem engineers. Ecosystem engineers are organisms that either create or significantly modify habitat (Jones et al., 1994). The fish reefs will function as hard reef habitat and will be heavily colonized by filter feeders. The most prominent of which, the eastern oyster, creates additional reef habitat as clusters of oyster break off, settle on the bottom, and continue to grow. The concrete structures and the colonizing oysters also provide structure for other marine life. SAV modifies habitat by stabilizing bottom conditions, baffling wave energy, and providing shelter to a wide variety of marine organisms. Development of this habitat, in turn, is expected to increase and improve the diversity and abundance of marine life in the Lynnhaven River system.

As stated earlier, alternative stable states are difficult to alter and are one explanation of why degraded ecosystems are often difficult to restore. Ecosystems that are the most difficult to restoration are those that are heavily controlled by abiotic factors (Didham et al., 2005). The Lynnhaven River is such an ecosystem, one where heavy human development in the Basin has increased TSS and created eutrophic conditions. The abiotic environment, which includes such things as basic water quality parameters like total nitrogen and phosphorus, can be greatly modified by biological ecosystem engineers. These organisms are often the agents of change between alternative stable states (Rietkerk et al., 2004). A large scale restoration using available ecosystem engineers, therefore, is likely the best means to effect change on a watershed scale.

If the restoration and modeled benefits are achieved, there should be significant water quality improvements related to habitat in the Lynnhaven River. Such improvements could allow the restored SAV beds to expand to additional suitable shallow water habitat as both water quality and water clarity improve. Similarly, oysters and their associated epifauna will expand their range as existing marginal bottom habitat becomes more suitable. Scallop populations will establish themselves in any new SAV bed in the high-salinity regions of the Lynnhaven River and though some expansion is possible, it will be more limited due to the scallop's narrower salinity tolerances compared to oysters and SAV. Coupled with the City of Virginia Beach's efforts to control storm water runoff and reduce anthropogenic nutrient inputs to the river, additional ecological benefits could also be realized. Additional benefits are related to positive feedback loops created by the improvements in biotic factors (e.g. SAV and oyster restoration) and improvement in the abiotic factors (e.g. water quality) via continued improvement efforts (Suding et al., 2004) by the City of Virginia Beach. Overall, the selected plan's benefits are forecasted to be significant and are expected to make a visible contribution to the ecological health of the entire Lynnhaven River system.

9.6.4 Dissolved Oxygen. The selected alternative is also predicted to have a positive impact on the DO levels in the Basin. SAV will directly add oxygen to the water column through the process of photosynthesis. The installation of reef habitat is also predicted to have an even larger impact on DO levels than the restoration of SAV beds. It is expected that significant numbers of oysters will colonize the concrete reef structures. This mollusk species is a filter feeder and will remove large quantities of TSS from the water column, which will impact DO levels. Large concentrations of TSS can reduce the amount of oxygen in the water column through a number of mechanisms. TSS absorbs the heat from sunlight, which results in increased water temperatures and decreased DO levels because warmer water holds less oxygen than cooler water. TSS in the water column also will reduce water clarity and inhibit photosynthesis when less light penetrates the water. As a result, less oxygen is produced by plants and algae and there is a further drop in dissolved oxygen levels. Then as the biologic component of TSS falls out of the water column and decomposes, DO is removed from the water column.

9.6.5 Executive Order 13508 on Chesapeake Bay Protection and Restoration. The primary goal of the proposed project is to improve the local ecosystem, which is a tributary of the Chesapeake Bay. The Chesapeake Bay has national significance and was recently the subject of an EO. This Order, 13508, is entitled "Chesapeake Bay Protection and Restoration" contains specific goals for restoration the Chesapeake Bay. One of the main features of the goals is its tributary by tributary strategy and advancing the Lynnhaven Feasibility Study is identified as an action for FY 2011. The proposed project, along with prior oyster shell reef restoration efforts by USACE in 2007 and 2008, will likely enable the listing of the Lynnhaven River as one of the first successfully restored tributaries.

10.0 PLAN IMPLEMENTATION

10.1 Project Schedule

Table 26 shows the schedule through initial construction for the Recommended Plan. This schedule assumes expeditious review and approval of the project through all steps, including authorization and funding. Actual project implementation could take longer. This schedule is subject to availability of funds. The final feasibility report and signed Chief's report must be submitted to Congress, having received Executive Branch approval, by August 31 two years prior to the fiscal year in which construction would start.

10.2 Division of Plan Responsibilities

10.2.1 General. The costs of USACE water resource studies and projects are shared between the Federal government and the non-Federal interest (sponsor), in accordance with the cost sharing requirements outlined in Federal law that are usually stated as percentages for the shares. These costs are then apportioned between the Federal government and the non-Federal sponsor. For projects that provide ecosystem restoration, the purposes are usually (1) ecosystem restoration and (2) separable recreation. For the Lynnhaven River Basin project there is no separable recreation component.

TABLE 26. PROJECT SCHEDULE

Item	Date
Alternatives Formulation Briefing Conducted	25 April 12
Draft Feasibility and Integrated EA Submitted for Concurrent Review to Higher HQ and Agencies and Public Review	26 April 13
Final Feasibility and Integrated EA Submitted	12 July 13
Civil Works Review Board Conducted	24 September 13
Final Feasibility and Integrated EA Distributed for State and Agency Review	05 October 13
FFR and Signed Chief's Report Submitted to ASA	February 14
FFR, Signed Chief's Report, and Signed FONSI Submitted to OMB	April 14
FFR, Signed Chief's Report, and Signed FONSI Submitted to Congress	June 14
Design	July 14
Water Resources Development Act Passed Giving Construction Authorization	*FY16
Project Partnership Agreement for Construction	February 16
NTP with real property acquisition	March 16
Real Estate Acquisition Complete	March 18
Certification of Chief of Real Estate	**February 17
Construction	February 17

*The date of the WRDA passing is an estimate; therefore all dates after the passage of the WRDA are also estimates and are not guaranteed.
**The project will be constructed in phases. It is estimated that the real estate for the first phase of the project will be completed within a year of the PPA being signed; which will allow certification from the Chief of Real Estate by Feb 2017. Certification from the Chief of Real Estate will be obtained for the other phases of construction as realestate is acquired.

10.2.2 <u>Cost Sharing</u>. The study costs are shared (50 percent Federal, 50 percent non-Federal) in accordance with the Feasibility Cost Share Agreement which was executed on September 22, 2004 between the Department of the Army and the City of Virginia Beach, Virginia. For specifically authorized ecosystem restoration projects the costs of construction shall be shared with the non-Federal sponsor, the City of Virginia

Beach. The Federal share will be 65 percent and the non-Federal share will be 35 percent of total project costs, including all applicable costs related to preconstruction, engineering and design, and construction of the project. The non-Federal sponsor shall provide all lands, easements, rights of way, relocations and dredge material disposal areas (LERRD's) determined by the Government to be necessary for the project, and be responsible for performine all required project operation, maintenance, repair, rehabilitation, and replacement (OMRR&R). The costs of LERRD's are included in the total project costs and effectively cost shared through the crediting of their value toward the sponsor's share. The value of LERRD shall be included in the non-Federal 35 percent share. The value of LERRD's is estimated at $725,000. The cost sharing for the project is shown in Table 27.

TABLE 27. PROJECT COST SHARING

Item	Total Costs
Construction	27,148,000
Adaptive Management	1,750,000
Lands, Easements, and Rights of Way	725,000
Construction Management	2,127,000
Preconstruction, Engineering, and Design	2,663,000
Total First Costs	34,413,000
Federal Share (65%)	$ 22,368,000
Non-Federal Share (35%)	$ 12,045,000

10.3 Views of the Non-Federal Sponsor

The Recommended Plan has been developed by a Steering Committee comprised of the non-Federal cost sharing sponsor, USACE, Lynnhaven River NOW, and other local and governmental representatives. The monthly meetings of this committee have provided many opportunities for input, discussion, and endorsement as the plans have evolved through the reconnaissance and feasibility study processes. The Recommended Plan, which has developed over this time, is acceptable to and enthusiastically supported by the City of Virginia Beach and Lynnhaven River NOW. There are restoration activities located throughout the Basin, lending local political and community acceptance to the plan. Because the Lynnhaven River Basin is a spawning and nursery habitat for many aquatic species, the NER plan will have far reaching effects throughout the river system, the Chesapeake Bay, and beyond.

10.4 Views of the U.S. Fish & Wildlife Service

The Norfolk District coordinated with USFWS throughout the entire planning process. Views of the USFWS were provided in a draft Fish and Wildlife Coordination Act Report, which can be found in the Environmental Appendix. The USFWS supports the Lynnhaven ecosystem restoration project and believes that the project will increase productivity of the Lynnhaven Bay system. The major recommendations from the report are:

- Monitoring should occur frequently shortly after planting to determine if animal disturbances such as grazing will be a problem. If the site is being disturbed at such a level that will be detrimental to its success, then additional protective measures should be considered. In addition, many contractors will provide a one year guarantee that all plant material is healthy but it is not specified who is responsible for monitoring for survival or if monitoring will be assessed following a specific protocol. If it is determined that replanting is needed, the contract should guarantee the replanted material for a year from when they are planted. The Service is also concerned about the potential for erosion and colonization by invasive species until the vegetation is established. A comprehensive monitoring program is needed to ensure the success of this restoration project.

- Because the success of the bay scallop restoration is contingent on successful SAV restoration, we recommend monitoring SAV health for a minimum of two years after restoration activities. Reseed the SAV restoration sites that do not meet the preestablished success criteria.

- Aerial herbicide spraying should only be conducted if wind speeds are less than five miles per hour (mph). Wind direction is a lesser consideration because spraying will only occur at wind speeds of less than five mph. The likelihood of precipitation should be considered when making the decision to spray. Weather forecasts and onsite conditions should be monitored before, during, and after spray operations. A chance of precipitation less than 30 percent within four hours prior to the start of spraying will result in a decision not to spray for that day. During herbicide treatment, the wind speed and direction, aircraft speed, spray altitude, and spray mist/droplet size should be monitored continuously.

SAV restoration efforts could be hampered or negated by mute swans. Legislation HR 4114 that proposes to remove protection of exotic species from the Migratory Bird Treaty Act is before Congress. The USFWS recommends that the mute swan population be monitored and that USACE work with the USFWS and the VDGIF to develop a response plan in case mute swans begin to negativity impact the restoration sites.

11.0 ENVIRONMENTAL IMPACT EVALUATION

11.1 Aquatic Resources

11.1.1 <u>Wetlands</u>. EO11990, "Protection of Wetlands," was enacted to avoid the further destruction or modification of wetlands. The EO directs Federal agencies to "minimize the destruction, loss, or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands." The Lynnhaven Restoration Project fulfills the mandate of this EO.

Three elements of the Recommended Plan, SAV planting, reef habitat installation, and Bay Scallops, will have no impact on wetlands. These components occur in subtidal areas of the Lynnhaven River. Therefore, no jurisdictional, vegetated wetlands exist within the footprints of these restoration elements.

The fourth major part of the Lynnhaven Project involves the restoration of four wetlands. All the restoration areas are included in the Fish and Wildlife Service's National Wetlands Inventory. Three of the four sites (GNN, GNP, and PA) are identified with the code E2EM1P. The description code identifies the areas as:

E System ESTUARINE: The Estuarine System describes deepwater tidal habitats and adjacent tidal wetlands that are influenced by water runoff from and often semi-enclosed by land. They are located along low-energy coastlines and they have variable salinity.

2 Subsystem INTERTIDAL: This is defined as the area from extreme low water to extreme high water and associated splash zone.

EM Class EMERGENT: Characterized by erect, rooted, herbaceous hydrophytes, excluding mosses and lichens. This vegetation is present for most of the growing season in most years. These wetlands are usually dominated by perennial plants.

1 Subclass Persistent: Dominated by species that normally remain standing at least until the beginning of the next growing season. This subclass is found only in the Estuarine and Palustrine systems.

P WATER REGIME Irregularly Flooded: Tidal water floods the land surface less often than daily.

The MDC site is described with the code PFO1R, which identifies the site as:

P System PALUSTRINE: The Palustrine System includes all nontidal wetlands dominated by trees, shrubs, emergents, mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean derived salts is below 0.5 ppt. Wetlands lacking such vegetation are also included if they exhibit all of the following characteristics: 1. are less than eight hectares (20 acres); 2. do not have an active wave-formed or bedrock shoreline feature; 3. have at low water a depth less than two meters (6.6 feet) in the deepest part of the Basin; 4. have a salinity due to ocean-derived salts of less than 0.5 ppt

FO Class FORESTED: Characterized by woody vegetation that is six meters tall or taller.

1 Subclass Broad-Leaved Deciduous: Woody angiosperms (trees or shrubs) with relatively wide, flat leaves that are shed during the cold or dry season; e.g., black ash (*Fraxinus nigra*).

R WATER REGIME Seasonal-Tidal: Palustrine, Riverine, and Lacustrine wetlands that are flooded by fresh water tides for extended periods especially early in the growing season, but is absent by the end of the growing season in most years are seasonally flooded-tidal. The water table after flooding ceases is variable, extending from saturated to the surface to a water table well below the ground surface.

At two of these sites, an invasive wetland plant species will be removed and the native tidal salt marsh community will be restored. At the remaining two sites, a native plant community cannot be restored as described in previous sections of the report. Instead, habitat features will be constructed in order to improve the function of the existing marsh. The modifications to the wetland sites will be completed through physical alteration of the existing topography and application of herbicides. These actions may result in short term impacts such as exposure of marsh sediment, damage to native wetland plants currently at the site, and mortality of sessile or slow moving organisms that inhabit the project area. Quick moving creatures may be frightened away from the area resulting in the disruption of their behaviors.

Regrading or removing of material from the marsh surface will result in exposed sediment that could enter the waterway and increase the turbidity of adjacent tidal streams. Materials generated from sediment excavation activities at the wetland restoration sites and disposed of at landfill facilities will be evaluated as a solid waste in accordance with HTRW guidance as appropriate. Best management practices will be used to control runoff and sedimentation until the plantings become established. Overspray of the herbicide may damage native marsh plants. Unintentional damage will be minimized by timing the spraying to correspond with the period in the fall when native vegetation has gone dormant but the *Phragmites* is still active. The motile wetland species are expected to return to the sites once construction has been completed. In areas that have been physically altered and replanted, the marsh community will return. However, the reestablishment of normal levels of biodiversity and biomass will be gradual.

The long term impacts of wetland restoration will be positive in nature. Fish and wildlife usage and habitat diversity would be enhanced with the restoration of wetlands at these sites. The indigenous salt marsh community will be reestablished at two sites. The possible short term impacts related to the Recommended Plan would be outweighed by the benefits which restored wetlands would provide.

The current design of the Recommended Plan complies with the criteria of Nationwide Permit (NWP) #27 “Aquatic Habitat Restoration, Establishment, and Enhancement Activities.” All the alterations that will occur at the wetlands sites are allowed by this NWP, including the removal “of non-native invasive, exotic, or nuisance vegetation,” “activities needed to reestablish vegetation,” “planting of appropriate wetland species,” “removal of accumulated sediments,” “construction of small nesting islands," and "construction of open water areas." Even though this work complies with the criteria of a NWP, USACE will acquire permits from VMRC and the Virginia Beach Wetlands Board via Virginia's joint permit application (JPA) process. A 401 Water Quality Certification will be obtained from the Division of Water prior to construction. The Section 404(b)(1) Evaluation and Compliance Review has been incorporated into this report.

The NAA (No Action Alternative) would result in no impacts at three of the four wetlands sites (PA, GNS, and MDC). These sites are completely dominated by *Phragmites australis*. If no action is taken, it is unforeseeable that this condition would be altered. If no action is taken at the GNN site, conditions may degrade as the *Spartina* community is replaced by the invasive *P. australis*. Areas adjacent to a supply of *Phragmites* seeds and rhizomes or in areas that are not flooded by tidal water at regular intervals will be especially susceptible to *P. australis* colonization.

11.1.2 <u>Submerged Aquatic Vegetation</u>. Very small SAV beds currently exist in the Lynnhaven Basin. Although populations have existed in the past, these beds have disappeared almost entirely over time due to poor water quality and increased sedimentation. The existing SAV beds will benefit both directly and indirectly from the implementation of the Lynnhaven Restoration Project. Direct benefits to SAV habitat will be gained through the planting of 94 acres widgeon and eel grass. The SAV beds will also benefit indirectly from the project because the construction of reef habitat and the establishment of a bay scallop population will result in improvements to water clarity, which will positively contribute to the bay-wide effort to increase the health and size of SAV beds within the Lynnhaven System.

The NAA will have no impacts on the SAV resources of the Lynnhaven Basin. The SAV beds may return to the Lynnhaven Basin without assistance; however, the current population is extremely small and may be an inadequate seed source to reestablish the beds to their past dimensions.

As part of the selected plan and the AM of the project, herbicides will be used to control the growth and spread of *Phragmites* at the four wetland sites. The USEPA approved herbicides for *Phragmites* control include one of two active ingredients: glyphosate or imazapyr. Both glyphosate and imazapyre are both broad-spectrum, foliar-applied chemicals. The chemicals do have the ability to kill most green plant tissue that they come in contact with, although Imazapyre does not kill conifers and some wetland shrubs. Both herbicides break down quickly in wet soils, but imazapyre remains active longer than glyphosate. No negative impacts to the existing SAV populations or to the restored population are expected if the herbicides used at the wetland sites are applied using a method prescribed by the manufacturer.

11.1.3 <u>Aquatic Fauna</u>. The construction of the Lynnhaven project may result in potential short-term, negative impacts to the nektonic community. These impacts include injuries and mortality due to direct encounters during placement of reef habitat and restoration of the wetland sites, disruption of normal behaviors, and a temporary decrease in water quality. Fish and other marine fauna could be injured during the placement of hard reef structures as the concrete structures and stabilization mats are lowered through the water column, or when the wetland sites are being altered. Fish, however, are extremely motile and will move out of the area during construction. Mortality to slower moving fauna may result if the organisms are buried under the fish reefs or if the organisms cannot move away from the project site when heavy equipment is being operated. Natural behaviors such as foraging and hunting may be interrupted while project activities occur. Organisms that are able to leave the immediate area may be scared away from the affected sites, but behaviors should return to normal once the construction phase has been completed.

Construction of reef habitat and restoration of the wetland sites may result in a temporary decrease in water quality; specifically, turbidity and the concentration of suspended solids and dissolved nutrients may increase while dissolved oxygen levels and water clarity may decrease. These changes could impact nekton by interfering with the respiration of organisms with gills and predators which hunt by sight. Water quality conditions will quickly return to pre-project levels once construction has been completed.

The construction of reef habitat and restoration of the salt marsh sites may also result in short term impacts to the benthic community which would be both minor and temporary. Benthic invertebrates will be buried during the placement of geomesh mats and hard reef structures. The amount of soft bottom covered by the building materials will depend on the size of the mats used. In areas where 8’X8’ mats are placed, approximately 15 percent or 1.59 acres will be covered. Where 9’X6’ mats are used, 17 percent or 1.81 acres will be covered. If evenly spaced, approximately 14 feet will separate each eight foot square mat and ten feet will separate the six foot square mats. Benthic organisms at the wetland sites will also be destroyed by construction activities. In addition, benthic populations in areas adjoining project sites may be adversely affected from decreases in water quality that will occur during construction; however, these impacts will only last during the construction phase and normal conditions will return once construction has been completed.

It is anticipated that losses to benthic populations at the wetland and reef sites will be quickly replaced by an alternate benthic community favoring hard substrate (the mats and fish reefs) and the reef habitat will result in increased diversity and biomass. Additionally, benthos have been found to increase in biomass along the edges of hard reef structures and geomesh areas due to the preference of larger mollusks (hard clams in particular, as well as soft clams) for soft substrate bordering harder areas, in particular reef structure (Wells 1957). These areas provide a partial refuge from predators, encouraging clam settlement and survival. Colonization of the hard reef structures will begin immediately after construction has been completed. Species composition on areas not subject to restoration will likely not be affected; though it is expected that biomass per unit area in areas outside reef footprints will go up due to the construction of the reefs. It will take approximately three years for a mature community to become established on the reef habitat (Burke 2010). It is expected that a similar time frame will be required to reestablish the community within the restored wetland sites.

The long term impacts of the project will be positive for the fauna of the lower Lynnhaven River. For example, increasing the amount of SAV beds will benefit aquatic organisms by stabilizing bottom sediment, improving water quality, and providing forage and nursery habitat. Adding reef habitat to the Lynnhaven Basin will benefit aquatic fauna by providing attachment surfaces for benthic egg masses produced by mollusks and fish and for sessile organisms, including oysters. Reef habitat will also provide shelter for fish and mobile invertebrates. The increased productivity resulting from the project may increase the populations of recreationally and commercially valuable finfish and shellfish communities. All of the environmental benefits produced by the implementation of the Lynnhaven Restoration Project have been discussed in detail in a previous section.

The NAA will have no impacts on the aquatic fauna of the Lynnhaven Basin.

11.2 Terrestrial Resources

Three elements of the Recommended Plan (i.e. SAV planting, reef habitat installation, and bay scallop stocking) will occur within subtidal areas of the Lynnhaven River and will not impact terrestrial resources in the short term. The activities involving the wetland sites may have some temporary negative impacts on terrestrial resources. For example, while the wetland sites are being reshaped, the heavy equipment used in the process may scare terrestrial wildlife. Normal behaviors will be disturbed briefly but will return to normal once the initial activity has been completed. At sites where invasive plants will be replaced by a native community, reestablishment of the elements of the wetland community will be gradual, depending on the success of marsh plantings. Another temporary impact to terrestrial resources would result from herbicide overspray. Misdirected herbicide may damage terrestrial plants adjacent to targeted species. Inadvertent damage will be minimized by timing the spraying to correspond with the period during which the native vegetation is dormant and the invasive species are still active.

Long term impacts of wetland restoration on the terrestrial resources of the Lynnhaven Basin will be primarily positive in nature. At the GNS and MDC sites, increasing habitat diversity through the creation of new habitat features will increase the types of wildlife which use the sites. Open shallow pools will encourage wading birds, while building and planting upland islands will attract song birds. The short term possible negative impacts related to the Recommended Plan will be outweighed by the benefits which restored wetlands typically provide.

The NAA will have no impacts on the terrestrial resources of the Lynnhaven Basin.

11.3 Threatened and Endangered Species

The Recommended Plan will have no negative impacts on federally threatened or endangered species or state species of concern. The proposed project will affect tidal salt marshes and shallow subtidal areas within the Lynnhaven Basin. The listed species documented as occurring or potentially occurring in the project area, described in length in Section 2.5 of this report, include five sea turtle species, one terrestrial bird, and three shore birds. The terrestrial bird, the red-cockaded woodpecker, inhabits forested areas. The piping plover is associated with sandy beaches and does not utilize habitat types found at the proposed project sites. The roseate tern is a marine species that nests in colonies and plunge dives for fish. This bird could possibly use the subtidal sites as feeding grounds; however, this species prefers open ocean habitats. The Red Knot is a transient species which is known to fly through the project area in order to reach the species' major North Atlantic staging areas located in the Delaware Bay and Cape May Peninsula. While sea turtles may forage in the proposed project area, they are highly mobile and would be able to avoid impacts due to construction. One of the primary benefits of the Lynnhaven Restoration Project is the increase in secondary production, resulting in larger populations of prey items for sea turtles and shore bird species that utilize the project area.

The NAA would have no effect on threatened or endangered species because no threatened or endangered species were found in the project area.

11.4 Essential Fish Habitat

The 1996 amendments to the Magnuson-Stevens Fishery Management and Conservation Act require Federal action agencies to consult with the NMFS regarding the potential effects of their actions on EFH, which is defined as those waters and substrates necessary to fish for spawning, breeding, feeding, or growth to maturity. AN EFH Assessment was completed and submitted to NMFS. All adverse impacts are determined to be short-term during contruction, localized, and minimal. EFH coordination is ongoing and no issues are anticipated.

11.4.1 <u>Description of Proposed Action</u>. See the Plan Description Section.

11.4.2 <u>Analysis of the Effects</u>. Appendix C, the Environmental Appendix, includes a description the 19 species in the vicinity of the project and at which life stage the NMFS has determined that those species would come in contact with project elements. A number of the EFH species, such as the clearnose skate, winter skate, Atlantic sea herring, and dusky shark, are not found in the Lynnhaven system and would not be impacted by the project. Other species, including the black sea bass and sand bar shark, have individual life stages that will enter estuarine waters and, therefore, short term impacts caused by the Lynnhaven project would only impact these species if the impacts coincided with the life stage. The last group of fish, including bluefish and Spanish mackerel, utilize estuarine waters throughout their entire life cycle, so negative impacts to the environment resulting from the project no matter when they occurred during the year would impact these species.

Most potentially adverse effects to EFH fish species that are expected to result from the implementation of the Lynnhaven project are minor and short term in their duration.

11.4.2.1 ***Scallop and SAV Restoratio***n - No negative impact, either short or long term would result from the restoration of SAV beds or the native scallop population within the Lynnhaven Basin. Numerous positive effects could be realized for EFH fish species, including increased prey populations, bottom sediment stabilization, and improved water quality.

11.4.2.2 ***Wetland Restoration*** **-** The wetland restoration efforts will occur in the intertidal zone and will not directly impact EFH fish species, but may have an indirect effect on these species. While restoration efforts are occurring, water quality may decrease due to earthmoving and the exposure of sediment. Open marsh areas will be revegetated, and BMPs will be employed to reduce the amount of sediment entering the water column.

11.4.2.3 ***Reef Habitat*** - The construction of reef habitat may result in temporary negative impacts to EFH species similar to those described in the previous section on impacts to the nektonic community. These effects include the disruption of normal activity, injury or mortality from direct contact with hard reef structures and mats during placement, and temporary reduction of water quality. These effects will be eliminated once the construction phase has been completed.

A long term change that will result from the construction of reef habitat is the alteration of sandy bottom habitat to hard reef structure. Currently, the Lynnhaven system consists almost entirely of open sandy or muddy bottom habitat. The uniform bottom type is an artificial remnant of the mismanagement and eventual collapse of the oyster fishery, as almost all of the hard reef structure that was originally present in the system has been lost. This project represents an effort to restore a small fraction of the reef structure to the system. Although some of the preferred habitat type of the sand bar shark that is present within the Lynnhaven system will be altered, large areas of sandy bottom will remain available and the structure added to the system will benefit other EFH species.

In addition to increasing habitat heterogeneity, the new reef structures will produce other long-term benefits. The reef will increase productivity of the system and provide habitat for prey species, such as crustaceans, mollusks, worms and fish. The hard reef structures will provides attachment surfaces for sessile organisms, cover and shelter for many species of fish and other motile invertebrates such as crabs and shrimp, and attachment surfaces for benthic egg masses. Additionally, it is predicted that the reefs will be utilized by oysters, mussels, and other filter feeding organisms, resulting in improved water quality.

11.4.2.4 ***Department of the Army's Views Regarding the Effects of the Action on EFH*** - Adverse effects on species from construction of reef habitat will be temporary and minimal. It is highly unlikely that any adverse effects will be caused by the construction of the hard reef structures due to the nektonic mobility of the EFH designated species. Many studies documenting the effects of turbidity resulting from dredging operations which lasted much longer, indicate that high levels of turbidity and suspended particulate matter at the time of breakwater construction and channel dredging had no lasting detrimental effects on biota near project sites (Van Dolah et al., 1987; Manny et al., 1985).

11.4.3 Discussion of proposed mitigation. No mitigation is proposed for this project because one of the primary goals of this project is to increase the quality and quantity of habitat for fish species that utilize the Lynnhaven River Basin, especially those which depend upon hard reef structure and SAV habitat. The specific benefits gained by the project are described previously in this report.

11.5 Water Quality

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

Areas of the Lynnhaven River are listed as impaired for fish consumption due to PCBs. Three of the four elements (SAV planting, scallop reintroduction, and construction of reef habitat) proposed in this project will not impact the bottom sediment. The wetlands measure calls for the removal or relocation of sediment. This material will be tested prior to construction for the presence of contamination. It is unlikely that the sediment at the restoration sites is the source of the PCB contamination found in fish tissue due to the lack of industry, existing or historic, in the Lynnhaven River Basin. However, the release of any sediment into the water column is unwanted and best management practices will be implemented to minimize sediment issues.

A positive result of the Lynnhaven Restoration Project is long term improvement of water quality within the system. SAV beds remove dissolved nutrients from the water column and reduce suspended sediments by stabilizing ocean bottom. The fish reefs will provide attachment sites for sessile filter feeders such as mussels and oysters. These organisms can remove substantial quantities of suspended material from the water column as they feed. For example, a single oyster is reported as being able to filter up to 60 gallons of water a day. Similar to mussels and oysters, Bay Scallops are filter feeders and can filter about 15 liters of water per hour. They also remove suspended solids from the water column, decreasing turbidity, reducing TSS levels, and increasing water clarity. The salt marsh sites will continue to provide the water quality benefits they are currently providing.

The NAA would not change the existing water quality conditions.

11.6 Air Quality

The Lynnhaven Restoration Project lies within the limits of the independent City of Virginia Beach, Virginia. According to the VDEQ Air Regulations (Chapter 20, Section 203), the City of Virginia Beach is designated as a maintenance area with respect to eight hour ozone. The air regulations (9 VAC 5-160 – Chapter 5, section 160) issued by the Virginia DEQ require Federal agencies to prepare a conformity determination if the total of both direct and indirect emissions produced by a Federal action in a maintenance area exceed 100 tons per year of nitrogen, NOx, or volatile organic compounds (VOC).

The most aggressive restoration efforts planned for the wetland sites would require the use of an excavator and a couple of dump trucks. It is estimated that construction efforts would take approximately six months at each site, so 960 hours of equipment use (40 hours over a 4 week period) were used to calculate the air emissions estimate. Using 2008 emissions factors from the USEPA NONROAD model, it was determined that 0.30 tons of VOC and 5.15 tons of NOx would be produced if all three pieces of equipment were operated 40 hours a week over the six month period.

For the SAV plantings and bay scallop stocking, 960 hours and 320 hours were used, respectively, to estimate air emissions. A small boat powered by a single two stroke outboard motor would be necessary to complete both activities. If two boats are used, then approximately 3.8 tons of VOC and 0.2 tons of NOx would be produced to plant the SAV beds, while 1.2 tons of VOC and 0.04 tons of NOx would be released into the atmosphere from the bay scallop stocking effort.

Finally, three pieces of construction equipment were used to calculate air emissions resulting from the placement of concrete fish reefs and stabilization mats, a diesel crane, a small boat powered by a two stroke engine, and a tugboat. It was estimated that 24 months would be required to complete the construction. Therefore, 1920 operational hours (40 hours X 4 weeks X 12 months) were used to calculate emission estimates. Approximately 4.0 tons of VOC and 1.2 tons of NOx per year would be produced in the creation of reef habitat.

The Recommended Plan would have no long term adverse effects on air quality. Minor, short-term effects on local air quality may occur during construction activities associated with the Recommended plan. Short-term health impacts that have been reported caused by air pollution include irritation to the eyes, nose, and through and upper respiratory infections such as bronchitis and pneumonia. Headaches, nausea, and allergic reactions can also result from short-term exposure. Additionally, short-term air pollution can aggravate the medical conditions of individuals with asthma and emphysema.

Negative impacts caused by air pollution would be primarily caused by increased emissions of carbon monoxide, hydrocarbons, and nitrous oxides from the operation of the necessary equipment. If all of the proposed construction was performed at the same time, which is not possible due to specific requirements described previously in the report, in total 9.3 tons of VOC and 6.59 tons of NOx would be produced, therefore the Recommended Plan is exempt from making a conformity determination since estimated emissions from construction equipment would be far below the *de minimis* standards of 100 tons/year, which is the minimum threshold for which a conformity determination must be performed.

The NAA would not involve any construction related air emissions, and would, therefore, have no impacts to air quality.

11.7 Noise

Each of the four elements of the Recommended Plan will result in the production of noise while construction takes place. Accurately predicting the levels of noise produced during construction is difficult due to variability of several factors, including the distance from the construction site, vegetation, changes in elevation, temperature, and humidity; however, an estimation of maximum level of noise that could be produced by each action was calculated.

SAV planting and bay scallop stocking will require the use of one to two small boats powered by outboard motors. SAV seeding is estimated to take six months and the stocking of bay scallop will be completed in two months. Although these two activities will take place at the same sites, they will not occur concurrently. The SAV beds must be seeded and given time to become established before the Bay Scallops can be stocked because the mollusks depend upon the SAV habitat. The noise produced by an outboard boat engine depends on the type of motor and how the motor is being run. At idling speeds, an outboard motor can produce between 70 and 75 dBA, but at full throttle, engines can produce between 85 and 90 dBA. During seeding and stocking activities, the boat motors will typically be idling or moving at slow speeds, which will limit the noise produced during the operation.

In total, the construction of reef habitat in the Lynnhaven Basin will take 24 months. The equipment needed to place the hard reef structures includes a crane positioned on a barge, a tow boat to move the barge, and small vessels powered with outboard motors. Decibel levels produced by a crane are approximately 80 to 90 dBA, while a tugboat will produce approximately 80 dBA, and an outboard motor will create between 70 and 90 dBA. If all three pieces of equipment are running at the same time, between 83 and 93 dBA of noise would be produced (NYDEC, 2001).

The restoration and diversification of wetlands sites will require the use of excavation equipment to dig out the top layer of the marsh and trucks to move the material off site at the PA and GNN sites. Approximately six months will be required at each site to complete the restoration efforts. A diesel excavator and two to three diesel dump trucks would be required at sites where excess sediment must be moved off site, while only an excavator will be required at sites where sediment is used onsite. The range of noise produced by various makes and models of dump trucks has been found to be 83 to 94 dBA, while a diesel excavator can produce between 72 to 93 dBA as measured at 50 feet (USEPA, 1971). If all four pieces of equipment are operated at the same time, between 83 and 100 dBA of noise would be produced (NYDEC, 2001).

The noise projections above describe the noise level at the source and do not take into account the factors that affect the noise levels experienced by a receptor. These include the distance from the source, obstacles that block noise such as barriers and buildings, topography, vegetation, and meteorological conditions such as wind direction and speed, temperature and temperature gradient, and humidity. Noise levels decrease as one moves further away from the source. A point source of noise, such as an idling truck or piece of construction equipment, decreases by a rate of six to nine dBA for each doubling of distance from the source. For example, the typical construction site generates 100 dBA of sound, while 500 feet from the source the noise level is reduced to 65 dBA. Noise is also reduced as it passes through buildings. Sound transmission loss through 230 mm brickwork plastered on both sides is estimated to be 55 dBA, while one layer of plasterboard can reduce sound by 25 dBA.

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

Ambient noise levels will increase while restoration measures are being constructed and may be noticeable by the residents living adjacent to the Lynnhaven system. However, due to the distances from the construction sites to local residences, obstructions between the construction sites and residences, and the sound absorption qualities of buildings, sound levels due to construction will not exceed the Municipal Codes for sound established by the City of Virginia Beach.

The No Action alternative will result in no significant impact on noise levels.

11.8 Hazardous, Toxic, and Radioactive Waste

The measures proposed for the Lynnhaven Basin Restoration Project are not expected to result in the identification and /or disturbance of HTRW. A Phase I investigation of potential HTRW, in accordance with ER 1165-2-132 (USACE, 1992), was completed and is located in the Environmental Appendix. Due to the operational history of the site and the data gathered during the ESA, there is no evidence that HTRW will be found within the wetland sites, when sediment is disturbed during construction.

Even though no HTRW is expected to be encountered, best management practices will be employed during construction at the wetland sites to avoid the suspension of sediment and the release of any contamination into the water column. An erosion control plan will be created and implemented to control the entry of sediments into the tidal streams and their migration downstream of the work area. Construction will occur during low tide when the marsh sites are dewatered to avoid the introduction of sediment into the water column.

Material that is excavated from the wetland sites is considered dredge material and is regulated by the Clean Water Act. The application for a combined permit for the dredging is included in the Environmental Appendix. Once excavated, the sediment will fall into two categories depending on their fate and are regulated by different laws. Material that is used on site to construct habitat features, such as hillocks, is still covered by Section 404(b) Clean Water Act and requires consideration of the potential impacts of the placement of the material, as described in this report. Material that will not be reused on site, but will instead be dewatered and removed to an upland disposal site, is classified as "soil" and is regulated as by the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). This sediment will be tested as required for proper upland disposal at a landfill facility. The testing will be completed in the next phase of this project.

No impacts in regards to hazardous contaminants would occur as a result of the NAA.

11.9 Social Impacts

In general, the Recommended Plan would have relatively minor social impacts. The measures involving SAV and scallop restoration are not anticipated to have any direct social effects. The placement of fish reef structures may enhance the recreational fishery as fishing stocks improve from the increased habitat, which would be a positive effect. The sites proposed for partial or total *P. australis* removal will experience some visual changes. For the Princess Anne High School area and at the GNS site, the *P. australis,* which is about ten feet tall, would be replaced with the much shorter *Spartina alterniflora,* which averages three feet. In the other two sites, swaths of the *P. australis* would be removed and replaced with habitat types including open pools and tidal streams that will provide open areas in the reed stands.

The Lynnhaven River is the locus of much recreational fishing. Speckled trout, red drum, flounder, spot, and croaker are the most notable species, and most who fish for them are fishing for food as well as sport. The Virginia Department of Health posted PCB warnings for two species striped bass and gizzard shad in late 2004. For both species the warning recommends no more than from two meals per month. The warning for striped bass covers the Chesapeake Bay and tidal tributaries and the one for gizzard shad is for the Eastern Branch of the Lynnhaven River only. This has not seemed to dampen the enthusiasm of local anglers for this location. In season, the shores of Lynnhaven Park on the south side of the inlet are crowded with anglers fishing. Kayak and boat fishing is common and the Lynnhaven River a favored location for the former. It is also noted as an area for saltwater fly fishing targeting speckled trout. Although most anglers eat what they catch, there is no documented subsistence fishing in the Lynnhaven.

The establishment of reef structures and SAV should increase the stability of sediments, as well as enhance fish habitat. While implementing these features could have some minor short term increase in turbidity, caused by bottom disturbance during construction, the long term effect on fishing would be positive.

Tourism is a leading industry in Virginia Beach. The resort area is widely known and draws regular overnight visitors from across the eastern United States and Canada. Visitors to Virginia Beach spent an estimated $890 million dollars in 2007 with a total economic impact of about $1.44 billion dollars in output from the city's industries, 15,100 jobs, and $378 million dollars in earnings (Yochim and Agarwal 2008: 6). Visitor spending was up to $1.129 billion by 2010 (VBgov.com). Of course the Atlantic Ocean and Chesapeake Bay beaches are the primary attractions for more than 2.7 annual overnight visitors annually (Yochim and Agarwal 2008: 19). Along with swimming, surfing, sunbathing, and fishing, a growing segment of tourists are attracted by eco-tourism, simply viewing and enjoying natural areas. In recognition of this, the City of Virginia Beach included an line for "Nature-Based Visitation Development" and a nature are in its tourism related capital improvement projects in 2007 (Yochim and Agarwal 2008). While Back Bay and First Landing State Park are noted eco-tourism destinations in Virginia Beach, the Lynnhaven River offers an appeal to those who want to experience a salt water estuarine environment. In this regard, the proposed project would have a beneficial effect on tourism.

The plan would not have any adverse effects on population, land use, community cohesion, transportation, or income levels. It would not result in any population displacement or private property acquisition. No permanent effect on employment would occur although project construction would provide employment during the period of construction for some workers. The plan would also provide positive opportunities for environmental education, especially at the Princess Anne High School site, and possibly community involvement.

There would be no social impacts as a result of the NAA.

11.10 Environmental Justice

An analysis of U.S. Census data from 2000 for the tracts that encompass the areas where the selected plan would be located showed that the tracts have a smaller minority population than the city as a whole, 18 percent compared to 29 percent. The percent of population in poverty was slightly higher for the tracts covering the project area than for the city, 6.4 percent compared to 5.1 percent, but this difference is not considered significant. Implementation of the Recommended Plan would not have a disproportionate effect on any minority or low income groups. In view of the fact that the plan would have positive environmental effects with no significant negative effects, project implementation should not have environmental justice issues regardless of the composition of the population in project area.

The NAA would be not cause environmental impacts.

11.11 Cultural Impacts

The expected effects of the Recommended Plan on cultural resources vary, depending on the specific component of the Recommended Plan. The restoration of SAV and scallops is not anticipated to have any effects on cultural resources. The SAV restoration measure which involves simply broadcast seeding of eelgrass and widgeon grass would not affect any undiscovered cultural resources that might lie on or be submerged in the bottom of the Lynnhaven River. Using mechanical planters to plant SAV would involve only a minor subsurface disturbance of only a few inches of depth as the plants are inserted in the substrate. Similarly, the placement of juvenile scallops, which are about one inch in diameter, in the areas targeted for SAV restoration would not affect any undiscovered cultural resources that might lie on or be submerged in the bottom of the Lynnhaven River. Therefore, a determination of no effect has been made for the SAV and scallop restoration measures that are parts of the final plan.

The placement of fish reef structures could potentially affect any undiscovered cultural resources that might lie on or be submerged in the bottom of the Lynnhaven River where these structures would be placed (see Figures 16 and 17). Although there are no records of any significant historical resources in the specific areas targeted for reef ball placement, the settlement patterns of the Lynnhaven River Basin and the use of the river do not preclude the possibility of submerged cultural resources in the areas where the hard reef structures would be placed. Therefore, a remote sensing survey would be carried out for the areas under consideration for placement of hard reef structures in the selected plan during the next phase of this study (the PED phase). Any suspicious targets found in this survey could then be avoided in the actual placement of the hard reef structures.

The *P. australis* removal would affect an area that has traditionally had lower elevations and been wetlands in the first half of the 20th century and probably earlier. The *P. australis* removal measure will involve soil disturbance with the cutting of channels through the areas to facilitate the flow of brackish water and provide a more varied habitat in the areas. No cultural resources have been found previously in these areas. In the case of the PA site, map evidence indicates that the proposed restoration site was previously the location of a sewage treatment/disposal facility. Because of this usage, this area has very likely been previously heavily disturbed, and it is unlikely that significant cultural resources still remain in an undisturbed state. A determination of no effect has been made for any project constructed at this site. For the other three sites (MDC, GNN, and GNS), a Phase I cultural resources investigation will be carried out in the next phase of the study (PED) to determine more definitively the likelihood of there being cultural resources that would be affected by implementation of the selected plan.

This study was initially coordinated with the VDHR by letter of August 4, 2005. Informal coordination by telephone has occurred as the study progressed. Formal coordination will continue through the review phases of the Feasibility Study and during the design phase as the cultural resource field studies are carried out.

No impacts to cultural resources would occur as a result of the NAA.

11.12 Sea Level Change

Data collected by the Sewells Point tide gauge in Virginia was used to project SLC for the Lynnhaven Project. This particular gauge has been collecting tide and sea level change information since 1927. As required by USACE policy (EC 1165-2-212 - Sea Level Change Considerations in Civil Works Programs) increases in sea level were calculated for three different accelerating eustatic SLC scenarios - low, intermediate and high. Sea level is projected to rise by 0.73 feet within fifty years if the rate of increase remains consistent with historic trends as described in the low scenario (Table 28). The intermediate scenario predicted a 1.14 foot increase in the sea level, while the high scenario forecasted that sea level will increase 2.48 feet over the 50 year life span of the project.

The two elements of the Lynnhaven Study that will be most influenced by sea level rise are SAV and wetland restoration, while SLC will have little or no effect on reef habitat and Bay Scallops. Although Bay Scallops prefer SAV habitat, they are also associated with sand and muddy bottoms and will persist without SAV. If the locations of the SAV beds shift due to the effects of SLC, the bay scallop population will adjust with the SAV beds. As sea level rises, the depth of the hard reef structures will increase; however, the fish and invertebrates within the Basin will continue to utilize the structures. SLC may limit the amount of algae that depends on light transmission using the reef habitat.

Table 28. PROJECTED INCREASE IN SEA LEVEL FROM INITIAL CONSTRUCTION, 2014 THROUGH THE 50 YEAR LIFE SPAN OF THE LYNNHAVEN RIVER BASIN ECOSYSTEM RESTORATION PROJECT

Year	Low Scenario (ft)	Intermediate Scenario (ft)	High Scenario (ft)
2014	0	0	0
2019	0.07	0.10	0.17
2024	0.15	0.20	0.36
2029	0.22	0.30	0.57
2034	0.29	0.41	0.79
2039	0.36	0.52	1.03
2044	0.44	0.64	1.29
2049	0.51	0.76	1.56
2054	0.58	0.88	1.85
2059	0.66	1.01	2.15
2064	0.73	1.14	2.48

Two recent studies have investigated the impact of SLC on the tidal wetlands of the Virginia Beach area. In the first, the U.S. Climate Change Science Program (Cahoon et al., 2009) assessed wetlands of the mid-Atlantic Region, and the second was completed by VIMS and concentrated specifically on tidal marshes in the Lynnhaven Basin (Berman and Berquist, 2009).

The U.S. Climate Change Science Program study predicted wetland survival using three different scenarios, twentieth century rates of SLC, a 2 mm/yr (0.007 ft/yr) acceleration of SLC, and a 7 mm/yr (0.02 ft/yr) increase (Cahoon et al., 2009). The study concluded that wetlands in the Virginia Beach area would keep pace with increases to ocean levels predicted in Scenario 1, but would not survive and would be converted to open water if sea level increased at the rate described by Scenario 3. The fate of local wetlands could not be determined at the Scenario 2 rate of increase and would be dependent on hydrology and sediment supply.

The VIMS wetland study also assessed SLC at three different rates (Berman, 2009). The most conservative prediction used an increase of 4.1 mm/yr (0.01 ft/yr), a rate similar to the historic SLC observed at the Sewell's Point, VA tide gauge. This scenario predicted increases in sea height by 102.50 mm (0.40 ft) and 205 mm (0.67 ft) at years 2032 and 2057 respectively, resulting in the loss of nearly 30 percent of all wetlands in the Lynnhaven Basin over the next 50 years. Two more aggressive rates, 7.35 mm/yr (0.02 ft/yr) and 17.20 mm/yr (0.06), were used to project SLC out to year 2100. Increases in sea level of 683 mm (2.24 ft) and 1600 mm (5.25 ft) were calculated for the medium and high accelerated rates, resulting in the loss of 95 percent and 100 percent of all wetlands.

The VIMS study did not account for vertical accretion or horizontal transgression; the study concluded that SLC is "clearly a risk to intertidal wetlands" and that virtually all tidal wetlands in the Lynnhaven Basin could be lost. Individually, the wetland sites have different exposures to increasing sea levels. Both the GNS and the MDC sites are impounded behind embankments and are connected to tidal influence by small culverts.

These sites were not even considered tidal wetlands in the VIMS study. It is possible that these sites might be protected from the increase in ocean height, and increased tidal inundation may help the sites revert back to a *Spartina sp.* dominated system. Both GNN and PA are exposed to the full effect of SLC. The VIMS study predicts the complete loss of these sites by 2100 for the two most aggressive predictions of SLC (4.1 mm/yr and 7.35 mm/yr). However, these sites are not completely surrounded by developed and hardened banks. The PA site has a wooded buffer zone between it and the school property, while the GNN site is adjacent to a Phragmites dominated area that is higher in elevation than marsh in the project site. Although the project sites may be lost to SLC, new marsh may expand into the undeveloped surrounding areas.

SAV beds are not static systems and can, to some degree, adjust to meet changing habitats conditions. As the water column becomes deeper due to SLC, aquatic plants will migrate into shallow waters if allowed by the geography and development of the inundated shoreline.

Elements of the Lynnhaven River Basin may limit the ability of the SAV beds to adjust to SLC. A large amount of the Lynnhaven shoreline is developed, consisting of high slopes, hardened shoreline, and structures. This development could hinder the natural movement of SAV beds and stop the natural progression of marine plants into newly inundated areas. Also, eelgrass, *Zostera marina*, is at the southern limits of its range in the Chesapeake Bay. As a result, the effects of climate change on eelgrass populations may be more pronounced that at other sites.

11.13 Cumulative Impacts

The cumulative impact assessment is the evaluation of the effects that other past, present, or reasonably foreseeable future actions, alternatives, or plans might have on the environment when considered along with the proposed project’s impacts.

11.13.1 <u>Population Growth and City Development</u>. In 1970, Virginia Beach was a small city, with a population of about 172,000 people. Between 1980 and 1990, the city’s population grew at a rate of 50 percent, making it one of the fastest growing cities in the United States. By 1993, the number of people living in Virginia Beach had reached more than 419,000. Through a diverse economy, various development projects, and burgeoning tourism, Virginia Beach became one of the largest cities in Virginia.

Currently, more than 434,000 people reside in the Virginia Beach area. Roughly one-half of the population resides on 1/5 of the city's land mass, in the northern section of the city, which includes the Lynnhaven River Basin. It is predicted that the population surrounding the Lynnhaven system will continue to grow, though not at a pace experienced in the 1980's and 1990's. Growth estimates predict that the population in the Norfolk-Virginia Beach-Newport News MSA will increase by 0.8 percent annually through 2030, while the Virginia Employment Commission projects that the Virginia Beach population will reach more than 490,000 by 2030.

In preparation for continued population growth, the City of Virginia Beach has produced a comprehensive growth plan in order to direct future development of the city (City of Virginia Beach, 2010). For the last 25 years, the city has encouraged growth in the northern region of the city, where the Lynnhaven system is located. City officials have designated strategic growth areas (SGAs) along the Route 264 corridor, west of Rosement Road, and north of Virginia Beach Boulevard. Areas which have been designated as SGAs are slated for concentrated growth in a strategic and sustainable manner, where centers of employment, living, commerce, shopping, arts, and culture will be developed. The SGAs will be modified from their currently undeveloped or suburban patterns into urban areas. Most SGAs are located within the Lynnhaven Basin, so the environmental impacts resulting from the creation of urban areas, such as increased acreage of impervious surfaces and amounts of runoff, will affect the Lynnhaven system.

Water quality in the Lynnhaven Basin deteriorated as Virginia Beach quickly developed into the urban city with surrounding suburban residential neighborhoods. Reduced environmental quality has resulted in the loss of almost the entire SAV population within the estuary. Additionally, elevated bacteria levels within the Lynnhaven River forced the Virginia Health Department to close almost all of the shellfishing grounds within the system for decades, and the area was included on the section 303(d) list of impaired waters due to fecal coliform concentrations (USEPA, 2009).

Over the last ten years, significant environmental improvements to the Lynnhaven system occurred due to partnerships between the City of Virginia Beach, motivated grassroots organizations, such as Lynnhaven River NOW and The Chesapeake Bay Foundation, and state and Federal agencies. In 2006, Virginia Department of Environmental Quality (DEQ) completed a TMDL for fecal coliform for the Lynnhaven River, with ultimate goal of meeting bacteria water quality standards in order to support "the production of edible and marketable natural resource" designated use. The TMDL implementation plan included sanitary sewer improvements, stormwater programs, boat programs, and pet waste programs. Local groups have worked together to implement the TMDL plan through increased public awareness, improvements to infrastructure, and changing city ordinances, all in an effort to restore the estuary to its former glory (USEPA, 2009).

Actions which have been taken to reduce the amount of bacteria entering the system include designating the Lynnhaven River as a No Discharge Zone, which prohibits the discharge of sanitary waste from boats, and offering a free summer boater pump out service (Lynnhaven River NOW, 2009). The City of Virginia Beach has also spent $45 million to reduce the number of sewer leaks and overflows into the river. The city has attempted to eliminate septic tanks within the Basin. Of the 11,600 septic tanks that were originally in the system, only 238 tanks remained in 2009.

Since the implementation of the TMDL, ongoing efforts have resulted in reduction of fecal coliform levels and the restoration of healthy shellfishing areas (USEPA, 2009). In late 2007, the Virginia Department of Health opened 1462 acres (29 percent) of the Lynnhaven to shellfish harvest, which included some areas for the first time since the 1930's. By 2009, a total of 1934 acres met the rigorous bacteria standard for safe shellfish harvest and were opened to shellfishing.

Stormwater entering the Lynnhaven River plays a pivotal role in the degraded water quality within the system. At present, stormwater enters the Lynnhaven River through approximately 1,000 stormwater outflows (Lynnhaven River Now, 2009). Most of the runoff, which contains materials such as pesticides, nutrients, pet waste, and petroleum products, is not treated before it enters surface waters of the Lynnhaven River.

Recently, stormwater management has improved in the Lynnhaven system. The City of Virginia Beach has installed a new filtration system and continues to use solar aeration to remove bacteria, sediment, and nutrients from stormwater; however, only 19 percent of stormwater is currently being treated before it enters the Lynnhaven system (Lynnhaven River Now, 2009). The Green Ribbon Committee of Virginia Beach has created new strategies for the management of stormwater, including support of low impact development, prohibiting direct discharges into wetlands, revisions to storm sewer discharge ordinances, and defining a city-wide minimum water quality standard. Once these strategies are implemented, it is expected that the amount of stormwater that receives treatment will increase. Additionally, in 2009 the city allocated another $1.2 million for the development of a Comprehensive Stormwater Management Plan and a new bacterial tracking method.

Although improvements to some elements for water quality have been observed, it is foreseeable that water quality will remain an ongoing challenge in the Lynnhaven River (Lynnhaven River Now, 2009). Each year, Lynnhaven River NOW, a private, environmental organization dedicated to the restoration of the Lynnhaven River, rates the system on many criteria including water quality. The most recent report, completed in 2009, noted that bacterial contamination, from human, pets, and wildlife fecal material, is still a large problem in the river. Dissolved nutrients, specifically nitrogen and phosphorus used in lawn and garden fertilizers, are continuing to enter the system in large quantities via stormwater runoff. Also in 2009, 7.9 mi^2 of the Lynnhaven River was classified as impaired due to low levels of dissolved oxygen. Finally, water clarity within the Lynnhaven River, due to elevated levels of suspended solids and algae, remains low enough to limit the distribution and restoration SAV.

11.13.2 <u>Native Oysters</u>. The current diminished population of native oysters within the Lynnhaven system is the direct result of past harvesting practices, disease, and degraded habitat quality. Harvesting oysters is destructive to the reef because oyster shell, which makes up the reef structure, is removed from the shellfish bed. Historically, shell material was not replaced, resulting in the loss of oyster habitat. In addition to habitat destruction, disease and overharvesting damaged impacted oysters to a point where the population could not keep pace with mortality. Oyster beds also suffered from the effects of decreased water quality specifically, increased sedimentation.

Public attention has recently focused on restoring native oyster reefs to the Lynnhaven River. Ten years ago, the Lynnhaven oyster population was estimated to be only 1 percent of historic abundance, but a recent estimate suggests that the current population has grown to approximately ten percent of historic numbers. The Norfolk District, USACE has played a large role in the restoration of native oyster populations through the construction of 58 acres (out of a total of 63 constructed in the River) of new sanctuary oyster reefs in the Lynnhaven, building 28 acres of reef in 2007, and constructing an additional 30 acres of new sanctuary oyster reefs in Broad Bay and Linkhorn Bay in 2008. Oyster populations have also been increased through oyster gardening efforts of local residents and the oyster shells saving programs, which return shells to sanctuary reefs. Other cooperative projects between Chesapeake Bay Foundation, the VMRC and the City of Virginia Beach have also resulted in the creation and seeding of reefs within the Lynnhaven River.

Overall, the majority of the reefs constructed by the USACE have been successful according to new Federal standards developed to support EO 13508. To be considered "minimally successful" at least 15 oysters of multiple age classes per square meter of restored reef should be present, and "successful" requires a minimum of 50. The majority of the USACE reefs have well over 50 oysters of multiple age classes per square meter of restored reef according to a survey conducted in winter 2012 and additionally, lots of "spat" (young-of-the-year) oysters were noted on most reefs, indicating continued recruitment of oysters and long-term sustainability of the reef structure.

11.13.3 <u>Sea Level Change</u>. Sea level rise is predicted to have significant negative impacts on the wetlands of the Eastern seaboard, including those within the Lynnhaven system. In a study completed by VIMS, (Berman and Berquist, 2009) it is estimated that if ocean levels continue to rise at historically recorded rates (4.1 mm/year), approximately 81 acres of wetlands will be lost by 2057. The worst case scenario (17.2 mm/year) that was analyzed during the study predicted that all wetland acreage would be inundated by sea water by 2100.

As discussed in an earlier section of this report, wetlands can accommodate an increase in water level of about 3.0 mm/year through vertical accretion, and the wetlands in the Lynnhaven system have kept up with increases of approximately 4.0 mm/year. Wetlands can also adjust to sea level rise by horizontal transgression or moving into upland areas as they become inundated. Developed shorelines, which contain bulkheads, riprap, and other forms of shoreline development, act as barriers which do not allow marshes to move with sea level. The ability of wetlands within the Lynnhaven system to move horizontally will be limited due to the amount of shoreline development. Of the 429 kilometers of shoreline in the system, wetlands are present along 205 kilometers, and 175 of those kilometers are associated with development.

Coastal management will play an important role in controlling the amount of wetland acreage ultimately lost to sea level rise. If soft structural stabilization and living shoreline approaches are supported over hard structures, losses of wetlands may be reduced. The future use and management of the remaining undeveloped land in the Basin will also be important for the preservation of wetlands. Setting aside open areas will provide a corridor that will allow wetland migration in the future.

11.13.4 <u>Conclusion</u>. The future will contain both continued challenges and improvements for the ecosystem of the Lynnhaven Basin. Population increases within the surrounding Basin and the development of the city towards an urban center will place added environmental stressors on an estuary. However, the City of Virginia Beach and other non-government organizations are motivated to restore the health and function of area, and significant strides have been taken to address the significant environmental issues affecting the system. These organizations will continue to implement programs towards the achievement of their long term goals of restoration. The proposed Lynnhaven River Basin Restoration project will complement their continuing efforts within the watershed. For example, one of the goals of Lynnhaven River Now is to establish 175 acres of SAV. The Lynnhaven River Basin Restoration project will both assist in the achievement of this objective directly, by seeding 90 acres of SAV beds, and indirectly, by improving water quality through establishment of reef habitat and the sessile filter feeders that will populate the reef structure.

Under a no action plan, none of the project elements will be constructed in the Lynnhaven system. Efforts by other organizations will continue to benefit water quality and ecosystem productivity. However, the improvements to the river will continue at a much slower pace than could be expected with project which so complement to their efforts.

11.14 Environmental Laws, Statutes, Executive Orders, and Memorandum

1. Archaeological and Historic Preservation Act of 1974, as amended, 16 U.S.C. 469 et seq.

Compliance: Draft report was submitted to the VDHR for comment. Continued coordination with VDHR, where required, signifies compliance.

2. Clean Air Act, as amended, 42 U.S.C. 7401 et seq.

Compliance: Submission of this report to the Regional Administrator of the USEPA for review pursuant to Sections 176 (c) and 309 of the Clean Air Act signifies compliance. Although the proposed project is located in Virginia Beach, Virginia, which currently is in nonattainment (marginal) for ozone, a formal conformity determination is not required due to emissions not exceeding regulatory thresholds.

3. Clean Water Act of 1977 (Federal Water Pollution Control Act Amendments of 1972 and Water Quality Act of 1987) PL 100-4, 33 U.S.C. 1251 et seq.

Compliance: A Section 404(b)(1) Evaluation and Compliance Review has been incorporated into this report. VMRC and Virginia Beach Wetlands Board permits will be acquired via Virginia's joint permit application (JPA) process. USACE has been and will continue to coordinate with DEQ as the project moves forward. A 401 Water Quality Certification will be obtained from the Division of Water prior to construction.

4. Coastal Barrier Resources Act.

Compliance: The project is not located within the Coastal Barrier Resources System (CBRS) or in an Otherwise Protected Areas (OPA).

4. CZM Act of 1972, as amended, 16 U.S.C. 1431 et seq.

Compliance: In accordance with the Coastal Zone Management Act (CZMA) and the approved Coastal Zone Management Program of Virginia, the proposed project has been evaluated for consistency with the coastal development policies. A consistency determination has been submitted to VDEQ. USACE has determined that the construction of the project is consistent to the maximum extent practicable with the enforceable policies of the Virginia Coastal Zone Management Program.

5. Endangered Species Act of 1973, as amended, 16 U.S.C. 1531 et seq.

Compliance: Review of databases and coordination with USFWS and NFMS produced no formal consultation requirements pursuant to Section 7 of the Endangered Species Act.

6. Estuarine Protection Act, 16 U.S.C. 1221 et seq.

Compliance: Coordination of this document with appropriate Federal and state resource agencies signifies compliance with this act.

7. Federal Water Project Recreation Act, as amended, 16 U.S.C. 4601-12 et seq.

Compliance: Coordination with the National Park Service and the VDCR, relative to the Federal and state comprehensive outdoor recreation plans, signifies compliance with this act.

8. Fish and Wildlife Coordination Act, as amended, 16 U.S.C. 661 et seq.
Compliance: Coordination with the USFWS, NMFS, and VDGIF signifies compliance with this act. Coordination Act comments have been included in correspondence from USFWS (Appendix E).

9. Land and Water Conservation Fund Act of 1965, as amended, 16 U.S.C. 4601-4 et seq.

Compliance: Coordination is not required because the proposed project does not involve an undertaking that will or may affect properties of facilities acquired or developed with the assistance from this Act..

10. Marine Protection, Research, and Sanctuaries Act of 1972, as amended 33 U.S.C. 1401 et seq.

Compliance: Not applicable; project does not involve the transportation or placement of dredged material in ocean waters pursuant to Sections 102 and 103 of the Act, respectively.

11. National Environmental Policy Act of 1969, as amended, 42 U.S.C. 432 et seq.

Compliance: Preparation of this report and public coordination and comment signify partial compliance with National Environmental Policy Act (NEPA). Full compliance is noted with the signing and issuing of the Finding of No Significant Impact.

12. National Historic Preservation Act of 1966, as amended, 16 U.S.C. 470 et seq.

Compliance: Coordination with the VDHR and agency concurrence with the findings of this report signify compliance with this act.

13. Rivers and Harbors Appropriation Act of 1899, as amended, 33 U.S.C. 401 et seq.

Compliance: Exempt.

14. Watershed Protection and Flood Prevention Act, as amended, 16 U.S.C. 1001 et seq.

Compliance: No requirements for USACE activities.

15. Wild and Scenic Rivers Act, as amended, 16 U.S.C. 1271 et seq.

Compliance: The proposed project would not adversely impact any component of the Virginia Scenic Rivers System. Coordination with the National Park Service and the VDCR, relative to the Virginia Scenic Rivers System, signifies compliance with this act.

16. Resource Conservation and Recovery Act. 42 U.S.C 6901 et seq (1979)

Compliance: During the next phase of the project, sediments removed from the wetland restoration sites will be tested to determine if they meet the standard of a “Hazardous Waste.” If they are such materials, then handling of the material will comply with all guidance within the law.

Executive Orders

1. Executive Order 11988, Floodplain Management, 24 May 1977, as amended by Executive Order 12148, 20 July 1979.

Compliance: Although, the proposed project is located in the flood plain, it would not result in adverse effects and incompatible development in the flood plains. Circulation of this report for public review fulfills the requirements of EO 11988, Section 2(a)(2).

2. Executive Order 11990, Protection of Wetlands, 24 May 1977.

Compliance: This project has minimized "the destruction, loss or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands." Circulation of this report for public review fulfills the requirements of EO 11990, Section 2(b).

3. Executive Order 12114, Environmental Effects Abroad of Major Federal Actions, 4 January 1979.

Compliance: Not applicable, this project is located within the U.S.

4. Executive Order 12898, Environmental Justice in Minority Populations and Low-Income Populations, 11 February 1994.

Compliance: No impacts are expected to occur to any minority or low income communities in the project area.

5. Executive Order 13508, Chesapeake Bay Protection and Restoration, 12 May 2009.

Compliance: The project will contribute to the goals and objectives of the EO

.

Executive Memorandum

1. Analysis of Impacts of Prime or Unique Agricultural Lands in Implementing NEPA, 11 August 1980.

Compliance: The project does not involve or impact agricultural lands.

11.15 Draft Finding of No Significant Impact

FINDING OF NO SIGNFICANT IMPACT
LYNNHAVEN RIVER BASIN ECOSYSTEM RESTORATION PROJECT
VIRGINIA BEACH, VIRGINIA

I have reviewed and evaluated the Environmental Assessment (EA) for this project in terms of the overall public interest. The overall purpose of the Lynnhaven River Basin Ecosystem Restoration Project is to provide ecosystem restoration and protection for the water resources of the Lynnhaven River Basin as authorized by the Resolution of the Committee on Transportation and Infrastructure of the U.S. House of Representatives, Docket 2558, adopted on May 6, 1998. The Recommended Plan and the No Action Alternative (NAA) were the only alternatives carried forward for detailed evaluation. The Recommended Plan includes four elements: the construction of 31 acres of reef habitat, restoration of 94 acres of Submerged Aquatic Vegetation (SAV), re-establishment of a population of Bay Scallops, and restoration of 38 acres of tidal salt marshes.

The Norfolk District has taken reasonable measures to assemble the known or foreseeable impacts of the project in the report. The possible consequences of the Recommended Plan and NAA were considered in terms of probable environmental impact, social well-being, and economic factors. This report presents the impacts that could potentially result from restoration efforts. All adverse effects of project implementation are considered insignificant and are temporary in nature.

The environmental impacts of the project were not found to be significant. There will be some loss of benthic organisms during the construction of the reef habitat and excavation at the wetland sites; however, the losses will be minor and will not affect the benthic community as a whole. Some water quality impacts are expected during the construction phase, but the impacts will be short in duration and minor in scope.

No expected adverse effects on threatened and/or endangered species and/or species of special concern are foreseeable with project implementation. However, monitoring measures and other precautions will be put in place if advised by the National Marine Fishery Service (NMFS) in order to avoid jeopardizing the continued existence of threatened and/or endangered species. Endangered Species Act, Section 7 consultation, may be undertaken and will conclude with a NMFS Biological Opinion.

The proposed project has been evaluated under the Clean Air Amendments of 1990. Due to the small amount of construction required for the completion of the project, the amounts of nitrogen oxides (NOx) and volatile organic compounds (VOC) are not expected to exceed the *de minimus* emission threshold that triggers the requirement to conduct a full-scale conformity determination. The project will comply with Section 176 (c) of the Clean Air Amendments of 1990.

No significant economic or social well-being impacts that are both adverse and/or unavoidable are foreseen as a result of the proposed action. The project will not have any impact on known sites of known significant archeological or historical importance. Further surveys will be carried out to confirm this.

The other project alternatives were not selected, as they had a greater cost per unit benefit to reach the desired project goals. The NAA would not provide any improvement to the environmental condition of the Lynnhaven River Basin.

The conclusions of this report are based on an evaluation of the effects that the proposed action would have on the entire ecosystem, including the land, air, and water resources of the Lynnhaven River Basin. Cumulative impacts of other activities were also considered in this evaluation. Implementing the Recommended Plan would not have a significant adverse effect on the environment. Design features and best management practices that will minimize adverse impacts will be incorporated into the project. The effect of the proposed action will not be environmentally controversial.

The long-term benefits to the ecosystem of the Lynnhaven River Basin will be positive as a result of project implementation. The number of local SAV beds and the amount of reef habitat will be increased. A population of Bay Scallops will be reintroduced into the system and a number of wetland sites will be restored to improve the environmental function.

Due to the absence of significant adverse environmental impacts, an Environmental Impact Statement will not be required.

______________________	______________________________
Date	PAUL B. OLSEN, P.E. Colonel, Corps of Engineers Commanding

12.0 CONCLUSIONS

The ecosystem problems and needs of the study area have been reviewed and evaluated with regard to the overall public interest and with consideration of engineering, economic, environmental, social, and cultural concerns. The conclusions of this study are as follows:

a. The Lynnhaven River Basin is in a stable but degraded state and will continue in its present condition without any restoration activities.

b. The Recommended Plan consists of 94 acres of submerged aquatic vegetation restoration, 38 acres of wetlands restoration, 31.5 acres of reef habitat restoration, and 22 acres for reintroduction of the bay scallop.

c. The Recommended Plan is feasible based on environmental, engineering and economic criteria and is acceptable by environmental, cultural, and social laws and standards.

d. The selected plan is supported by the non-Federal sponsor, the City of Virginia Beach. The sponsor has the capability to provide the necessary non-Federal requirements identified and described in report Section 11.2, Division of Plan Responsibilities.

13.0 RECOMMENDATIONS

I have considered all significant aspects in the overall public interest which included environmental, social, and economic effects; and engineering feasibility. In view of these considerations, and the conclusions presented above, I recommend that the Lynnhaven River Basin ecosystem restoration be implemented in accordance with the National Ecosystem Restoration plan (the NER Plan), with such modifications as in the discretion of the Commander, HQUSACE, may be advisable, at an total estimated first cost of $34,413,000, with a total first cost to the United States estimated at $22,368,000.

The recommended NER plan involves a combination of restoring submerged aquatic vegetation, reef habitat, reintroduction of Bay Scallops, and wetland restoration and diversification at four different sites throughout the river system.

This recommendation is subject to the non-Federal sponsor agreeing to comply with all applicable Federal laws and policies and other requirements including but not limited to:

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

    1. Provide the required non-Federal share of design costs in accordance with the terms of a design agreement entered into prior to commencement of design work for the project;

    2. Provide, during the first year of construction, any additional funds necessary to pay the full non-Federal share of design costs;

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

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

b. Shall not use funds from other Federal programs, including any non-Federal contribution required as a matching share therefore, to meet any of the non-Federal obligations for the project unless the Federal agency providing the

Federal portion of such funds verifies in writing that expenditure of such funds for such purpose is authorized by federal law;

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

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

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

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

g. Give the Federal Government a right to enter, at reasonable times and in a reasonable manner, upon property that the non-Federal sponsor owns or controls for access to the project for the purpose of completing, inspecting, operating, maintaining, repairing, rehabilitating, or replacing the project;

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

i. Keep and maintain books, records, documents, or other evidence pertaining to costs and expenses incurred pursuant to the project, for a minimum of three years after completion of the accounting for which such books, records, documents, or other evidence are required, to the extent and in such detail as will properly reflect total project costs, and in accordance with the standards for financial management systems set forth in the Uniform Administrative Requirements for Grants and Cooperative Agreements to State and Local Governments at 32 Code of Federal Regulations (CFR) Section 33.20;

j. Comply with all applicable Federal and State laws and regulations, including, but not limited to: Section 601 of the Civil Rights Act of 1964, Public Law 88-352 (42 U.S.C. 2000d) and Department of Defense Directive 5500.11 issued pursuant thereto; Army Regulation 600-7, entitled "Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army"; and all applicable Federal labor standards requirements including, but not limited to, 40 U.S.C. 3141- 3148 and 40 U.S.C. 3701 – 3708 (revising, codifying and enacting without substantial change the provisions of the Davis-Bacon Act (formerly 40 U.S.C. 276a *et seq.*), the Contract Work Hours and Safety Standards Act (formerly 40 U.S.C. 327 *et seq.*), and the Copeland Anti-Kickback Act (formerly 40 U.S.C. 276c *et seq.*);

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

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

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

n. Comply with Section 221 of Public Law 91-611, Flood Control Act of 1970, as amended (42 U.S.C. 1962d-5b), and Section 103(j) of the Water Resources Development Act of 1986, Public Law 99-662, as amended (33 U.S.C. 2213(j)), which provides that the Secretary of the Army shall not commence the construction of any water resources project or separable element thereof, until each non-Federal interest has entered into a written agreement to furnish its required cooperation for the project or separable element.

Federal participation in the recommended project is endorsed provided that, prior to construction, the non-Federal sponsor will execute the final Project Partnership Agreement with the Federal Government.

The recommendations contained herein reflect the information available at this time and current departmental policies governing formulation of individual projects. They do not reflect program and budgeting priorities inherent in the formulation of a national Civil Works construction program nor the perspective of higher review levels within the Executive Branch. Consequently, the recommendations may be modified before they are transmitted to higher authority as proposals for authorization and implementation funding. However, prior to transmittal to higher authority, the sponsor, the States, interested Federal agencies, and other parties will be advised of any modifications and will be afforded an opportunity to comment further.

PAUL B. OLSEN, P.E.
Colonel, Corps of Engineers
Commanding

14. LITERATURE CITED

Able, K.W., S.M. Hagan, and S.A. Brown. 2003. Mechanisms of marsh habitat alteration due to *Phragmites*: Response of young-of-the-year mummichog (*Fundulus heteroclitus*) to treatment of *Phragmites* removal. Estuaries 26:484-494.

Abril G., Commarieu M.V., Sottolichio A., Bretel P. and Guérin F. (2009) Turbidity limits gas exchange in a large macrotidal estuary. Estuarine Coastal and Shelf Science. 83: 342-348.

Amsberry, L., M.A. Baker, P.J. Ewanchuk, M.D. Bertness. 2000. Clonal integrational and the expansion of *Phragmites Australis*. Ecological Applications 10(4):1110-1118.

Armentano, T.V. and G.M. Woodwell. 1975. Sedimentation rate in a Long Island marsh determined by 210 Pb dating. Limnology and Oceanography. Vol. 20, No. 3, pp. 452-456.

Arnold, W. S., D. C. Marelli, C. P. Bray, and M. M. Harrison. Recruitment of bay scallops Argopecten irradians in Floridan Gulf of Mexico waters: Scales of coherence. Mar. Ecol. Prog. Ser., 170:143–157 (1998).

Barnard, T and D Dumlele, 1979. City of Virginia Beach marsh inventory, v 2, Special report 217 in applied science and ocean engineering, Virginia Institute of Marine Science, School of Marine Science, College of William and Mary, Gloucester Point, VA.

Bell, J. D., D. M. Bartley, K. Lorenzen, and N. R. Loneragan. Restocking and stock enhancement of coastal fisheries: Potential, problems and progress. Fish. Res., 80: 1–8 (2006).

Berman, M. and H. Berquist. 2009. The effects of sea level rise on tidal wetlands in the Lynnhaven River watershed. Virginia Institute of Marine Science, School of Marine Science, College of William and Mary, Gloucester Point, VA.

Berry, E.W. 1914. Upper Cretaceous and Eocene floras of South Carolina and Georgia. U.S. Geological Survey Professional Paper No. 84.

Biebl, R. and C. P. McRoy. Plastmatic resistance and rate of respiration and photosynthesis of *Zostera marina* at different salinities and temperatures. Marine Biology, vol. 8(1): 48-56 (1970).

Bilkovic, D.M., D. Stanhope and K. Angstadt. 2007. Shallow water fish communities and coastal development stressors in the Lynnhaven River. Virginia Institute of Marine Science, Gloucester Point, Virginia.

Bohnsack, J. A., and Sutherland, D. L. 1985. Artificial reef research: a review with recommendations for future priorities. Bulletin Marine Science, 37: 11–39.

Botsford, L. W., F. Micheli, and A. Hastings. Principles for the design of marine reserves. Ecol. Appl., 13: S25–S31 (2003).

Breine, J. P. Quataert, M. Stevens, F. Ollevier, F. A.M. Volckaert, E. Van den Bergh and J. Maes. 2010. A zone-specific fish-based biotic index as a management tool for the Zeeschelde estuary (Belgium). Marine pollution bulletin.

Bureau of Economic Analysis, Regional Economic Accounts, 2010. http://www.bea.gov/regional/index.htm#state

Burke, R.P. 2010. Alternative Substrates as a Native Oyster (*Crassostrea virginica*) Reef Restoration Strategy in Chesapeake Bay. PHD Dissertation, The College of William and Mary, Virginia Institute of Marine Science, Gloucester Point, Virginia.

Cahoon, D.R, D.J. Reed, A.S. Kolker and M.M. Brinson. 2009. Coastal Wetlands Sustainability. In Titus, J.G. Coastal Sensitivity to Sea-Level Rise: a Focus on the Mid-Atlantic Region. Report by The U.S. Climate Change Science Program and the Subcommittee on Global Change Research.

Carpenter, S. R. and D. M. Lodge. 1986. Effects of submersed macrophytes on ecosystem processes. Aquat. Bot., 26:341-370.

Carroll JM, Peterson BJ, Bonal D, Weinstock A, Smith CF, Tettlebach ST (2009) Comparative survival of Bay Scallops in eelgrass and the introduced alga, Codium fragile, in a New York Estuary. Mar. Biol. DOI 10.1007/s00227-009-1312-0

Cerco, C. F. and M. R. Noel. 2005. Evaluating Ecosystem Effects of Oyster Restoration in Chesapeake Bay. A report to the Maryland Department of Natural Resources, September 2005. US Army Engineer Research and Development Center, Vicksburg MS.

Cerco, C., and Moore, K. (2001) "System-wide Submerged Aquatic Vegetation Model for Chesapeake Bay," Estuaries 24(4): 522-534.

Chambers, R.M, L.A. Meyerson, and K.Saltonstall. 1999. Expansion of *Phragmites australis* into tidal wetlands of North America. Aquatic Botany 64:261-273.

Chambers, R.M., Mozdzer, T.J., and Ambrose, J.C. 1998. Effects of salinity and sulfide on the distribution of *Phragmites australis* and *Spartina alterniflora* in a tidal saltmarsh. Aquatic Botany 62:161-169.

Chesapeake Bay Program, 1999. http://www.chesapeakebay.net/fish1.htm

Chintala, M., E. Hinchey, T. Gleason and W. Berry. 2005. Juvenile bay scallop (*Argopecten irradians*) habitat preferences. Presentation at National Health and Environmental Effects Research Laboratory, Atlantic Ecology Division, Narragansett, RI.

Chipman, W.A. and J.G. Hopkins. 1954. Water filtration by the bay scallop, *Pecten irradians*,as observed with the use of radioactive plankton. Biological Bulletin, Vol. 107: 80-91.

Chipman, W.A. 1948. Conditions affecting shellfish production in Lynnhaven Bay, Virginia, and the possibilities of improving them by increasing tidal flow. United States Department of the Interior, Fish and Wildlife Service, Washington, D.C.

Chmura, G. L., Coffey, A. and R. Crago. 2001. Variation in surface sediment deposition on salt marshes in the Bay of Fundy. Journal of Coastal Research, Vol. 17, No. 1, pp. 221-227)

Cho, H.J., P. Biber and C. Nica. 2009. The Rise of Ruppia in Seagrass Beds: Changes in Coastal Enviroment and Research Needs. In: Handbook on Environmental Quality, E.K. Drury and T.S. Pridgen (eds.). Chapter 12, pp:1-15.

Cho, J.H. and Y.L. Sanders. 2009. Note on dormancy of estuarine Ruppia maritime L. seeds. Hydrobiologia 617:197-201.

City of Virginia Beach, 2009. Comprehensive Plan, Technical Report.

Clarke S.M. 1987. Sediment-seagrass dynamics in Holdfast Bay: summary. *Safish* 11: 4 10.

Cliche, G., Vigneau, S. and Giguere, M. (1997) Status of a commercial sea scallop enhancement project in Iles-de-la-Madeleine (Quebec, Canada). Aquaculture International 5, 259–266.

Colosimo, S.L. 2007. Comparison of Perkinsus marinus infection and oyster condition in southeastern North Carolina tidal creeks. Master's thesis, University of North Carolina, Wilmington.

Cooper, R.A. and N. Marshall. 1963. Condition of the bay scallop, *Aequipectan irradians*, in relation to age and the environment. Chesapeake Science. 4: 126-134.

Cowen, R. K., K. M. M. Lwiza, S. Sponaugle, C. B. Paris, and D. B. Olson. Connectivity of marine populations: Open or closed? Science, 287: 857–859 (2000).

Cross, J.N., C.A. Zeitlin, P.L. Berrien, D.L. Johnson, and C. McBride, 1999. National Oceanographic and Atmospheric Administration. National Marine Fisheries Service. Northeast Region. Essential Fish Habitat Source Document: Butterfish, *Preprilus triacanthus*, Life History and Habitat Characteristics. September 1999. NOAA Technical Memorandum NMFS-NE-145. Woods Hole, MA.

Dauer, D.M., W.W. Robinson, C.P. Seymour, and A.T. Leggett, Jr. 1979. Effects of nonpoint pollution on benthic invertebrates in the Lynnhaven River system. Bulletin of Virginia Water Resource Center 117:112.

Dauer, D.M., R.M. Ewing, G.H. Tourtellotte, W.T. Harlan, J.W. Sourbeer and H. R. Barker Jr. 1982a. Predation, resource limitation and the structure of benthic infaunal communities of the lower Chesapeake Bay. Internationale Revue der gesamten Hydrobiologie (International Review of Hydrobiology) 67(4):477-489.

Dauer, D.M., G.H. Tourtellotte, and R.M. ewing. 1982b. Oyster shells and artificial worm tubes: The role of refuges in structuring benthic communities of the lower Chesapeake Bay. Internationale Revue der gesamten Hydrobiologie (International Review of Hydrobiology) 67(5):661-677.

Dauer, D.M., J.A. Ranasinghe, and S.B. Weisberg. 2000. Relationships between benthic community condition, water quality, sediment quality, nutrient loads, and land use patterns in Chesapeake Bay. Estuaries 23:80-96.

Dauer, D.M. 2006. Benthic biological monitoring of the Lynnhaven River. Old Dominion University, Norfolk, Virginia.

Dauer, D.M., 2007. Benthic biological monitoring of the Lynnhaven River. Old Dominion University, Norfolk VA.

Deegan, L.A., Finn, J.T., Ayvazian, S.G., Ryder-Kiefer, C.A., Buonaccorsi, J., 1997. Development and validation of an estuarine biotic integrity index. Estuaries 20, 601–617.

De Martini, E. E., Barnet, A. M., Johnson, T. D., and Ambrose, R. F. 1994. Growth and reproduction estimates for biomass-dominant fishes on a southern California artificial reef. Bulletin of Marine Science, 55: 484–500.

Diaz, R.J. and L.C. Schaffner. 1990. The functional role of estuarine benthos. Pp. 25-56 in *In* Haire, M. and E. C. Krome. (eds.). Perspectives on the Chesapeake Bay, 1990. Advances in Estuarine Sciences. United States Environmental Protection Agency. Gloucester Point, VA.

Didham, RK, Watts, CH and DA Norton. 2005. Are systems with strong underlying abiotic regimes more likely to exhibit alternative stable states? Oikos 110, 409-416.

Doherty, P. J. Spatial and temporal patterns in recruitment, pp. 261–293. In: The Ecology of Fishes on Coral Reefs. (Sale, P. F., Ed.). New York: Academic Press (1991).

Dynamic simulation of littoral zone habitats in lower Chesapeake Bay. II. Seagrass habitat primary production and water quality relationships. C. P. Buzzelli, R. L. Wetzel, and M. B. Meyers. Estuaries. 1998. 21: 673-689.

Ehlers, A., Worm, B. and B.H. Reutsch. 2008. Importance of genetic diversity in eelgrass *Zostera marina* for its resilience to global warming. Marine ecology progress series 355: 1-7

Environmental Protection Agency (EPA). 2000. Chesapeake Bay Submerged Aquatic Vegetation Water Quality and Habitat-Based Requirements and Restoration Targets: A Second Technical Synthesis.

Falls, J.A. The Survival Benefit of Benthic Macroalgae Gracilaria vermiculophylla as an Altnerative Nursery Habitat for Juvenile Blue Crabs. 2008. MS Degree Thesis, The College of William and Mary, Virginia Institute of Marine Science, Gloucester Point, Virginia.

Faulds, A. and Wakefield, K. 2003 Phragmites: A tale of two strains. Seagrants. 13(3) http://seagrant.psu.edu/publications/fs/Phragmites.pdf

Fay CW, RJ Neves, and GP Pardue. 1983. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Mid-Atlantic) - bay scallop. U.S. Fish and Wildlife Service, Division of Biological Services, FWS/OBS-82/11.12. US Army Corp of Engineers, TR EL-82-4. 17pp.

Fegley, S.R., C.H. Peterson, N.R. Geraldi and D.W. Gaskill. 2009. Enhancing the potential for population recovery: restoration options for bay scallop populations, *Argopecten irradians concentricus*, in North Carolina. Journal of Shellfish Research, Vol. 28 No. 3: 477-489.

Frazier Associates, 1992. Reconnaissance Level Phase I Architectural Survey Report.

Fredette, T. J., R. J. Diaz, J. van Montfrans, and R. J. Orth. 1990. Secondary Production Within a Seagrass Bed (*Zostera marina* and *Ruppia maritima*) in Lower Chesapeake Bay. Estuaries. 13(4): 431-440.

Fonseca, M.S. and J.S. Fisher. 1986. A comparison of canopy friction and sediment movement between four species of seagrass with reference to their ecology and restoration. *Marine Ecology Progress Series* 29:15-22.

Fulford, R.S., D. L. Breitburg, R. I. E. Newell, W.M. Kemp and M.W. Luckenbach. 2007. Effects of oyster population restoration strategies on phytoplankton biomass in Chesapeake Bay: a flexible modeling approach. Marine Ecology Progress Series. 336:43-61.

Goldberg, R., J. Pereria and P. Clark. 2000. Strategies for enhancement of natural bay scallop, *Argopecten irradians irriadians*, populations: a case study in the Niantic River estuary, Connecticut, USA. Aquaculture International 8: 139-158.

Goode, Amy and David Dutton, 1999. Archaeological Resource Management Plan First Landing/Seashore State Park.

Grubbs, R.D., 1995. Preliminary recruitment patterns and delineation of nursery grounds for *Carcharhinus plumbeous* in the Chesapeake Bay. SB-III-11. Prepared for the 1996 NMFS Shark Evaluation Workshop, Miami, FL, as cited in Camhi, 1998.

Haven, D. S., J. P. Whitcomb and P. C. Kendall. 1981. The Present and Potential Productivity of the Baylor Grounds in Virginia. Volumes I and II and Chart Supplement. Special Report No. 293 in Applied Marine Science and Ocean Engineering of the Virginia Institute of Marine Science, Gloucester Point, Virginia 23062.

Haven DS, Morales-Alamo R (1966) Aspects of biodeposition by oyster and other invertebrate filter feeders. Limnol Oceanogr 11:487–498.

Hawthorne S.D. and D.M. Dauer. 1983. Macrobenthic communities of the Lower Chesapeake Bay. III. Southern Branch of the Elizabeth River. Internationale Revue der gesamten Hydrobiologie (International Review of Hydrobiology) 68:193-205.

Hayes, Seay, Mattern and Mattern, 1988. "Biological Investigation of Lynnhaven River-Eastern Branch." Prepared for the USACE, Norfolk District.

Heck, K. L., K. Able, C. Roman, and M. Fahay. 1995. Composition, abundance, biomass and production of macro-fauna in a New England estuary: Comparisons among eelgrass meadows and other nursery habitats. *Estuaries* 18: 379-389.

Hellings, S.E., and J.L. Gallagher. 1992. The effects of salinity and flooding on Phragmites australis. Journal of Applied Ecology 29, 41–49.

Hernandez-Cordero, A.L. 2010. Exploring the potential for bay scallop, *Argopecten irradians concentricus*, restoration in the Lynnhaven River sub-estuary of Chesapeake Bay. Master's Thesis, College of William and Mary, Virginia Institute of Marine Science, Gloucester Point, VA.

International Shark Attack File, 2001. Administered by the Florida Museum of Natural History and the American Elasmobranch Society. Website: www.flmnh.ufl.edu/fish/Sharks/ISAF/ISAF.htm

Jensen, A. 2002. Artificial reefs of Europe: perspective and future. ICES Journal of Marine Science, 59: 3-13.

Johnson, M.R., S.L. Williams, C.H. Lieberman and A. Solbak. 2003. Changes in the abundance of the seagrasses Zostera marina L. (eelgrass) and Ruppia maritima L. (widgeongrass) in San Diego, California, following and El Nino event. Estuaries, Vol. 26. no. 1, pp:106-115.

Kiviat, E. 2006. *Phragmites* management sourcebook for the tidal Hudson River. Report to the Hudson River Foundation, New York, New York. Hudsonia Ltd. Annadale NY 12504 USA.

Kiviat, E and E. Hamilton. 2001. *Phragmites* use by Native North Americans. Aquatic Botany, Vol. 69 (2-4): 341-357.

Koch EW. 2001. Beyond light: physical, geological, and geochemical parameters as possible submersed aquatic vegetation habitat requirements. Estuaries 24(1): 1-17.

Koch EW and Gust G. 1999. Water flow in tide and wave dominated beds of the seagrass *Thalassia testudinum. Mar Ecol-Prog Ser* 184: 63–72.

Krause, L.H., Rietsma, C., Kiviat, E. 1997. Terrestrial insects associated with *Phragmites australis*, *Typha angustifolia*, and *Lythrum salicaria* in a Hudson River tidal marsh. In: Nieder, W.C., Waldman, J.R. (Eds.), Final Reports of the Tibor T. Polgar Fellowship Program, 1996. Hudson River Foundation and New York State Department of Environmental Conservation, pp.V-1 to V-35.

Kuehl, S.A. 2008. Lynnhaven River Sedimentation Study. Virginia Institute of Marine Science, Gloucester Point, Virginia.

Lamotte, R.S. 1952. Catalogue of the Cenozoic plants of North America through 1950. Geological Society of America Memoir 51.

Leonard, L.A., P.A. Wren, and R.L. Beavers. 2002. Flow Dynamics and Sedimentation in Spartina alterniflora and Phragmites australis Marshes of the Chesapeake Bay. Wetlands 22(2): 415-424.

Leverone, J.R. 1993. Environmental requirements assessment of the bay scallop *Argopecten Irradians Concentricus*. Mote Marine Laboratory Technical Report No. 253.

Lipcius, R.N., D.B. Eggleston, S.J. Schreiber, R.D. Seitz, J. Shen, M. Sisson, W.T. Stockhausen, and H.V. Wang. 2008. Metapopulation connectivity and stock enhancement of marine species. Reviews in Fisheries Science 16: 101-110.

Lipcius RN, Burke RP (2006) Abundance, biomass and size structure of eastern oyster and hooked mussel on a modular artificial reef in the Rappahannock River, Chesapeake Bay. Spec. Rept. Appl. Mar. Sci. Ocean Eng. No. 390, Virginia Institute of Marine Science, The College of William and Mary, Gloucester Point, VA 23062

Lissner, J., and Schierup, H.H. 1997. Effects of salinity on the growth of *Phragmites australus* (Cav.) Trin ex Steudel. Aquatic Botany 55:247-260.

Maguire Associates, 1993. "Western Branch Lynnhaven River Environmental Assessment." Prepared for the City of Virginia Beach.

Malcolm Pirnie Engineers, Inc., 1980. "Conditions in the Lynnhaven Estuarine System, Virginia Beach, Virginia." Prepared for the Department of the Army, Norfolk District USACE, Norfolk, Virginia.

Manny, B. A., D.W. Schloesser, C.L. Brown, and J.R.P. French, III, 1985. "Ecological Effects of Rubble-Mound Breakwater Construction and Channel Dredging at West Harbor, Ohio (Western Lake Erie)." Technical Report EL-85-10. Prepared by U.S. Fish and Wildlife Service for U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Marshall, N. 1947. An abundance of Bay Scallops in the absence of eelgrass. Ecology 28: 321-322.

McCay, F.D.P and J.J. Rowe, 2003. Habitat restoration as mitigation for lost production at multiple trophic levels. Mar. Ecol. Prog. Ser. 264:235-249.

McKinney, R.A., and Wigland, C. 2006. A framework for the assessment of the wildlife habitat value of New England salt marshes. EPA/600/R-06/132. Office of Research and Development. Washington, DC 20460.

McKinney, R.A., Charpentier, M.A., and Wigand, C. 2009a. Assessing the wildlife habitat value of New England salt marshes: I. Model and application. *Environmental Monitoring and Assessment*, in review.

McKinney, R.A., Charpentier, M.A., and Wigand, C. 2009b. Assessing the wildlife habitat value of New England salt marshes: II. Model testing and validation. *Environmental Monitoring and Assessment*, in review.

Meng, L., C.D. Orphanides and J. Christopher-Powell. 2002. Use of a fish index to assess habitat quality in Narragansett Bay, Rhode Island. Transactions of the American Fisheries Society 121:731-742.

Meyer, D.L., J.M Johnson and J.W. Gill. 2001. Comparison of nekton use of *Phragmites australis* and *Spartina alterniflora* marshes in the Chesapeake Bay, USA . Marine Ecology Progress Series 209: 71-84.

Meyerson, L.A., K. Saltonstall, L. Windham, E. Kiviat and S. Findlay. 2000. A comparison of Phragmites australis in freshwater and brackish marsh environments in North America. Wetlands Ecology and Management 8:89-103.

Moore, K.A. and J.C. Jarvis. 2008. Environmental factors affecting recent summertime eelgrass diebacks in the lower Chesapeake Bay: Implications for long-term persistence. Journal of Coastal Research, Vol. 55, pp. 135-147.

Moore, K.A. 2004. Influence of seagrasses on water quality in shallow regions of the lower Chesapeake Bay. Journal of Coastal Research, Vol. 45, pp:162-178.

Montague, C.L., Zale, A.V. and Percival, H.F. 1987. Ecological effects of coastal marsh impoundments: a review. Environmental Management 11:743-756.

Murdy, E.O., R.S. Birdsong, and J.A. Musick, 1997. Fishes of the Chesapeake Bay. Smithsonian Press, Washington, DC.

Musick, J.A., 1972. Fishes of the Chesapeake Bay and adjacent coastal plains. *In* M.L. Wass ed. A checklist of the biota of the Lower Chesapeake Bay, pp.175-212. Virginia Institute of Marine Science Special Scientific Report 65.

Musick, J.A., S. Branstetter, and J.A. Colvocoresses, 1993. Trends in shark abundance from 1974-1991 for the Chesapeake Bight region of the Mid-Atlantic coast. NOAA Technical Report NMFS 115, as cited in Camhi, 1998.

National Marine Fisheries Service, 1997. Report to Congress. Status of the fisheries of the United States: Report on the status of fisheries of the United States. September 1997. Available: http://www.nmfs.noaa.gov/sfa/Fstatus.html.

National Oceanic and Atmospheric Administration (NOAA)/National Marine Fisheries, March 1999. Guide to Essential Fish Habitat Designations in the Northeastern United States, Volume V: Maryland and Virginia.

National Oceanic and Atmospheric Administration. 2010. Summary of Essential Fish Habitat (EFH) Designation. Website: http://www.nero.noaa.gov/hcd/STATES4/virginia/virginia/36507600.html

Neilson, B.J., 1976. "Water Quality in Small Coastal Basins." Special Report Number 129, Virginia Institute of Marine Science, School of Marine Science, College of William and Mary, Gloucester Point, VA.

Nelson, K. A., Leonard, L. A., Posey, M. H., Alphin, T. D. and M. A. Mallin. 2003. Using transplanted oyster (*Crassostrea virginica)* beds to improve water quality in small tidal creeks: a pilot study. Journal of Experimental Marine Biology and Ecology. Vol. 298, No. 2, pp: 347-368.

Newell RIE, W. M. Kemp, J. D. Hagy III, C. F. Cerco, J. M. Testa , W. R. Boynton. 2007. Top-down control of phytoplankton by oysters in Chesapeake Bay, USA: Comment on Pomeroy et al. (2006). Mar. Ecol. Prog. Ser. 341: 293–298

Newell, RIE. 1988. Ecological changes in Chesapeake Bay: are they the result of overharvesting the Eastern oyster *Crassostrea virginica*? Pages 536-546 In: M.P. Lynch and E.C. Krome, (eds.) Understanding the Estuary: Advances in Chesapeake Bay Research. Chesapeake Research Consortium Publication 129 (CBP/TRS 24/88), Gloucester Point, VA.

NYDEC. New York State Department of Environmental Conservation. 2001. Assessing and Mitigating Noise Impacts Conservation. Available online: http://www.dec.ny.gov/docs/permits_ej_operations_pdf/noise2000.pdf

Olff, H., De Leeuw, J., Bakker, J. P., Platerink, R. J. and H. J. van Wijnen. 1997. Vegetation Succession and Herbivory in a salt marsh: changes induced by sea level rise and silt deposition along an elevational gradient. Journal of Ecology, Vol. 85, No. 6, pp. 799-814.

Olney JE, Boehlert GW (1988) Nearshore ichthyoplankton associated with seagrass beds in the lower Chesapeake Bay. Mar Ecol Prog Ser 45:33–43

Olney, J., 1998. Reproductive ecology of cobia in Chesapeake Bay. Virginia Institute of Marine Science website: http://www.vims.edu/adv/cobia/.

Orth R.J. various et al. 1978-2010. Distribution of Submerged Aquatic Vegetation in Chesapeake Bay and Coastal Bays. Virginia Institute of Marine Science, College of William and Mary, Gloucester Point VA 23062 Special Reports.

Orth RJ and Moore. 1983. Chesapeake Bay: An unprecedented decline in submerged aquatic vegetation. Science 222:51-53.

Orth, R., S. Marion, S. Granger and M. Traber. 2008. Restoring eelgrass (Zostera marina) from seed: a comparison of planting methods for large-scale projects. ERDC/TN SAV-08-01, March 2008.

Orth, R. J., M. L. Luckenbach, S. R. Marion, K. A. Moore, and D. J. Wilcox. 2006.

Seagrass recovery of in the Delmarva Coastal Bays, USA. *Aquatic Botany* 84: 26-36.

Orth R.J. , McGlathery K.J. 2012. Eelgrass recovery in the coastal bays of the Virginia Coast Reserve, USA. Marine Ecology Progress Series 448:173-176

Pacheco, A., and W.B. Stotz. 2006. Will providing a filamentous substratum in the water column and shell litter on the bottom increase settlement and post-larval survival of the scallop *Argopecten purpuratus*? Journal of Experimental Marine Biology and Ecology. 333: 27-39.

Paerl, H. W., L. M. Valdes, J. L. Pinckney, M. F. Piehler, J. Dyble,and P. H. Moisander. 2003. Phytoplankton photopigments as indicators of estuarine and coastal eutrophication. BioScience 53: 953–964.

Parker K. 2006. Bay Scallops saltwater early-warning systems. Florida Wildlife May/June 2006. pg 54-55.

Pearson, T.H. and R. Rosenberg. 1979. Predation, competitive exclusion and diversity in the soft-sediment benthic communities of estuaries and lagoons. Oceanography and Marine Biology Annual Review 16:229-311.

Peterson, C.E. and R.N. Lipcius. 2003. Conceptual progress towards predicting quantitative ecosystem benefits of ecological restorations. Marine Ecology Progress Series 264: 297-307

Peterson, C. H., and Associates. 2003. Scaling compensatory restoration for the Craney Island expansion project in the Elizabeth River estuary. A report to the USACE, Norfolk District, C.H. Peterson and Associates.

Peterson, C. H., Grabowski, J. H. and S. P. Powers. 2003. Estimated enhancement of fish production resulting from restoring oyster reef habitat: quantitative valuation. Marine Ecology Progress Series 264: 249-264.

Peterson, C.H., H.C. Summerson and R.A. Luettich Jr. 1996. Response of Bay Scallops to spawner transplants: a test of recruitment limitation. Marine Ecology Progress Series. 132: 93-107.

Pohle D.G., V.M. Bricelj, and Z. Garcia-Esquivel. 1991. The eelgrass canopy: an above-bottom refuge from benthic predators for juvenile Bay Scallops *Argopecten irradians*. Marine Ecology Progress Series 74: 47-59.

Powers, S.P. J.H. Grabowski, C.H. Peterson, W.J. Lindberg. 2003. Estimating enhancement of fish production by offshore artificial reefs: uncertainty exhibited by divergent scenarios. Marine ecology progress series. Vol. 264: 265-277.

Ray, G.L. 2008. Habitat Equivalency Analysis: A Potential Tool for Estimating Environmental Benefits. ERDC TN-EMRRP-EI-02.

Reed, D.J. 1995. The response of coastal marshes to sea-level rise: survival or submergence? Earth Surface Processes and Landforms 20:39-48.

Reed, D.J. 1989. Patterns of sediment deposition in subsiding coastal salt marshes, Terrebonne Bay, Louisiana: the role of winter storms. Estuaries. Vol. 12, No. 4, pp. 222-227.

Reed, D. J., T. Spencer, A. L. Murray, J. R. French, and L. Leonard. 1999. Marsh surface sediment deposition and the role of tidal creeks: Implications for created and managed coastal marshes. Journal of Coastal Conservation 5:81–90.

Rice, D., J. Rooth and J.C. Stevenson . 2000. Colonization and expansion of *Phragmites australis* in upper Chesapeake Bay tidal marshes. Wetlands 20:280-299.
Roman and Montague

Roman, C.T., Niering, W.A. and Warren, R.S. 1984. Salt marsh vegetation changes in response to tidal restrictions. Environmental Management 8:141-150.

Rose, D.A., 1998. Shark fisheries and trade in the Americas. TRAFFIC North America, Washington, D.C., as cited in Food and Agriculture Organization of the United Nations, 1999, *Carcharhinus obscurus*, FAO website: http://www.fao.org/WAICENT/FAOINFO/FISHERY/sidp/htmls/sharks/ca_ob_ht.htm

Saltonstall, K. 2002. Cryptic invasion by a non-native genotype if the common reed, *Phragmites australis*, into North America. Proceedings of the National Academy of Sciences USA 99(4):2445-2449.

Schauss, P.R. Jr.1977.Seasonal occurrence of some larval and juvenile fishes in Lynnhaven Bay, Virginia. American Midland Naturalist 98(2):275-282.

Schillinger, J.E. and J.J. Gannon. 1985. Bacterial adsorption and suspended particles in urban stormwater. Journal of the water pollution control federation. Vol. 57, No. 5, pp. 384-389.

Schomer, P. 2001. A White Paper: Assessment of Noise Annoyance. Schomer and Associates. Available online: http://www.nonoise.org/library/schomer/assessmentofnoiseannoyance.pdf

Schulte, D.M. and R.N. Lipcius. In preparation. Mechanisms of failed recruitment of selectively bred eastern oyster, *Crassostrea virginica*, in restoration.

Seaman, W. and L.M. Sprague. 1991. Artificial habitats for marine and freshwater fisheries. Academic Press, San Diego, California.

Seitz, R.D., R.N. Lipcius and A.L. Hernandez. 2009. Pilot field experiments on Bay scallop restoration in the Lynnhaven River subestuary. Final Report. Virginia Institute of Marine Science, Gloucester Point, Virginia.

Sisson, M. H. Wang, W. Reay, Y Li, Y. Teng, J. Shen and A. Kuo. 2009. Identification and Assessment of Water Quality Problems in Mill Dam Creek and Dey Cover Tributaries of Lynnhaven, Virginia Beach. Final Report to the USACE, Norfolk District and the City of Virginia Beach. Special Report No. 410 In Applied Marine Science and Ocean Engineering. Virginia Institute of Marine Science, Gloucester Point, VA 23062

Sisson, M. J. Shen, W. Reay, E Miles, A. Kuo and H. Wang. 2010. A Numerical Modeling Assessment for the Implementation of a Runoff Reduction Strategy Plan for the Restoration of Thalia Creek, Virginia Beach. Final Report to the USACE, Norfolk District and the City of Virginia Beach. Special Report No. 416 In Applied Marine Science and Ocean Engineering. Virginia Institute of Marine Science, Gloucester Point, VA 23062

Sisson, M. L. Kellog, M. Luckenbach, R. Lipcius, A. Colden, J. Cornwell, and M. Owens. 2011. Assessment of Oyster Reefs in Lynnhaven River as a Chesapeake Bay TMDL Best Management Practice. Final Report to the U.S. Army USACE of Engineers, Norfolk District and the City of Virginia Beach. Special Report No. 429 In Applied Marine Science and Ocean Engineering. Virginia Institute of Marine Science, Gloucester Point, VA 23062

Smith, S.E., D.W. Au, and C. Show, 1998. Intrinsic rebound potentials of 26 species of Pacific sharks. Marine and Freshwater Research. 49(7):663-678, as cited in Food and Agriculture Organization of the United Nations, 1999, *Carcharhinus obscurus*, FAO website: http://www.fao.org/WAICENT/FAOINFO/FISHERY/sidp/htmls/sharks/ca_ob_ht .htm

Snider, L., 1996. Fisheries Position Paper: Cobia (*Rachycentron canadum*). Coastal Conservation Association of Virginia. (http://www.virginiamag.com/cca/ppcobia.htm).

Soniat, T.M., E.N. Powell, E.E. Hofmann and J.M. Klinck. 1998. Understanding the success and failure of oyster populations: The importance of sampled variables and sample timing. Journal of shellfish research. 17:1149-1165.

Steimle, F., K. Foster, R. Kropp and B. Conlin. 2002. Benthic macrofauna productivity enhancement by an artificial reef in Delaware Bay, USA. ICES Journal of Marine Science. 59: 100-105.

Stephens, J., Pondella, D., 2002. Larval productivity of a mature artificial reef: the ichthyoplankton of King Harbor, California, 1974–1997. ICES J. Mar. Sci. 59, S51–S58.

Stevenson, J. C. 1988. Comparative ecology of submersed grass beds in freshwater, estuarine, and marine environments.Limnology and Oceanography 33:867–893.

Stockhausen, W. T., and R. N. Lipcius. Single large or several small marine reserves for the Caribbean spiny lobster? Mar. Freshwater Res., 52: 1605–1614 (2001).

Stormwater. Journal of the water pollution control federation. Vol. 57, No. 5, pp. 384-389.

Strieb, M.D., V.M. Bricelj, S.I. Bauer. 1995. Population biology of the mud crab, *Dyspanopeus Sayi*, an important predator of juvenile Bay Scallops in Long Island (USA) eelgrass beds. Journal of Shellfish Research. 14: 347-357.

Suding, KN, Gross, KL and GR Housen. 2004. Alternative states and positive feedbacks in restoration ecology. Trends in Ecology and Evolution, Vol. 19 no. 1: 46-53.

Svane, I., Peterson, J., 2001. On the problems of epibioses, fouling and artificial reefs, a review. Mar. Ecol. 22, 169–188.

Tapp, J.F., N. Shillabeer, and C.M. Ashman. 1993. Continued observation of the benthic fauna of the industrialized Tees estuary, 1979-1990. Journal of Experimental Marine Biology and Ecology 172:67-80.

Tettelbach, S. T. & C. F. Smith. 2009. Bay scallop restoration in New York. Ecol. Res. 27:20–22.

Tettlebach ST and EW Rhodes. 1981. Combined effects of temperature and salinity on embryos and larvae of the northern bay scallop *Argopecten irradians concentricus*. Marine Biology 63:249-256.

Thomson, J.D. (1992) Scallop enhancement – how, and is it worth the effort? In: Recruitment Processes (ed. D.A. Hancock), A-station Government Printing Service, Canberra, pp. 183–186.

Tomasko, D. A., C. A. Corbett, H. S. Greening, AND G. E. Raulerson. 2005. Spatial and temporal variation in seagrass coverage in Southwest Florida: Assessing the relative effects of anthropogenic nutrient load reductions and rainfall in four contiguous estuaries. Marine Pollution Bulletin 50:797–805.

Tourtellotte, G.H. and D.M. Dauer. 1983. Macrobenthic communities of the lower Chesapeake Bay. II. Lynnhaven Roads, Lynnhaven River, Broad Bay, and Linkhorn Bay. Internationale Revue der gesamten Hydrobiologie (International Review of Hydrobiology) 68:59-72.

Ulanowicz, R.E. and J. Tuttle. The trophic consequences of oyster stock rehabilitation in Chesapeake Bay. Estuaries 15:298-306.

U.S. Census, 2010. http://factfinder.census.gov

USEPA. United States Environmental Protection Agency. “Noise from Construction Equipment and Operations, Building Equipment, and Home Appliances,” NJID 300.1, December 31, 1971.

Van Dam, L. 1954. On the respiration in scallops. Biol. Bull. (Woods Hole) 107: 192-202.

Van Dolah, R.F., P.H. Wendt, C.A. Wenner, R.M. Martore, G.R. Sedberry, C.J. Moore, 1987. “Ecological Effects of Rubble Weir Jetty Construction at Murrells Inlet, South Carolina; Volume III: Community Structure and Habitat Utilization of Fishes and Decapods Associated with the Jetties.” Technical Report EL-84-4. Prepared by South Carolina Wildlife and Marine Resources Department, Charleston, S.C., for U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Virginia Canals and Navigations Society, 1998. The Great Dismal Atlas.

Virginia Department of Game and Inland Fisheries (VDGIF). 2010. Fish and Wildlife Information Service. Website: http://vafwis.org/fwis/?Menu=Home

Virginia Department of Health. 2009. Shellfish Closure and Shoreline Survey Documents, City of Virginia Beach. Website: http://www.vdh.state.va.us/EnvironmentalHealth/Shellfish/closureSurvey/virginiabeach/index.htm

Virginia Employment Commission, 2010. State Demographer Projections. http://www.vawc.virginia.gov/analyzer/searchAnalyzer.asp?cat=HST_DEMOG&session=POPULAT&subsession=7&time=&geo=&currsubsessavail=7&incsource=&blnStart=True

Virginia Fisheries Commission. 1928-1933. Annual Reports to the Governor. Special Archives at the Hargis Library, Virginia Institute of Marine Science, Gloucester Point, Virginia.

Virginia Institute of Marine Science, 1999. Virginia Institute of Marine Science website: http://www.vims.edu/cbnerr/species/sshark.html.

Virginia Marine Resource Commission (VMRC), VMRC Plans and Statistics Department. 2010. Species caught Lynnhaven Bay, Commonwealth of Virginia, All years. Data request.

Virginia Oyster Heritage Program, 1999. "Virginia Oyster Heritage Program." Fact Sheet.

Wanless, H.R., 1981. Fining-upwards sedimentary sequences generated in seagrass beds. J. Sedim. Petrol. 51, pp:445–454.

Watts, Gordon, 2004. Archaeological Data Recovery at 44VB239 Lynnhaven Inlet, Virginia, Tidewater Atlantic Research.

Weinstein, M.P. and J. H. Balletto. 1999. Does the common reed, Phragmites australis, affect essential fish habitat? Estuaries 22(3B):793-802.

Weinstein, M. P, S.Y. Litvin, K.L. Bosley,C.M. Fuller and S.C. Wainright. 2000. The role of tidal salt marsh as an energy source for marine transient and resident finfishes: A stable isotope approach. Transactions of the American Fisheries Society 129:797–810.

Weldon Cooper Center for Public Service, University of Virginia. Demographics and Workforce, 2010. Estimate of Population for Virginia Counties and Cities, Final 2008 and Provisional 2009. http://www.coopercenter.org/demographics/virginia-population-estimates

Wells, H. W. 1957. Abundance of the hard clam *Mercenaria mercenaria* in relation to environmental factors. Ecology 38(1): 123-128.

Wilbur, A. E., S. Seyoum, T. M. Bert & W. S. Arnold. 2005. A genetic assessment of bay scallop (*Argopecten irradians*) restoration efforts in Florida's Gulf of Mexico coastal waters (USA). Conserv. Genet. 6:111–122.

Wilson J.G. and D.W. Jeffrey. 1994. Benthic biological pollution indices in estuaries, p.311-327. In J.M. Kramer (ed.), Biomonitoring of Coastal Waters and Estuaries. CRC Press, Boca Raton, Florida.

Wilson, J., C.W. Osenberg, C.M. St. Mary, C.A. Watson and W.J. Lindberg. 2001. Artificial reefs, the attraction-production issue, and density dependence in marine ornamental fishes. Aquarium Sciences and Conservation 3: 95-105.

Wilson, K. D., A.W.Y. Leung and R. Kennish. 2002. Restoration of Hong Kong fisheries through deployment of artificial reefs in marine protected areas. ICES Journal of Marine Science, 59: 157-163.

Windham, L. and R.G. Lathrop. 1999. Effects of *Phragmites australis* (common reed) invasion on above ground biomass and soil properties in brackish tidal marsh of the Mullica River, New Jersey. Estuaries 22(4):927-935.

Wilson, J., C.W. Osenberg, C.M. St. Mary, C.A. Watson and W.J. Lindberg. 2001. Artificial reefs, the attraction-production issue, and density dependence in marine ornamental fishes. Aquarium Sciences and Conservation 3: 95-105.

Wong, M. C., M. A. Barbeau, A. W. Hennigar & S. M. C. Robinson. 2005. Protective refuges for seeded juvenile scallops (*Placopecten magellanicus*) from sea star (*Asterias* spp.) and crab (*Cancer irroratus* and *Carcinus maenas*) predation. Can. J. Fish. Aquat. Sci. 62:1766–1781.