US Army Corps of Engineers
Philadelphia District

Delaware Department of
Natural Resources and
Environmental Control

Delaware Beneficial Use of Dredged Material for the Delaware River

Feasibility Report and Integrated Environmental Assessment

Volume I

11/23/2016

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ABSTRACT: This Feasibility Report and Integrated Environmental Assessment presents the draft findings of a study to determine a coastal storm risk management plan for bayshore and flood-prone urban areas along the Delaware River and Bay/Estuary shoreline, as well as along Delaware's Inland Bays. The report describes the engineering, economic, social and environmental analyses that were conducted to develop a tentatively selected plan.

NOTE TO READER: To provide full and convenient access to the environmental, economic and engineering documentation prepared for the study, the Environmental Assessment has been integrated into this feasibility report in accordance with Engineering Regulation 1105-2-100.

Delaware Beneficial Use of Dredged Material for the Delaware River Feasibility Study

Feasibility Report and Integrated Environmental Assessment

Executive Summary

1 Study Information

The purpose of this report is to analyze coastal storm risk management (CSRM) issues in various Delaware communities, with the intent to beneficially use dredged material from Federal navigation channels within the Delaware River and Bay. The U.S. Army Corps of Engineers (USACE) and the Non-Federal Sponsor (Delaware Department of Natural Resources and Environmental Control – DNREC) entered into a feasibility cost share agreement (FCSA) on 27 February 2014.

This report was prepared in response to an October 26, 2005 resolution of the Committee on Environment and Public Works of the United States Senate, as well as the Disaster Relief Appropriations Act, 2013 (PL 113-2) which was passed in the aftermath of Hurricane Sandy (October 2012).

2 Problem

The primary problems identified in this study are storm surge and elevated water levels from coastal storm events, shoreline erosion and sea-level change (SLC), which cause flood-related damages to the bayshore and flood-prone urban areas along the Delaware River and Bay/Estuary shoreline, as well as along Delaware's Inland Bays. Based on the nature of the problem and overall characteristics of the study area, 26 specific CSRM problem areas were identified. The nature of the CSRM problem and the study area characteristics also present the following opportunities:

- Minimize flood-related damages to Delaware communities located along and adjacent to the Delaware River and Bay/Estuary shoreline.
- Increase the resiliency of the Delaware shoreline by reducing its vulnerability to large-scale flood and storm events.
- Beneficially use dredged material minimize flood-related damages and increase resiliency along the Delaware shoreline.

Based on the characteristics of the study area and the associated problems, the study area was evaluated in two defined planning reaches within the Delaware River/Bay system. The "northern reach" is north of the river/bay boundary (Liston Point, DE), while the “southern reach” extends south from the river/bay boundary to the mouth of the Delaware Bay.

3 Plans Considered

The primary planning objectives of this study are:

1. Reduce flood-related impacts to people, property and infrastructure along and adjacent to the Delaware shoreline from 2020 to 2070, via the beneficial use of dredged material.

2. Increase the resiliency of coastal Delaware, specifically along the Delaware River/Bay and Delaware Inland Bay shoreline, via the beneficial use of dredged material.

A wide variety of management measures were developed that would address one or more of the planning objectives. These measures were then evaluated and screened. The original 26 problem areas were subjected to Cycle 1 screening to confirm that CSRM was the primary problem and that the use of dredged material was potentially feasible in a management measure for the problem area. The PDT formulated structural and non-structural measures for each problem area. In Cycle 2, the measures were compared against the planning objectives to see if they were in line with the study purpose.

In the northern planning reach, five action alternatives were formulated based on the identified problems and shoreline characteristics of each problem area. In New Castle, a Levee/Dike Plan was formulated to improve the CSRM provided by the existing New Castle levees/dikes (Red Lion Creek Dike, Army Creek Dike, Gambacorta Marsh Dike, Broad Marsh Dike and Buttonwood Dike) and to potentially close gaps between the levees/dikes. The other four action alternatives included various combinations and permutations of beach restoration, including stand-alone beach restoration, beach restoration with groin(s), beach restoration with breakwater and beach restoration with groin(s), breakwater, living shoreline and wetland. In the three other northern planning reach sites (Augustine Beach, Bay View Beach and Woodland Beach), stand-alone beach restoration was formulated at all three locations. Beach restoration with groin(s) and beach restoration with breakwater were also formulated at Bay View Beach and Woodland Beach. Based on the existing presence of an expansive marsh/wetland environment along the Augustine Beach shoreline, beach restoration with groin(s), breakwater, living shoreline and wetland was formulated.

In the southern planning reach, three action alternatives were formulated based on the identified problems and shoreline characteristics of each problem area (Pickering Beach, Kitts Hummock, Bowers Beach, South Bowers Beach, Big Stone Beach, Slaughter Beach, Prime Hook Beach and Lewes Beach). At each of the southern reach problem areas, the following alternatives were formulated: stand-alone beach restoration, beach restoration with groin(s) and beach restoration with breakwater.

The final array of alternative plans for the entire study area included the following:

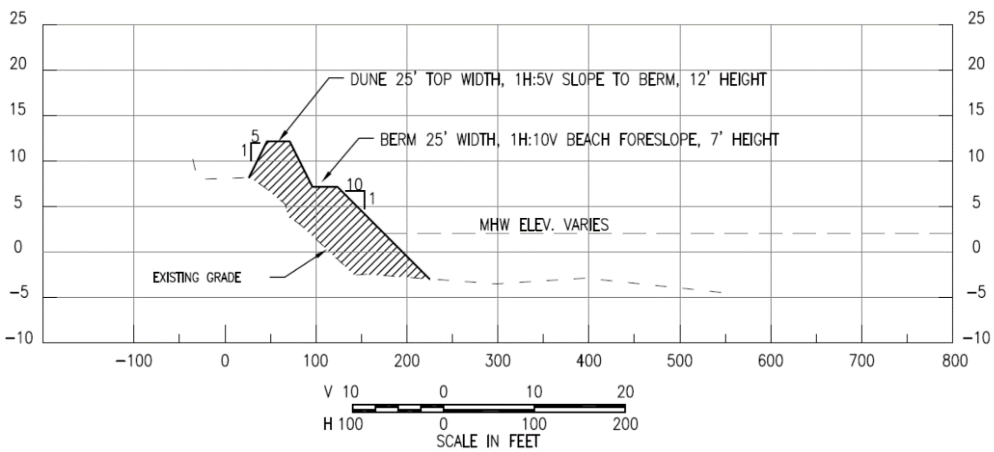
1. No Action Plan
2. Levee/Dike Plan
3. Beach Restoration Plan
4. Beach Restoration with Groin(s) Plan
5. Beach Restoration with Breakwater Plan
6. Beach Restoration with Groin(s), Breakwater, Living Shoreline & Wetland Plan

4 Tentatively Selected Plan

The tentatively selected plan (TSP) consists of dune and berm construction at 8 dredged material placement locations in the southern reach of the study area. The 8 dredged material placement locations span approximately 29 miles along the Delaware Bay and include (from north to south): Pickering Beach, Kitts Hummock, Bowers Beach, South Bowers Beach, Big Stone Beach, Slaughter Beach, Prime Hook Beach and Lewes.

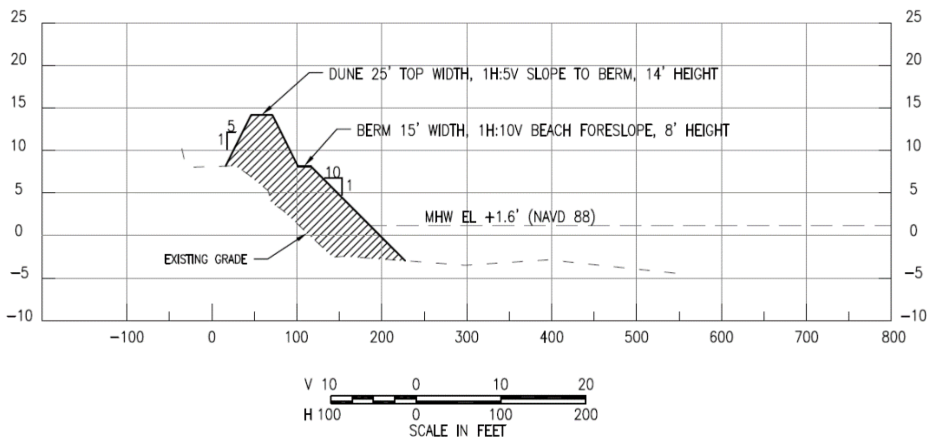
Based on the summary of existing conditions at each site, the range of existing project dimensions along Delaware Bay (Broadkill Beach, Prime Hook National Wildlife Refuge and Lewes), the assumption that the design purpose is to provide storm damage reduction benefits and the assumption that the design will include periodic nourishment, the PDT developed the with-project template. At 7 of the 8 dredged material placement locations, excluding Lewes, the proposed design template features a berm of 25' width at a height of 7' (NAVD 88) with a foreslope of approximately 400' length on a slope of 1V:10H extending bayward to depth of closure of -5.0' (NAVD 88). The berm is topped with a dune whose crest width is 25' at a height of 12' (NAVD 88). The dune transitions both bayward to the berm and landward to existing grade on a slope of 1V:5H., as indicated on Figure 1.

Figure ES-1 - Dredged Material Placement Locations Design Template (Excluding Lewes)



For Lewes Beach, the design template was intended to expand the linear footprint of an existing authorized project by 10,100’ to the southeast. The authorized project consists of a dune and berm extending from Roosevelt Inlet approximately 900 feet southeast with a 500 feet taper. Initial construction included the reconstruction of the adjacent terminal groin for Roosevelt Inlet for the purpose of navigation and the aforementioned beachfill that consisted of a 15’ wide berm (NAVD 88) extending bayward at a slope of 1V:10H above MHW, and a dune with a 25' crest width with an elevation of 14' (NAVD 88) for the purpose of coastal storm damage reduction. The Lewes Beach portion of the TSP proposes to utilize the design template of the existing Lewes project in the remaining 10,100' stretch of the community, as indicated on Figure 2.

Figure ES-2 - Dredged Material Placement Locations Design Template (Lewes)



Varying volumes of dredged material are required at each of the 8 placement locations, depending on the length of shoreline to be nourished and the existing beach profile. A 4-year periodic nourishment cycle is anticipated to maintain optimal coastal storm risk management. This nourishment cycle is in line with the proposed operation and maintenance (O&M) dredging to be performed in Lower Reach E (the proposed project dredged material source area); however, it will be further refined during plan optimization.

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1 STUDY INFORMATION

The purpose of this report is to analyze coastal storm risk management (CSRM) issues in various Delaware communities, with the intent to beneficially use dredged material from Federal navigation channels within the Delaware River. The U.S. Army Corps of Engineers (USACE) and the Non-Federal Sponsor (Delaware Department of Natural Resources and Environmental Control – DNREC) entered into a feasibility cost share agreement (FCSA) on 27 February 2014.

1.1 PROBLEM DESCRIPTION

Storm surge and elevated water levels from coastal storm events, shoreline erosion and sea-level change (SLC) cause flood-related damages to the bayshore and flood-prone urban areas along the Delaware River and Bay/Estuary shoreline, as well as along Delaware's Inland Bays.

The overall objective of the planning study is to improve CSRM and the quality of life for Delaware communities located along the Delaware River/Bay area.

1.2 STUDY AUTHORITY

The study authority for the Delaware Beneficial Use of Dredged Material for the Delaware River Study (DMU) was the October 26, 2005 resolution of the Committee on Environment and Public Works of the United States Senate. The resolution reads as follows:

> "Resolved by the Committee on Environmental and Public Works of the United States Senate, that the Secretary of the Army is requested to review the report of the Chief of Engineers on the Delaware River between Philadelphia, Pennsylvania and Trenton, New Jersey, and Philadelphia to the Sea, published as House Document 358, Eighty Third Congress, Second Session (1954), and other pertinent reports, with a view to determining whether any modifications of the recommendations contained therein are advisable in the interest of beneficial use of dredged material resulting from the aforementioned project, including transfer and transport facilities for the drying, rehandling, and transferring of dredged material, as it relates to comprehensive watershed and regional sediment management (RSM), ecosystem restoration, navigation, stream restoration, water quality, restoration of coal and other mined areas, cover material for sanitary landfills and other allied purposes."

In October 2012, a catastrophic storm (Hurricane Sandy) struck the Atlantic coastline, resulting in loss of life, severe damage to the coastline, widespread power outages, and damage to infrastructure, businesses and private residences. The storm also resulted in degraded coastal features, which increased the risks and vulnerability from future storms. Expected changes in sea level, an increased probability of extreme weather events, and other impacts of climate change are likely to increase those risks even further.

In the aftermath of Hurricane Sandy and the subsequent passage of the Disaster Relief Appropriations Act, 2013 (PL 113-2), Congress authorized supplemental appropriations to Federal agencies for expenses related to the consequences of Hurricane Sandy. Chapter 4 of PL 113-2 identifies those actions directed by Congress specific to USACE, including preparation of two interim reports to Congress, a project performance evaluation report, and a comprehensive study to address the flood risks of vulnerable coastal populations in areas affected by Hurricane Sandy within the boundaries of the North Atlantic Division of USACE.

The Second Interim Report to Congress (dated 30 May 2013) states that PL 113-2 "provides supplemental appropriations to address damages caused by Hurricane Sandy and to reduce future flood risk in ways that will support the long-term sustainability of the coastal ecosystem and communities, and reduce the economic costs and risks associated with large-scale flood and storm events." The Delaware DMU study was identified in the Second Interim Report as an "Ongoing Study" for reducing flooding and storm damage risks in the area affected by Hurricane Sandy.   This CSRM study has been conducted in accordance with the October 2005 resolution and PL 113-2 and its associated reports, thereby formulating for coastal storm damage reduction via the beneficial use of dredged material.

1.3 PURPOSE AND SCOPE (PURPOSE AND NEED)

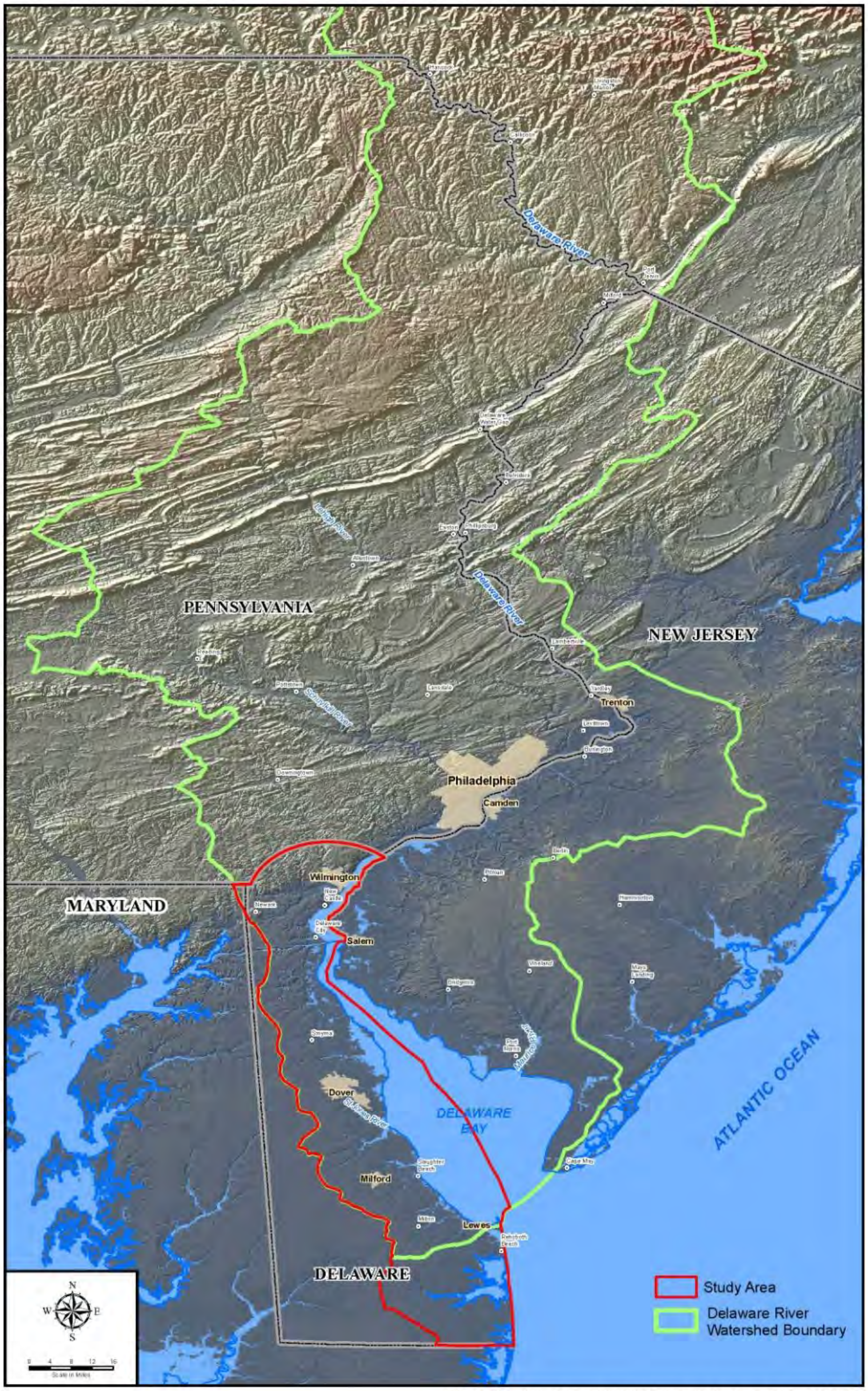
The purpose of this report is to present the findings of a feasibility investigation that was conducted to determine if there is a Federal interest in providing CSRM improvements to various Delaware communities. The study investigated the feasibility of addressing CSRM problem(s) via the beneficial use of dredged material. CSRM alternatives utilizing dredged material were formulated, compared/evaluated against the without project condition and ultimately will be optimized in order to identify the NED plan. If screening does not indicate a viable opportunity to implement CSRM alternatives with dredged material in select problem areas, then other alternatives may be recommended for further analysis under another study authority.

1.4 LOCATION OF THE STUDY AREA

The study area is located within the section of the Delaware River watershed which lies within the State of Delaware, the Delaware River itself, and inland bay communities along the Atlantic Ocean coastline of Delaware (Figure). The north/south boundaries of the study area extend from the Delaware-Pennsylvania state line to the Delaware-Maryland state line. Given the alignment of the state boundary between Delaware and New Jersey, the study area also includes some land located on the east bank of the Delaware River which is contiguous with New Jersey (portions of Killcohook and Artificial Island confined disposal facilities - CDFs).

For the purposes of CSRM, the study area not only includes flood prone areas along the mainstem Delaware River and Delaware Bay, but also the tributaries of the Delaware which are exposed to both tidal and fluvial flooding. The tributaries to the Delaware River and Bay include: Brandywine Creek, Christina River, Chesapeake and Delaware Canal, Smyrna River, Leipsic River, St. Jones River, Murderkill River, Cedar Creek, Simons River, Mahon River, Little River, Mispillion River, Broadkill River, Canary Creek, and the Lewes and Rehoboth Canal.

Figure 1 - Study Area



This feasibility study evaluated coastal storm-related damages in Delaware occurring in two defined planning reaches within the Delaware River/Bay system. The "northern reach" is north of the river/bay boundary (Liston Point, DE), while the "southern reach" extends south from the river/bay boundary to the mouth of the Delaware Bay. The northern reach includes one distinct zone of the tidal Delaware River watershed, as defined by the Delaware River Basin Commission (DRBC): Zone 5 (extending from River Mile 78.8 to 48.2). The southern reach includes Zone 6 (extending from River Mile 48.2 to the Sea – River Mile 0) (Figure 4). In addition, the study evaluated the inland bays of the Delaware ocean coastline.

In the northern reach, the width of the waterway is relatively smaller and the principal CSRM damages are due to inundation during high tide conditions coincident with periods of coastal storm surge, as occurs during hurricanes or nor'easters. However, in the southern reach, the width of the bay (fetch) increases and allows wind to generate greater wave energy at the shoreline, so that waves create an additional risk mechanism beyond inundation alone. Due to the additional damage mechanisms, the southern reach experiences CSRM damages from the combined effects of inundation, waves and storm erosion, analogous to the damage mechanisms experienced on the open ocean coast.

Sediment composition and grain size also varies between the northern and southern reaches. Sediment deposition in the northern reach is dominated by fine-grained sediments, predominantly silts and clays. All dredged sediment from the navigation channel in the northern reach is placed in USACE upland CDFs, which contain hundreds of millions of cubic yards of sediment. In the southern reach, sediment deposition becomes progressively coarser southward such that shoaling in the southernmost 15 miles of the navigation channel consists of predominantly coarse-grained material. The nature of this sediment is discussed in more detail in Section 5.1.3.

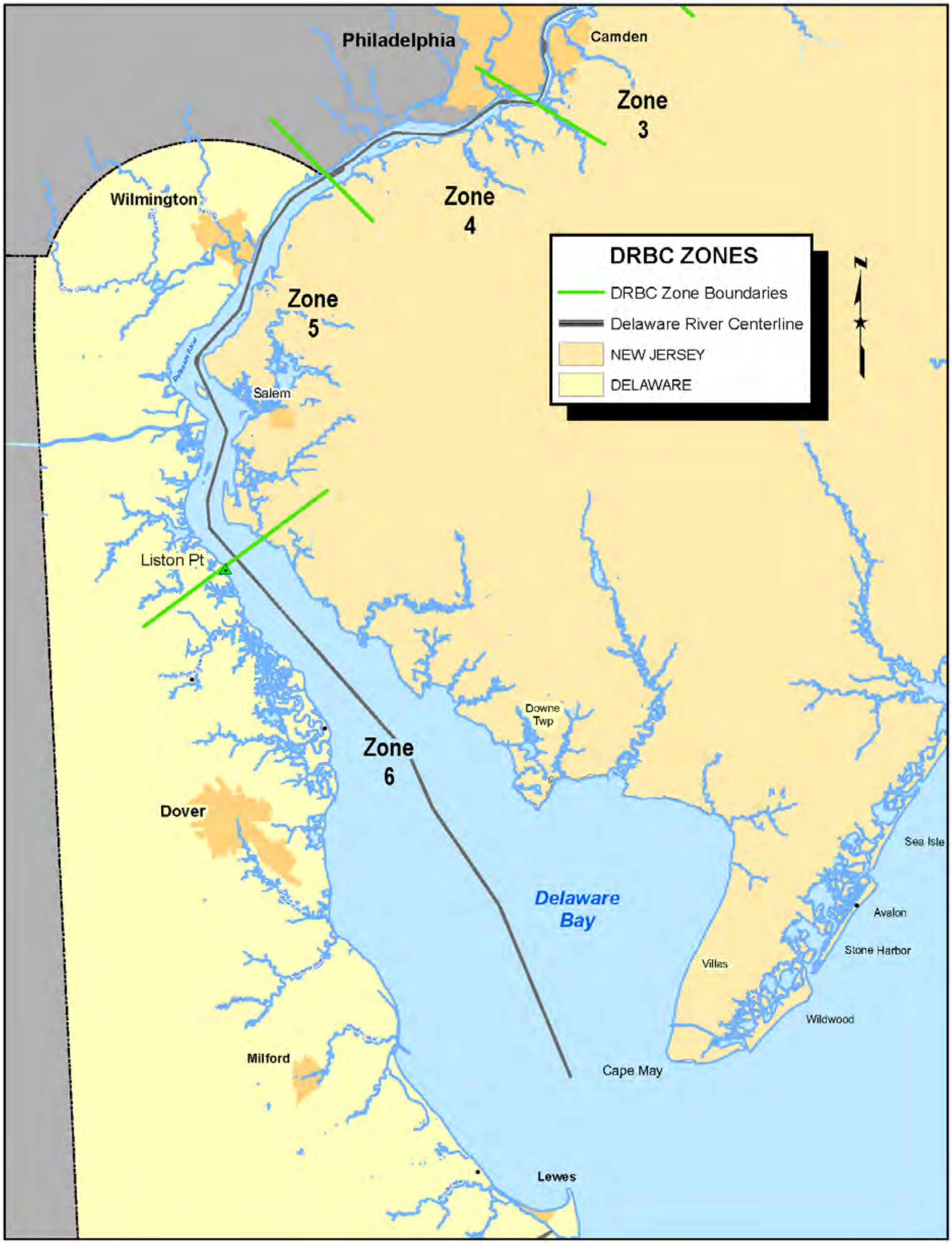
Traditionally, all sediment dredged from this reach has been either placed at Buoy 10 (approximately 1 mile east of the navigation channel) or brought north for placement at the Artificial Island CDF. More recently, material from the Delaware River Main Channel Deepening project was beneficially placed as beach fill at Broadkill Beach during 2015-2016.

DRBC Zone 5 includes urban Wilmington, New Castle and Delaware City. Wilmington is characterized by mixed industrial and commercial use and urban residential development. Major roads include Interstate 495 and Interstate 95. There are seven ports, one power plant and three rail bridges. New Castle is located further south and is characterized by mixed industrial and commercial use and urban residential development with extended areas of wetland shoreline. Major roads include the Delaware Memorial Bridge (Interstate 295). There are two rail bridges. South of New Castle, Delaware City borders the Delaware River and lies approximately two miles north of the Chesapeake and Delaware Canal (C&D). The C &D has a 1.8 mile branch channel which enters the Delaware River at Delaware City. Delaware City is characterized by a mix of residential and commercial development.

In addition, the bayshore communities of Augustine Beach and Bay View Beach are located in DRBC Zone 5. These beach communities are characterized by broad marshes with a narrow barrier of sand along the beach (Kraft *et al.*, 1976). DRBC Zone 6 includes additional bayshore communities (Woodland Beach, Pickering Beach, Kitts Hummock, Bowers Beach, South Bowers Beach, Big Stone Beach, Slaughter Beach and Lewes Beach) with similar shoreline characteristics. The sand barrier is widest and most well-developed near the mouth of the bay south of Prime Hook, becoming less prevalent to the north.

The Inland Bays Region includes bays that are connected to the Atlantic Ocean by Indian River Inlet. The region includes Dewey Beach, Joy Beach/Old Landing, Long Neck, Oak Orchard, the South Side of Indian River Bay, Fenwick Island, Mallard Lakes, Bethany Beach and South Bethany. The Inland Bay communities are characterized as medium density urban residential and beach community development. The shoreline for these areas consists of beaches, bluffs, wetlands, bulkheads, docks and urban development. The major road in this region is Delaware State Route 1 which intersects the local arteries such as State Routes 9 and 13 near the Dover Air Force Base. Further south on Little Assawoman Bay lies Fenwick Island. This area is characterized by medium density urban residential and beach community development. Delaware State Route 1 is the major artery in this region.

Figure 2 - Delaware River Basin Commission (DRBC) Zones



1.5 PRIOR REPORTS AND EXISTING PROJECTS

The Philadelphia District has been responsible for the construction and maintenance of the Delaware River navigation channel since the late 19th Century, allowing deep-draft commercial vessels to call on the Port of Philadelphia and other regional port facilities. As a result, there are several existing Federal navigation projects which are maintained by USACE within the study area. There have also been several water resource studies previously conducted within the study area.

USACE Projects

Delaware River, Philadelphia to the Sea NJ, PA & DE: This project provides a channel from Allegheny Avenue, Philadelphia to deep water in Delaware Bay. It also provides six anchorages, dikes, and training works for the regulation and control of tidal flow. The project channel, previously maintained at a depth of 40 feet, was authorized for deepening to a depth of 45 feet mean lower low water (MLLW) by Congress in 1992. Construction of the deepened channel was initiated in 2010 and is scheduled for completion in 2017. Maintenance dredging of the 45 foot channel will be required and will be performed as needed based on shoaling conditions and project funding. It is expected that maintenance dredging of the project will occur on an annual basis. Federal maintenance dredging of the 40 foot channel has historically generated approximately 3,000,000 cubic yards of dredged material annually.

Intracoastal Waterway, Delaware River to Chesapeake Bay, DE & MD (C&D Canal): The C&D Canal connects the Delaware River to the Chesapeake Bay. The C&D Canal system provides a continuous sea level channel connecting the Port of Baltimore to the ports of Wilmington, DE, Philadelphia, and the northern trade routes. Overall, this project provides a waterway extending from Reedy Point on the Delaware River through a land-cut westward to Elk River, four high-level fixed highway bridges, a vertical lift railroad bridge, a bascule drawbridge, extensions of the entrance jetties at Reedy Point, enlargement of the anchorage and mooring basin in Back Creek, and maintenance of Delaware City Branch channel and basin.

Wilmington Harbor: This project provides for a channel within the Christina River that extends for 9.9 miles from its confluence with the Delaware River to Newport, DE. Channel depths range from 38 to 7 feet over the length of the project. The project also includes jetties at the mouths of the Christina and Brandywine Rivers and a turning basin that is adjacent to the Wilmington Marine Terminal and is 2,050 feet long, 640 feet wide and 38 feet deep. Maintenance dredging, channel surveys, and maintenance of the CDFs (Wilmington Harbor North and South) are also components of the project.

Mispillion River: This project provides for an entrance channel six feet deep and 60 feet wide from Delaware Bay to the landward side of the jetties. The project entrance channel was last dredged in 2009. The waterway marks the boundary between Kent and Sussex Counties, Delaware.

Cedar Creek: This project provides a channel five feet deep, 80 feet wide and 3,730 feet long from the confluence of Cedar Creek with the Mispillion River to the state launching ramp, and five feet deep and 50 feet wide thereafter for a distance of 2,470 feet to a point 1,000 feet upstream of the State Route 36 Bridge.

Delaware Bay Coastline, Roosevelt Inlet-Lewes Beach, DE: This project includes 1,400 feet of beach fill with a 100-feet wide berm and a dune 15 feet above mean sea level.

Inland Waterway from Rehoboth Bay to Delaware Bay, Sussex County, DE: This project provides for an entrance channel through Roosevelt Inlet near Lewes, DE (10 feet deep and 200 feet wide protected by two parallel jetties 500 feet apart, and an extension of the jetties), a channel 10 feet deep and 100 feet wide to the South Street Bridge at Lewes, and a channel 6 feet deep and 50 feet wide to the Rehoboth Bay entrance.

USACE Studies and Reports

Delaware Bay Coastline, DE & NJ Feasibility Study (USACE, 1991): The Delaware Bay Coastline, DE & NJ Feasibility Study evaluated shore protection and ecosystem restoration problems along the Delaware Bay coastline in Delaware and New Jersey. The feasibility study evaluated seven interim study areas with four sites in New Jersey and three in Delaware. The study areas in Delaware included Broadkill Beach, Roosevelt Inlet/Lewes Beach, and Port Mahon. Congress subsequently authorized the projects at Roosevelt Inlet-Lewes Beach, Port Mahon and Broadkill Beach, Delaware. Roosevelt Inlet-Lewes Beach was constructed in 2004. Broadkill Beach was constructed in 2015-2016 as part of the Delaware River Deepening project.

Chesapeake and Delaware (C&D) Canal Trail Recreation Study (USACE, 2008): The goal of this study was to work with Delaware and Maryland State agencies and other interested partners to investigate potential future recreational usage including a multi-use trail for walkers, joggers, equestrians, and bicyclists along the C&D Canal. Due to the lack of Federal funding, the project is being funded by State partners. The project will be built by the Delaware Department of Transportation (DelDOT) and maintained by the DNREC.

Delaware Bay Oyster Revitalization Project (USACE, 2005-2008): The native oyster population in the Delaware Bay is imperiled by diseas. This project revitalized the natural oyster beds through shell planting/transplanting over a four year period and has helped to maintain habitat diversity within the Bay. The study area includes all of the Delaware Bay, both New Jersey and Delaware. USACE's project efforts were completed in 2008 but additional shell plants by the Partnership for the Delaware Estuary and its collaborating partners have been conducted on a much smaller scale thereafter.

Delaware River Basin Comprehensive (USACE, 2006): This reconnaissance study was completed in May 2003. A FCSA was signed with the DRBC in July 2006. The objectives of this study were to: realize ecosystem restoration benefits gained by the effective restoration of habitat impacted by mining operations and wells, restore and protect the ecosystem and watershed; preserve open space and farmland; adopt sound land use planning practices; make infrastructure investments that do not promote sprawl; and invest in restoring public lands. The location of the study is within the Delaware River Basin, which is located in 28 counties in portions of New York, New Jersey, Delaware and Pennsylvania. The basin drains an approximate area of 12,765 square miles.

Biological Assessment (USACE, 2009): The BA evaluated potential impacts to Federally Listed Threatened and Endangered Species resulting from the Delaware River Main Stem and Channel Deepening Project. The BA included formal consultation with NMFS, pursuant to the Endangered Species Act.

Supplemental Biological Assessment (USACE, 2011): The Supplemental BA evaluated potential impacts to the New York Bight distinct population segment of Atlantic sturgeon (*Aciperser oxyrinchus oxyrinchus*) which is proposed for Federal Endangered Species Listing resulting from the Delaware River Main Stem and Channel Deepening Project. The Supplemental BA included formal consultation with NMFS, pursuant to the Endangered Species Act.

Delaware Estuary Salinity Monitoring Study (USACE, 2013): This study was completed in October 2013. The study provides hydrodynamic modeling capabilities for the Delaware Estuary to examine flow dynamics, salinity, and water quality. The study also collected population dynamics data for the Eastern Oyster and Atlantic and shortnose sturgeon, which have shown historically low populations along the Atlantic coast of North America. The model was used to assess the impacts of salinity variance to estuarine water users and the information gathered was useful to the States of New Jersey, Delaware and the DRBC in assessing low flow augmentation for the Delaware River and Bay.

Delaware River New Jersey, Delaware, and Pennsylvania Dredged Material Utilization and Beneficial Use Opportunities Expedited Reconnaissance Study (USACE, 2013): In response to the original study authorization from October 26, 2005 (provided in Section 3.0), the Philadelphia District conducted this Expedited Reconnaissance Study. The purpose of this study was to examine beneficial use opportunities using maintenance dredged material from the Delaware River and its tributaries for multiple purposes. The findings of the expedited reconnaissance study indicated that there is Federal interest in further investigations of multiple-purpose beneficial sediment reuse opportunities through a feasibility study within Delaware.

1.7 PLANNING PROCESS AND REPORT ORGANIZATION

The planning process consists of six major steps: (1) Specification of water and related land resources problems and opportunities; (2) Inventory, forecast and analysis of water and related land resources conditions within the study area; (3) Formulation of alternative plans; (4) Evaluation of the effects of the alternative plans; (5) Comparison of the alternative plans; and (6) Selection of the recommended plan based upon the comparison of the alternative plans. The chapter headings and order in this report generally follow the outline of an Environmental Assessment (EA). Chapters of the report related to the six steps of the planning process as follows:

- Chapter 2, Problem Description and Objectives of the Proposed Action, covers the first step in the planning process (Specification of water and related land resources problems and opportunities).
- Chapter 3, Plans, is the heart of the report and is therefore placed before the detailed discussion of resources and impacts. It covers the third step in the planning process (Formulation of plans), the fifth step in the planning process (Comparison of alternative plans) and the sixth step of the

planning process (Selection of the recommended plan based upon the comparison of the alternative plans).

- Chapter 4, Affected Environment, covers the second step of the planning process (inventory, forecast and analysis of water and related land resources in the study area).
- Chapter 5, Effects on Environmental Resources, covers the fourth step of the planning process (Evaluation of the effects of the alternative plans).

This report was written in accordance with USACE Planning Modernization and meets the requirements, under the National Environmental Policy Act, as a full disclosure document of environmental effects of the proposed Federal agency actions. Information contained in the report demonstrates the decision-making process. For more information on the detailed analysis, please refer to the appendices.

2 PROBLEM DESCRIPTION AND OBJECTIVES OF THE PROPOSED ACTION

This chapter presents the results of the first step of the planning process, the specification of water and related land resources problems and opportunities in the study area. The chapter concludes with the establishment of planning objectives and planning constraints, which is the basis for the formulation of alternative plans.

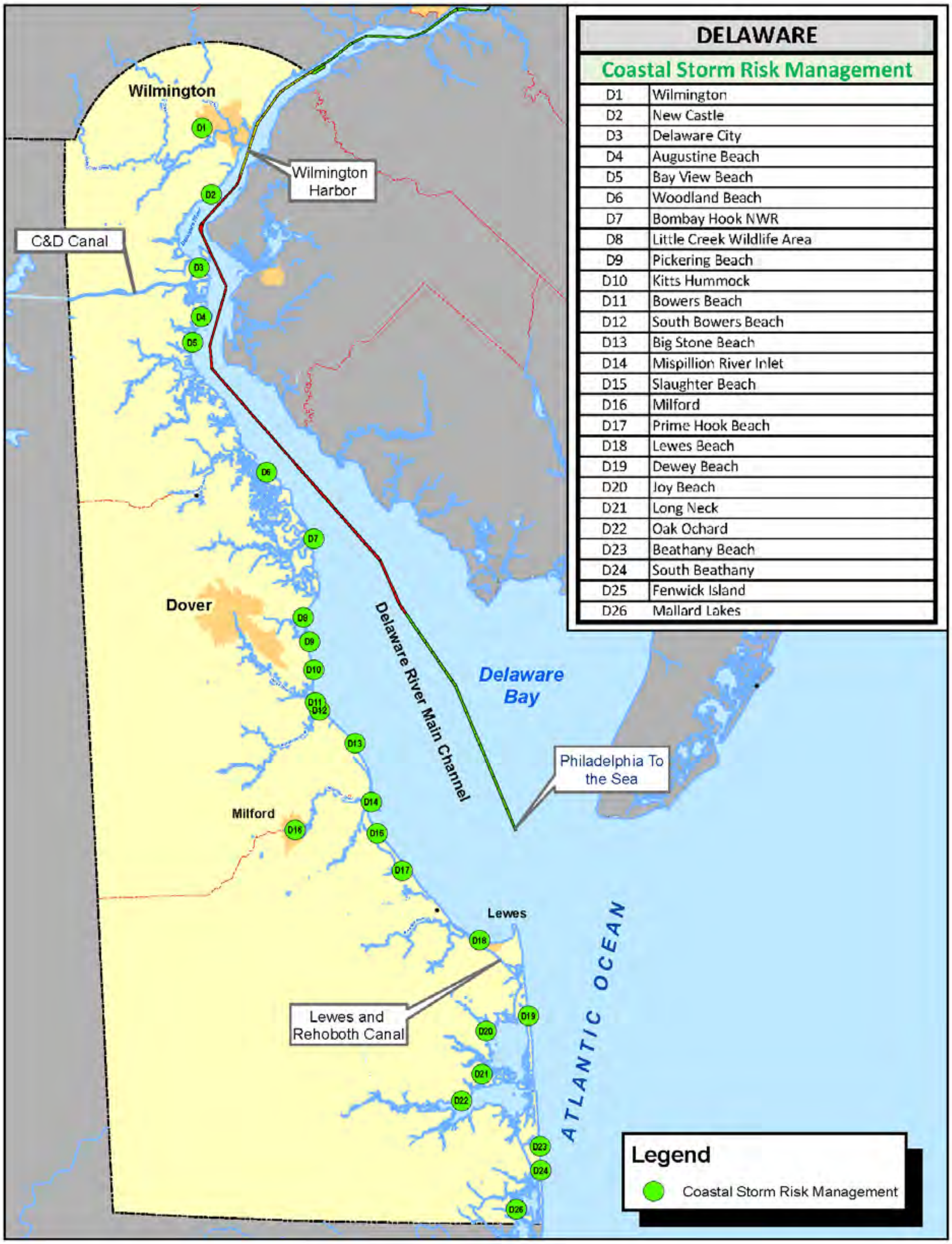
2.1 NATIONAL OBJECTIVES

The national or Federal objective of water and related land resources planning is to contribute to National Economic Development (NED). In addition, it must be consistent with protecting the nation's environment, pursuant to national environmental statutes, with applicable executive orders and with other Federal planning requirements. Contributions to NED are increases in the net value of the national output of goods and services, expressed in monetary units. Contributions to NED are the direct net benefits that accrue in the planning area and in the rest of the nation as a result of reducing storm damages with the selected plan in place within the study area.

2.2 PUBLIC CONCERNS

The North Atlantic Coast Comprehensive Study: Resilient Adaptation to Increasing Risk (NACCS) identified the Delaware River/Bay and Inland Bay shorelines as "High Storm Impact" areas from Hurricane Sandy. Under the purview of the NACCS, there was significant coordination with state, county and local community agencies and representatives of non-profit organizations to identify specific flood-prone problem areas within the "High Storm Impact" zone. For the state of Delaware, 26 CSRM problem areas were originally identified extending from New Castle to Sussex Counties, as shown in Figure 5.

Figure 3 – CSRM Problem Areas



2.3 PROBLEMS AND OPPORTUNITIES

This section describes the needs in the context of problems and opportunities that can be addressed through water and related land resource management. The problems and opportunities are based upon the project conditions that are described in Chapter 4, Affected Environment.

The primary problems identified in this study are storm surge and elevated water levels from coastal storm events, shoreline erosion and sea-level change (SLC), which cause flood-related damages to the bayshore and flood-prone urban areas along the Delaware River and Bay/Estuary shoreline, as well as along Delaware's Inland Bays. The nature of the CSRM problem and the study area characteristics also present the following opportunities:

- Minimize flood-related damages to Delaware communities located along and adjacent to the Delaware River and Bay/Estuary shoreline.
- Increase the resiliency of the Delaware shoreline by reducing its vulnerability to large-scale flood and storm events.
- Beneficially use dredged material minimize flood-related damages and increase resiliency along the Delaware shoreline.

2.4 EXISTING COASTAL STORM RISK

The shorelines of the Delaware River/Bay and Inland Bays are characterized by flat, low-lying coastal plains that are subject to tidal flooding during storms, as well as the ongoing effects of shoreline erosion and SLC. The Delaware Bay is 47 mi long and 27 mi wide measured at the widest point. The shoreline consists of tidal marshes and sandy barriers or developed residential and commercial infrastructure. Public and private property at risk includes densely populated sections of the shoreline bordering the Delaware River/Bay and associated tidal tributaries. Specifically, there are densely developed urban areas, private residences, businesses (including refineries and chemical plants), schools, infrastructure, roads and evacuation routes for coastal emergencies. Additionally, the study area includes undeveloped areas that provide ecological, fisheries and recreational benefits as well as ecosystem services. Dunes, beaches, marshes and estuarine ecosystems are quite fragile in some locations and are threatened by coastal storm events and the effects of climate change. In addition, there is an extensive network of private and state-preserved agricultural land in the study area.

Different regions of the Delaware Estuary exhibit differing flood and erosion problems. Developed residential areas incur frequent flood damages to homes and businesses from storm events while lesser developed regions incur excess inundation to natural habitat and farmland, incurring community and recreational access and economic losses due to flooding.

The northern planning reach of the Delaware River and Bay have densely developed urban areas, and businesses (including refineries and chemical plants). The primary urban areas in this region include Wilmington, New Castle and Delaware City. Wilmington is characterized by a mixed industrial and commercial use and urban residential development. There are seven ports, one power plant and three rail bridges. Just south of Wilmington, New Castle is characterized as a mixed industrial and commercial use and urban residential development with extended areas of wetland shoreline.   There are two rail bridges. South of New Castle, Delaware City borders the Delaware River and lies approximately two miles north of Chesapeake and Delaware Canal (C&D). The C &D has a 1.8 mile branch channel which enters the Delaware River at Delaware City. Delaware City is characterized by a mix of residential and commercial development. Just south of Delaware City and the C&D Canal, the upper bay region is less developed and more rural. The community of Augustine Beach is adjacent to extensive marshes and wildlife areas.

In the southern planning reach, flood prone areas include the communities of Woodland Beach, Pickering Beach, Kitts Hummock, Bowers Beach, South Bowers Beach, Big Stone Beach, Slaughter Beach, Prime Hook Beach and Lewes Beach. Most of the Delaware Bay shoreline between Pickering Beach and Broadkill Beach is characterized by broad marshes with a narrow barrier of sand along the beach. The barrier is widest and most well-developed near the mouth of the bay south of Prime Hook, becoming less prevalent to the north.

There are several notable wildlife areas experiencing coastal erosion and habitat loss due to flooding. These include Augustine Wildlife areas, Silver Run Wildlife area, Appoquinimink Wildlife area, Cedar Swamp Wildlife area, Bombay Hook National Wildlife refuge, Little Creek Wildlife area, Ted Harvey Wildlife area Logan Tract, and Prime Hook National Wildlife refuge.

2.4.1 Historical Flooding

According to the National Climatic Data Center (NCDC), 57 flood events were reported in Sussex County, DE between 13 MAR 1993 and 20 NOV 2009, resulting in more than $45 million in property damage in Sussex County alone. During that same time period, approximately $24 million in damages were reported in New Castle County, DE.

An example of the type of coastal flooding encountered in this region was Hurricane Floyd which battered New Castle County on September 16, 1999. The storm brought torrential rains and damaging winds. The hurricane caused widespread flash flooding as rain totals averaged around nine inches, most of which fell in a 12-hour period from the early morning through the afternoon on the 16th. Approximately 300 residents of New Castle and Sussex Counties were evacuated to shelters. The combination of winds funneling into Delaware Bay and the runoff from inland waterways produced tidal flooding at the times of high tide in New Castle County. The hardest hit community within the county was Glenville (near Stanton) along the White Clay Creek. About 100 homes were flooded with up to six feet of water. During the height of the storm, 40 roads and bridges were closed including sections of Delaware State Routes 1 and 9.

During Hurricane Sandy, several of the dikes in New Castle were overtopped and weakened.   Augustine and Bay View Beach experienced flooding of homes and erosion of beaches during Hurricane Sandy as well. In addition, both the Mispillion and Murderkill Rivers inlet structures were damaged resulting in flooding and erosion of adjacent beaches in these areas.

Some reaches within the study area that have experienced tidal flooding are located inland. Milford is located on the Mispillion River 7 miles inland from the river confluence with the Delaware Bay. Coastal storm surge and stormwater runoff during Hurricane Sandy caused flooding of Milford homes and roadways. The Inland Bays region, connected to the Atlantic Ocean by Indian River Inlet is located in the southernmost part of the state. The Inland Bay communities are moderately dense urban residential communities with shoreline beaches, bluffs, and marshes. The oceanfront community of Bethany Beach has experienced frequent stormwater flooding due to a combination of tidal surge, heavy rainfall and westerly winds.

Adjacent to but inland of the Delaware shoreline is an extensive network of agricultural land including approximately 1,300 agricultural properties. During Hurricane Sandy, approximately 350 agricultural properties were impacted by flood inundation.

Kitts Hummock, DE – May 2008

Kitts Hummock, DE – May 2008

Lewes Beach, DE – Oct 2012

2.4.2 Existing Coastal Storm Risk Management

For approximately 50 years, DNREC has implemented periodic CSRM measures for many of the DE bayshore communities, including Big Stone Beach, Bowers Beach, Broadkill Beach, Kitts Hummock, Lewes Beach, Pickering Beach, Slaughter Beach and South Bowers Beach. While the predominant CSRM measure involved emergency and/or periodic beach nourishment, groin construction/maintenance and jetty construction/maintenance were also part of the CSRM measures.

Table 1 - DNREC Existing Coastal Storm Risk Management Projects

Project location	Year	Project Type	Fill Amount (CY)	Length (Ft)
Big Stone Beach	1962	Beachfill	26000	0
Bowers	1962	Beachfill	35500	0
Bowers	1968	Beachfill	18000	0
Bowers	1969	Beachfill	6500	0
Bowers	1972	Beachfill	21200	0
Bowers	1973	Beachfill	15800	1400
Bowers	1974	Beachfill	28800	1000
Bowers	1976	Groin	0	900
Bowers	1976	Groin	0	400
Bowers	1985	Beachfill	35700	
Bowers	1986	Beachfill	13700	500
Bowers	1986	Groin		213
Bowers	1988	Beachfill	51700	
Bowers	1988	Groin		290
Bowers	1988	Groin		320
Bowers	1994	Beachfill	12000	500
Bowers	1998	Beachfill	46240	2200
Bowers	1998	Beachfill	55165	
Bowers, North Murderkill	1995	Jetty		100
Bowers	2009	Jetty		120+/-
Bowers		Beachfill	1000	400
Bowers	2009	Beachfill	9000	2615+/-
Bowers	2009	Beachfill	7000	2000+/-
Bowers	2012	Beachfill	13000	2700
Broadkill Beach	1908	Jetty	0	1263
Broadkill Beach	1950	Groin	0	196
Broadkill Beach	1950	Groin	0	196
Broadkill Beach	1950	Groin	0	199
Broadkill Beach	1954	Groin	0	195
Broadkill Beach	1954	Groin	0	186
Broadkill Beach	1957	Beachfill	76800	1500
Broadkill Beach	1961	Beachfill	120000	0
Broadkill Beach	1964	Groin		

Broadkill Beach	1964	Groin		
Broadkill Beach	1964	Revetment		
Broadkill Beach	1973	Beachfill	118100	
Broadkill Beach	1975	Beachfill	295000	6100
Broadkill Beach	1976	Beachfill	59700	2200
Broadkill Beach	1981	Beachfill	127700	0
Broadkill Beach	1996	Beachfill	25,000	
Broadkill Beach	1987-88	Beachfill	81100	
Broadkill Beach	1993-94	Beachfill	67000	
Broadkill Beach	2005	Beachfill	152000	5700
Broadkill Beach	2011	Beachfill	30000	5000
Broadkill Beach	2012	Beachfill	10000	1500
Broadkill Beach	2013	Beachfill	10000	1500
Broadkill Beach	2014	Beachfill	29000	2700
Kitts Hummock	1961	Beachfill	80000	4250
Kitts Hummock	1962	Beachfill	30600	0
Kitts Hummock	1969	Beachfill	12000	0
Kitts Hummock	1973	Beachfill	3000	0
Kitts Hummock	1974	Beachfill	46500	1700
Kitts Hummock	1979	Beachfill	74000	5000
Kitts Hummock	1979	Breakwater	0	330
Kitts Hummock	1979	Breakwater	0	330
Kitts Hummock	1979	Breakwater	0	330
Kitts Hummock	1987	Groin		180
Kitts Hummock	1988	Beachfill	15780	1000
Kitts Hummock	1996	Beachfill	32850	1000
Kitts Hummock	2006	Beachfill	400+/-	south end
Kitts Hummock	2008	Beachfill	15000	1400
Kitts Hummock	2010	Beach	10000	1,000
Kitts Hummock	2012	Beachfill	7000	1500 +/-
Kitts Hummock	2014	Beachfill	7500	1500+/-
Lewes	1898	Breakwater	0	5300
Lewes	1901	Breakwater	0	8000
Lewes	1937	Jetty	0	1700
Lewes	1937	Jetty	0	1700
Lewes	1948	Groin	0	145
Lewes	1948	Groin	0	135
Lewes	1948	Groin	0	150
Lewes	1950	Groin	0	172
Lewes	1950	Groin	0	161
Lewes	1950	Groin	0	164
Lewes	1953	Beachfill	55100	0
Lewes	1954	Beachfill	44900	0
Lewes	1956	Groin	0	0
Lewes	1956	Groin	0	0
Lewes	1956	Groin	0	0

Lewes	1957	Beachfill	79000	0
Lewes	1957	Beachfill	434400	0
Lewes	1962	Beachfill	20700	0
Lewes	1963	Beachfill	87000	0
Lewes	1969	Beachfill	135600	0
Lewes	1973	Beachfill	69800	3700
Lewes	1975	Beachfill	101700	4800
Lewes	1977	Beachfill	11400	1000
Lewes	1978	Beachfill	31000	1000
Lewes	1981	Beachfill	113900	0
Lewes	1983	Beachfill	50500	
Lewes	1987	Beachfill	11000	
Lewes	1989	Beachfill	1500000	
Lewes	1990	Beachfill	32000	
Lewes	1990	Groin		350
Lewes COE	2004	Beachfill	180745	1400
Lewes COE	2004	Jetty	18220 tons	
Lewes COE	2011	Beachfill	111757	1500
Lewes	2012	Beachfill	8315	
Lewes Beach	2013	Beachfill	25000	
Mispillion River Breach	1985	Dike	19500 tons	970
Pickering Beach	1962	Beachfill	39600	0
Pickering Beach	1969	Beachfill	5000	0
Pickering Beach	1978	Beachfill	85200	1600
Pickering Beach	1978	Beachfill		
Pickering Beach	1979	Breakwater	0	400
Pickering Beach	1984	Breakwater	0	200
Pickering Beach	1990	Beachfill	55400	2400
Pickering Beach	2001	Beachfill	27150	
Prime Hook Beach	1962	Beachfill	20200	0
Slaughter Beach	1940	Groin	0	150
Slaughter Beach	1940	Groin	0	150
Slaughter Beach	1940	Groin	0	150
Slaughter Beach	1940	Groin	0	150
Slaughter Beach	1943	Groin	0	150
Slaughter Beach	1943	Groin	0	150
Slaughter Beach	1947	Groin	0	110
Slaughter Beach	1947	Groin	0	110
Slaughter Beach	1947	Groin	0	115
Slaughter Beach	1947	Groin	0	140
Slaughter Beach	1947	Groin	0	150
Slaughter Beach	1947	Groin	0	150
Slaughter Beach	1947	Groin	0	150
Slaughter Beach	1950	Groin	0	179
Slaughter Beach	1950	Groin	0	138

Slaughter Beach	1950	Groin	0	139
Slaughter Beach	1954	Groin	0	168
Slaughter Beach	1954	Groin	0	172
Slaughter Beach	1957	Groin	0	98
Slaughter Beach	1957	Groin	0	154
Slaughter Beach	1958	Beachfill	49000	0
Slaughter Beach	1961	Beachfill	165000	0
Slaughter Beach	1962	Beachfill	56600	0
Slaughter Beach	1975	Beachfill	179500	4700
Slaughter Beach	1976	Beachfill	277700	9600
Slaughter Beach	1979	Beachfill	20000	0
Slaughter Beach	1979	Perched Beach	20000	0
Slaughter Beach	1985	Beachfill	26200	1700
Slaughter Beach	1985	Beachfill	10300	
Slaughter Beach	2002	Beachfill	8,600	500
Slaughter Beach	2005	Beachfill	115,000	4400 lf
South Bowers	1961	Beachfill	20000	0
South Bowers	1962	Beachfill	10000	0
South Bowers	1969	Beachfill	4000	0
South Bowers	1974	Beachfill	4000	830
South Bowers	1975	Beachfill	15000	1000
South Bowers	1976	Beachfill	9400	0
South Bowers	1976	Groin	0	325
South Bowers	1976	Groin	0	325
South Bowers	1984	Beachfill	17000	
South Bowers	1988	Groin		600
South Bowers	1989	Beachfill	8000	
South Bowers	1992	Beachfill	2000	
South Bowers	1997	Beachfill	7500	500
South Bowers	2009	Beachfill	2000	400 +/-
South Bowers	2012	Beachfill	2000	700

2.4.3 Future Without Project Conditions

In August 1991, the Corps conducted a review of the Delaware Bay and its tributaries to determine the magnitude, location, and effect of the shoreline erosion problems under the scope of the Delaware Bay Coastline - New Jersey and Delaware Reconnaissance Study. The study examined the Delaware shoreline extending from Woodland Beach to Lewes, DE. At the time of the study, there was little information available on shoreline change upstream of Woodland Beach, DE. Table 2 provides a summary of shoreline erosion trends from Woodland Beach to Lewes, DE.

Table 2 – Delaware Shoreline Erosion Rates

Delaware	Minimum Shoreline Change Rate (ft/yr)	Maximum Shoreline Change Rate (ft/yr)	Average Shoreline Change Rate (ft/yr)
Woodland Beach	-2	-7	-4.5
Port Mahon	-9	-12	-10.5
Pickering Beach	-5	-5	-5
Bowers Beach	-2	-2	-2
South Bowers Beach	-8	-8	-8
Big Stone Beach	-5	-6	-5.5
Big Stone Beach to Mispillion Inlet	-10	-13	-11.5
Mispillion Inlet	-9	-11	-10
Slaughter Beach	-2	-2	-2
Slaughter Beach to Fowler	-1	-5	-3
Broadkill Beach	-3	-3	-3
Lewes Beach (near Roosevelt Inlet)	-3	-3	-3

The minimum and maximum shoreline change rates listed on Table 2 were extracted from the 1991 Delaware Bay Coastline - New Jersey and Delaware Reconnaissance Study. The average of the minimum and maximum shoreline change rates was then calculated by the PDT. This table highlights that the Delaware average shoreline erosion rates ranged from -2 ft/yr to -11.5 ft/yr in the entire study area.

Assuming these erosion trends continue and are potentially exacerbated by SLC, a significant amount of shoreline erosion will occur along the Delaware shoreline in the absence of a Federal project. In addition to the ongoing effects of shoreline erosion and SLC, the Delaware Bay shoreline is vulnerable to flood-related damages from coastal storm events.

Section 3.6.3 provides further discussion on the future without project conditions and the potential economic impacts of such conditions.

2.4.3 Federal Interest

The Federal Government investigates prospective projects from a national point of view. When determining the need for Federal investment in a project, the primary analysis centers on significance of the problem and the benefits of possible solutions. In the case of this study, the focus is primarily on CSRM benefits. It is also in the Federal and non-Federal sponsor's interest to select a cost-efficient plan, specifically one in which the benefits exceed costs. It is important to note that benefits can include non-monetary benefits such as reducing life-safety issues and improving the environmental quality. Federal interest in the project is identified when both requirements are satisfied.

Based on historical records, the identified problems areas experience significant flood-related damage every couple of years. It is within USACE and Federal interest to study the CSRM issues in this study area because there are significant flood damages that result in residential and commercial property loss. Impacts from frequent flooding in the past include significant economic costs. Developing a project that will reduce the frequency of these damages and protect human life is within the Federal interest and a primary mission of USACE.

2.5 PLANNING OBJECTIVES

The water and related land resource problems and opportunities identified in this study area are stated as specific planning objectives to provide focus for the formulation of plans and development of criteria. These planning objectives represent desired positive changes in the “without project” conditions. The base year, the year the project is assumed to be fully operational, is 2020, and the period of analysis is through the year 2070. The planning objectives are as follows:

1. Reduce flood-related impacts to people, property and infrastructure along and adjacent to the Delaware shoreline from 2020 to 2070, via the beneficial use of dredged material.

2. Increase the resiliency of coastal Delaware, specifically along the Delaware River/Bay and Delaware Inland Bay shoreline, via the beneficial use of dredged material.

According to the NACCS, coastal resilience is a function of the shoreline’s adaptive capacity. Adaptive capacity is defined as a measure’s ability to adjust through natural processes, operation and maintenance activities, or adaptive management, to preserve the measure’s function.

2.6 PLANNING CONSTRAINTS

Unlike planning objectives that represent desired positive changes, planning constraints represent restrictions that should not be violated. The planning constraints identified in this study are as follows:

- Avoid inducing flood damages.
- Avoid conflicts with the existing engineering policies for CSRM projects.
- Do not formulate CSRM plans for a single private property.
- Avoid impacts to Threatened and Endangered Species.
- In areas of existing habitat, avoid nesting season, flood season, and minimize impacts to native vegetation during proposed construction.
- Avoid degradation to water quality.
- Avoid and/or minimize effects on cultural resources and historic structures, sites and features.
- Limit extensive changes to local land use designations and zoning.

3 PLANS

This chapter describes the development of alternative plans that address the planning objectives, the comparison of those plans and the selection of a plan. It also describes the recommended plan and its implementation requirements.

3.1 PLAN FORMULATION RATIONALE

As referenced in Section 2, 26 CSRM problem areas were identified in the study area. As part of the alternative plan development, the project delivery team (PDT) applied multiple rounds of screening to the 26 problem areas to determine which areas could be addressed by a Federal project, in accordance with the study objectives.

Each of the identified problem areas was screened by the PDT to better understand the nature and extent of the CSRM problems. Initially, the PDT posed the question as to whether CSRM was the primary problem at each location. CSRM was considered a primary problem at a location if the Composite Exposure Index (CEI), as calculated in the NACCS, was greater than 50%. In calculating the CEI, the NACCS defined exposure as the presence of people, infrastructure, and/or environmental and cultural resources affected by coastal storm risk hazard. Specifically, three exposure indices were combined to develop the CEI:

- Population Density and Infrastructure Index – the affected population and critical infrastructure
- Social Vulnerability Index – segments of the population that may have more difficulty preparing for and responding to natural disasters
- Environmental and Cultural Resources Index – important habitat and cultural and environmental resources that would be vulnerable to storm surge

Each index was multiplied by a relative weight and the results were summed to develop the total index. Population density and infrastructure were weighted 80%, while social vulnerability and environmental/cultural resources were each weighted 10%. The PDT chose to use the NACCS CEI as a Cycle 1 screening tool since the CEI was heavily weighted toward the impact of CSRM risks to people and infrastructure. While it was heavily weighted toward people and infrastructure, there were other metrics (social vulnerability and environmental/cultural indices) that contributed to the overall CEI; therefore, the PDT used also applied best professional judgment to validate that the problem areas with greater than 50% CEI were predominantly inhabited by people and structures. If the problem area had a CEI greater than 50% and was subsequently validated by PDT best professional judgment, it was evaluated further to determine if dredged material would be a feasible CSRM measure in the problem area.

During Cycle 1 screening, a primary driver behind assessing the feasibility of using dredged material was determining if potential sediment sources were within a reasonable distance (less than 20 miles) from the problem area(s). From there, potential sources of dredged material were identified:

- Confined Disposal Facilities (CDFs) – In the Delaware River Watershed, the predominant dredged material management practice has been to place material in upland CDFs after it is dredged from the channel. Sediment is then sequestered and managed in the CDF for an indefinite period of time. Within Delaware, the PDT has identified 6 CDFs (Wilmington Harbor North, Wilmington Harbor South, Reedy Point North, Reedy Point South, and portions of Killcohook and

Artificial Island) that could serve as potential sediment sources for CSRM solutions. The Delaware CDFs are located within the northern planning reach and may serve as a potential source for project areas in that portion of the watershed.

- Delaware River/Bay Main Channel – The Delaware River/Bay channel could also serve as a source area during O&M channel dredging, via a hopper dredge and associated piping/pumping of the dredged material to a potential project area. Depending on the type of material needed and the nature of the proposed project, dredging and piping/pumping from the main channel may serve as a potential source throughout the study area.
- Buoy 10 – Buoy 10 is an open water disposal site that is used for disposal of sandy dredged material. Buoy 10 is located in the southern planning reach near the mouth of the Delaware Bay and may be a viable sediment source for project areas in the lower portion of the study area.

In addition, the amount of space and land available to place dredged material at the problem area was considered, as well as the shoreline type at the problem area, per the NACCS.

If Cycle 1 screening indicated that CSRM was the primary problem and dredged material was a feasible measure, the problem area was carried forward for further analysis under this "Ongoing Study." If CSRM was not the primary problem or dredged material was not considered a feasible measure, the problem area was screened out and recommended for further analysis under another authority. The results of the Cycle 1 screening are detailed in Table 3 below:

Table 3 – Problem Area Screening - Cycle 1

Cycle 1 Screening – DE DMU		Question 1: Is CSRM the primary problem?	Question 2: Is DM a feasible measure?	Carry Forward for Further Analysis under "Ongoing Sandy Study"
D1	Wilmington	**Y**	**N**	**N**
D2	**New Castle**	**Y**	**Y**	**Y**
D3	Delaware City	**Y**	**N**	**N**
D4	**Augustine Beach**	**Y**	**Y**	**Y**
D5	**Bay View Beach**	**Y**	**Y**	**Y**
D6	**Woodland Beach**	**Y**	**Y**	**Y**
D7	Bombay Hook NWR	**N**	**Y**	**N**
D8	Little Creek Wildlife Area	**N**	**Y**	**N**
D9	**Pickering Beach**	**Y**	**Y**	**Y**
D10	**Kitts Hummock**	**Y**	**Y**	**Y**
D11	**Bowers Beach**	**Y**	**Y**	**Y**
D12	**South Bowers Beach**	**Y**	**Y**	**Y**
D13	**Big Stone Beach**	**Y**	**Y**	**Y**
D14	**Mispillion River Inlet**	**Y**	**Y**	**Y**
D15	Slaughter Beach	**N**	**Y**	**N**
D16	Milford	**Y**	**N**	**N**
D17	**Prime Hook Beach**	**Y**	**Y**	**Y**
D18	**Lewes Beach**	**Y**	**Y**	**Y**
D19	Dewey Beach	**Y**	**N**	**N**
D20	Joy Beach	**Y**	**N**	**N**
D21	Long Neck	**Y**	**N**	**N**
D22	Oak Orchard	**Y**	**N**	**N**
D23	Bethany Beach	**Y**	**N**	**N**
D24	South Bethany	**Y**	**N**	**N**
D25	Fenwick Island	**Y**	**N**	**N**
D26	Mallard Lakes	**Y**	**N**	**N**

After the Cycle 1 screening, 13 sites were screened out from the initial 26 and recommended for further potential analysis under another authority. Specifically, the 8 inland bay problems areas (D19 through D26) were screened out because much of the inland bay shoreline has bulkheads and boat docks; therefore, dredged material placement was not considered a feasible measure in these CSRM problem areas. The Wilmington (D1) and Delaware City problem areas (D3) were screened out because they have a fairly hardened and protected shoreline with limited available space for the placement of dredged material. Also in Delaware City, there is a port for the adjacent refinery that requires deeper water for large ship traffic; therefore, placement of dredged material in this area may disrupt refinery activities. Milford (D16) was screened out because the closest source of dredged material (Buoy 10) was approximately 20 to 25 miles away. Bombay Hook NWR (D7) and Little Creek Wildlife Area (D8) were screened out because CSRM was not considered to be the primary problem because the CEI was less than 50% and the areas were not primarily inhabited by people and infrastructure.

3.2 MANAGEMENT MEASURES

Alternative plans are a set of one or more management measures functioning together to address one or more planning objectives. Management measures are the building blocks of alternative plans and are defined as features or activities that can be implemented at a specific geographic site to address one or more planning objectives. The PDT formulated as many measures as possible, with the understanding that there would be at least one measure for each planning objective:

Structural Measures:

1. Levees and Dikes – Levees and dikes are embankments constructed along a waterfront to prevent flooding in relatively large areas. They are typically constructed by compacting soil into a large berm that is wide at the base and tapers toward the top. If a levee or dike is located in an erosive shoreline environment, revetments may be needed on the waterfront side to reduce impacts from erosion, or in cases of extreme conditions, the dike face may be constructed entirely of rock. Levees may be constructed in urban areas or coastal areas; however, large tracts of real estate are usually required due to the levee width and required setbacks.
2. Flood Wall(s) –
    a. Permanent Flood Wall - A flood wall is a concrete or sheet pile structure that parallels the channel on either side, rising above the surrounding floodplain (or above existing levees). Similar to a levee, a flood wall reduces the volume of water leaving the river channel.
    b. Rapid Deployment Flood Wall (RDFW) – A flood wall that is temporarily erected along the banks of a river or estuary, or in the path of floodwaters to prevent water from reaching the area behind the structure. After the storm or flood, the structure is removed. This category also includes permanently installed, deployable flood barriers that rise into position during flooding due to the buoyancy of the barrier material and hydrostatic pressure.
3. Shoreline Stabilization
    a. Seawalls/Bulkheads - Structures are often needed along shorelines to provide risk reduction from wave action or to stabilize and retain in situ soil or fill. Vertical structures are classified as either seawalls or bulkheads, according to their function, while protective materials laid on slopes are called revetments (USACE 1995). A bulkhead is primarily intended to retain or prevent sliding of the land, while reducing the impact of wave action is of secondary importance. Seawalls, on the other hand, are typically more massive structures whose primary purpose is interception of waves and reduction of wave-induced overtopping and flooding of the land structures behind. Note that under this definition seawalls do not include structures with the principal function of reducing risk to low-lying coastal areas. In those cases a high, impermeable, armored structure known as a sea dike is typically required to prevent coastal flooding (USACE 2002).
    b. Revetments - Onshore structures with the principal function of reducing the impacts to the shoreline from erosion and typically consist of a cladding of stone, concrete, or

asphalt to armor sloping natural shoreline profiles (USACE 2002). They consist of an armor layer, filter layer(s), and toe protection.

4. Natural and Nature-Based Features (NNBF) – Per the NACCS, natural features are created and evolve over time through the action of physical, biological, geologic, and chemical processes operating in nature. Nature-based features are those that may mimic characteristics of natural features, but are created by human design, engineering, and construction to provide specific services such as coastal risk reduction. Nature-based features are acted upon by the same physical, biological, geologic, and chemical processes operating in nature, and as a result, generally must be maintained to reliably provide the expected level of service.
    a. Beach Restoration - Beach restoration, also commonly referred to as beach nourishment or beachfill, typically includes the placement of sand fill to either replace eroded sand or increase the size (width and/or height) of an existing beach, including both the beach berm and dunes. Material similar to the native grain size is artificially placed on the eroded part of the beach.
    b. Living Shoreline - Living shorelines represent a shoreline management option that combines various erosion control methods and/or structures while restoring or preserving natural shoreline vegetation communities and enhancing resiliency. Typically, creation of a living shoreline involves the placement of sand, planting marsh flora; and, if necessary, construction of a rock structure on the shoreline or in the near shore (VIMS 2013b). Living shorelines can use a variety of stabilization and habitat restoration techniques that span several habitat zones and use a variety of materials. Specifically, living shorelines can be used on upland buffer/back shore zones, coastal wetlands and beach strand zones, and the subtidal water zone. Living shoreline materials may include sand fill, clean dredged material, tree and grass roots, marsh grasses, mangroves, natural fiber logs, rock, concrete, filter fabric, seagrasses, etc. (Maryland DNR, 2007).
    c. Overwash Fans - Overwash is the landward transport of beach sediments across a coastal barrier feature. Large coastal storms and their associated high winds, waves, and tides can result in overwash of the beach and dune system. During storm conditions, elevated storm tides and high waves may erode beaches and dunes, and the eroded sand can be carried landward by surging water. The sand and water may wash over or break through the dunes, and spill out onto the landward side of the barrier island. This deposit is usually fan-shaped and therefore is known as an overwash fan (or washover) fan (Delaware Sea Grant, 2009). Engineered overwash fans would increase overall barrier island stability and back bay coastal storm risk management capacity by increasing its width/volume and providing a substrate suitable for wetland growth.
    d. Reefs - Artificial reefs enhance the resilience of coastal areas by reducing the degradation and shoreline erosion that would occur during a storm event.
    e. Wetlands - Coastal wetlands may contribute to wave attenuation and sediment stabilization. The dense vegetation and shallow waters within wetlands can slow the advance of storm surge somewhat and slightly reduce the surge landward of the

wetland or slow its arrival time (Wamsley *et al.* 2010). Wetlands can also dissipate wave energy.

5. Storm Surge Barriers - Storm surge barriers reduce risk to estuaries against storm surge flooding and waves. In most cases the barrier consists of a series of movable gates that stay open under normal conditions to let the flow pass but are closed when storm surges are expected to exceed a certain level.
6. Groins - Groins are structures that extend perpendicularly from the shoreline. They are usually built to stabilize a stretch of natural or artificially nourished beach against erosion that is due primarily to a net longshore loss of beach material. The effect of a single groin is accretion of beach material on the updrift side and erosion on the downdrift side; both effects extend some distance from the structure.
7. Breakwaters - In general, breakwaters are structures designed to reduce risk to shorelines, beaches, or harbor areas from the impacts of wave action thereby reducing shoreline erosion and storm damage. Breakwaters are usually built as rubble-mound structures (USACE 2002) though they can be constructed from a variety of materials such as geotextile and concrete. The dissipation of wave energy allows sand to be deposited behind the breakwater. This accretion further reduces risk the shoreline and may also widen the beach.

Non-Structural Measures

1. Acquisition and Relocation – Buildings may be removed from vulnerable areas by acquisition (buy-out), subsequent demolition, and relocation of the residents. Often considered a drastic approach to storm damage reduction, property acquisition and structure removal are usually associated with frequently damaged structures. Implementation of other measures may be effective but if a structure is subject to repeated storm damage, this measure may represent the best alternative to eliminating risks to the property and residents.
2. Building Retrofit - Building retrofit measures include dry flood proofing or elevation of a structure. Dry floodproofing involves sealing flood prone structures from water with door and window barriers, small scale rapid deployable floodwalls, ring walls, or sealants. Elevation of structures is usually limited to residential structures or small commercial buildings. Whether a structure may be elevated depends on a number of factors including the foundation type, wall type, size of the structure, condition, etc.
3. Enhanced Flood Warning & Evacuation Planning - Flood warning systems and evacuation planning are applicable to vulnerable areas. Despite improved tracking and forecasting techniques, the uncertainty associated with the size of a storm, the path, or its duration necessitate that warnings be issued as early as possible. Evacuation planning is imperative for areas with limited access, such as barrier islands, high density housing areas, elderly population centers, cultural resources, and areas with limited transportation options.
4. Flood Insurance - Residents that are uncertain about reducing risk to their belongings may be prone to attempt to remain in vulnerable areas during storm events, creating further risk. Knowing that personal property is insured, residents may be more comfortable with evacuating vulnerable areas at the approach of a storm.

As previously referenced, the original 26 problem areas were subjected to Cycle 1 screening to confirm that CSRM was the primary problem and that the use of dredged material was potentially feasible in a management measure for the problem area. The PDT formulated structural and non-structural measures for each problem area. In Cycle 2, the measures were compared against the planning objectives to see if they were in line with the study purpose.

The NACCS criteria for assessing each measure's Storm Damage Reduction Function was applied to determine if a measure met Objective 1. The Storm Damage Reduction Function was based on the measure's ability to mitigate flooding, attenuate wave action and reduce shoreline erosion. Per the NACCS, if the selected measure received at least a "medium" ranking for one of these three criteria and dredged material was feasible to use for implementation of the measure, the PDT determined that the measure met Objective 1.

The NACCS criteria for assessing each measure's resilience was applied to determine if a measure met Objective 2. Specifically, if the NACCS ranking indicated a "medium" or higher "adaptive capacity" for a selected measure, the PDT determined that the measure increased the shoreline resilience and met Objective 2. Adaptive capacity is defined as a measure's ability to adjust through natural processes, operation and maintenance activities, or adaptive management, to preserve the measure's function.

In order for measures to be carried forward for further analysis, they must have met one of the two study objectives.

Table 4 – Objectives/Measures Matrix

Management Measure	Structural	Non-Structural	Objective 1: Reduce flood-related impacts to people, property and infrastructure along and adjacent to the Delaware coastline from 2021 to 2071, via the beneficial use of dredged material.	Objective 2: Increase the resiliency of coastal Delaware, specifically along the Delaware River/Bay and Delaware Inland Bay shoreline, via the beneficial use of dredged material.	Management Measure Carried Forward for Further Analysis (Y/N)?
Levees and Dikes	X		Y	N	Y
Flood Wall 1. Permanent 2. RDFW	X		1. Permanent - N 2. RDFW - N	1. Permanent - N 2. RDFW - N	N
Shoreline Stabilization 1. Seawalls/Bulkheads 2. Revetments	X		1. Seawalls/Bulkheads - N 2. Revetments – N	1. Seawalls/Bulkheads - N 2. Revetments - N	N
Storm Surge Barriers	X		N	N	N
Beach Restoration 1. Dune & Berm 2. Dune 3. Berm 4. Perched Beach 5. Geotubes	X		Y	Y	Y
Groins	X		N	Y	Y
Breakwaters	X		N	Y	Y
Overwash Fan	X		N	Y	Y
Living Shoreline	X		N	Y	Y
Reef	X		N	Y	Y
Wetland	X		N	Y	Y
Acquisition and Relocation		X	N	N	N
Building Retrofit		X	N	N	N
Enhanced Flood Warning & Evacuation Planning		X	N	N	N
Flood Insurance		X	N	N	N

Structural Measures

During the Cycle 2 screening, beach restoration met both study objectives; therefore, beach restoration measures were carried forward for further analysis. Per the NACCS, a well-designed beach restoration project reduces risk to the structures and population behind it by providing a buffer against the increased wave energy and storm surge generated during a coastal storm event. While it can function well as a stand-alone measure, beach restoration can be used in combination with other structural shoreline risk management measures, such as groins, breakwaters and reefs, in highly erosional areas. Groins, breakwaters and reefs were also carried forward for further analysis because they potentially enhance the functionality of beach restoration measures, thereby creating a more resilient shoreline.

Three additional structural measures (living shorelines, overwash fans and wetlands) were also carried forward for further analysis because they met Objective 2. While these measures did not meet Objective 1, they did exhibit enough adaptive capacity to be considered resilient measures that meet Objective 2. Specifically, living shoreline creation involves the placement of sand, planting marsh flora, and if necessary, construction of a rock structure on the shoreline or in the near shore (VIMS 2013b). Per the NACCS, living shoreline materials may include sand fill, clean dredged material, tree and grass roots, marsh grasses, mangroves, natural fiber logs, concrete, filter fabric, seagrasses, etc. (Maryland DNR, 2007). They are generally applicable to relatively low current and wave energy environments in estuaries, rivers and creeks.

Engineered overwash fans would increase shoreline stability and resilience by increasing the shoreline width/volume and providing a substrate suitable for wetland/plant growth. Essentially, the engineered overwash fan would mimic the beneficial effects of natural overwash without the damages typically associated with overwash. Sandy sediment for the overwash fan could come from borrow sources and/or dredged material and be applied in a “thin layering” technique to mitigate for wetland erosion and the impacts of SLC on wetlands.

Wetlands can increase shoreline resiliency by contributing to coastal CSRM wave attenuation and sediment stabilization. The magnitude of these effects depends on the specific characteristics of the wetlands, including the type of vegetation, its rigidity and structure, as well as the extent of the wetlands and their position relative to the storm track. Sandy sediment is preferred in wetlands so that plant roots develop more effectively; however, wetlands can contain a higher percentage of fines than the beach region in front of them.

According to the NACCS, levees and dikes contribute a low level of wave attenuation and little or no erosion reduction; however, the PDT believes they are a potentially effective method of CSRM in portions of the study area with more limited wave and erosion processes.

Floodwall(s), shoreline stabilization and storm surge barriers were not carried forward for further analysis because they did not meet the study objectives.

Non-Structural Measures

The non-structural measures were screened out because they did not meet the two study objectives. While acquisition had a high storm damage reduction function and adaptive capacity, it did not involve the use of dredged material. The same is true for the other three non-structural measures; therefore, they were not carried forward for further analysis.

3.3 PLAN FORMULATION

During the development of the array of alternatives, the management measures that passed Cycle 2 screening were applied to the remaining 12 CSRM problem areas that passed Cycle 1 screening, as indicated on Table 5 below. Measures that were not beneficial use of dredged material, but had the potential to augment or to be considered as a scale to work with beneficial use were included in the formulation process (groins, breakwaters, reefs, etc.).

Table 5 – Measure Applicability by Problem Area

Problem Area	Beach Restoration	Groins	Breakwaters	Reef	Living Shoreline	Overwash Fans	Wetlands	Levees/Dikes	Shoreline Stabilization	Storm Surge Barrier
New Castle								X		
Augustine Beach	X	X	X		X		X			
Bay View Beach	X	X	X							
Woodland Beach	X	X	X							
Pickering Beach	X	X	X							
Kitts Hummock	X	X	X							
Bowers Beach	X	X	X							
Big Stone Beach	X	X	X							
South Bowers Beach	X	X	X							
Slaughter Beach	X	X	X							
Prime Hook Beach	X	X	X							
Lewes Beach	X	X	X							

In the northern planning reach, five action alternatives were formulated based on the identified problems and shoreline characteristics of each problem area. In New Castle, a Levee/Dike Plan was formulated to improve the CSRM provided by the existing New Castle levees/dikes (Red Lion Creek Dike, Army Creek Dike, Gambacorta Marsh Dike, Broad Marsh Dike and Buttonwood Dike) and to potentially close gaps between the levees/dikes. The other four action alternatives included various combinations and permutations of beach restoration, including stand-alone beach restoration, beach restoration with groin(s), beach restoration with breakwater and beach restoration with groin(s), breakwater, living shoreline and wetland. In the three other northern planning reach sites (Augustine Beach, Bay View Beach and Woodland Beach), stand-alone beach restoration was formulated at all three locations. Beach restoration with groin(s) and beach restoration with breakwater were also formulated at Bay View Beach and Woodland Beach. Based on the existing presence of an expansive marsh/wetland environment along the Augustine Beach shoreline, beach restoration with groin(s), breakwater, living shoreline and wetland was formulated.

In the southern planning reach, three action alternatives were formulated based on the identified problems and shoreline characteristics of each problem area (Pickering Beach, Kitts Hummock, Bowers Beach, South Bowers Beach, Big Stone Beach, Slaughter Beach, Prime Hook Beach and Lewes Beach). At each of the southern reach problem areas, the following alternatives were formulated: stand-alone beach restoration, beach restoration with groin(s) and beach restoration with breakwater.

The final array of alternative plans for the entire study area included the following:

1. No Action Plan
2. Levee/Dike Plan
3. Beach Restoration Plan
4. Beach Restoration with Groin(s) Plan
5. Beach Restoration with Breakwater Plan
6. Beach Restoration with Groin(s), Breakwater, Living Shoreline & Wetland Plan

3.4 FINAL ARRAY OF ALTERNATIVES EVALUATION AND COMPARISON

After the final array of alternatives was formulated, the first task was to forecast the most likely with-project condition expected under each alternative plan. The criteria used to evaluate the alternative plans included: contributions to the Federal objective and the study planning objectives, compliance with environmental protection requirements, and the Principles & Guidelines' (P&G's) four evaluation criteria (completeness, effectiveness, efficiency and acceptability). The second task was to compare each with-project condition to the without-project condition and document the differences between the two. The third task was to characterize the beneficial and adverse effects of magnitude, location, timing and duration. The fourth task was to identify the plans that will be further considered in the planning process, based on a comparison of the adverse and beneficial effects and the evaluation criteria. The System of Accounts (National Economic Development, Environmental Quality, Regional Economic Development and Other Social Effects) was used to facilitate the evaluation and display of effects of alternative plans.

National Economic Development (NED) – Contributions to the National Economic Development (NED) Account (increases in the net value of the national output of goods and services, expressed in monetary units) through the reduction in wave, erosion and inundation damages were measured with the following considerations: project cost, annual cost, total annual benefits, annual net benefits and benefit to cost ratio.

Regional Economic Development (RED) – The RED account registers changes in the distribution of regional economic activity that result from each alternative plan. Two measures of the effects of the plan on regional economies are used in the account: regional income and regional employment.

Environmental Quality (EQ) – Beneficial effects in the EQ account are favorable changes in the ecological, aesthetic, and cultural attributes of natural and cultural resources. Adverse effects in the EQ account are unfavorable changes in the ecological, aesthetic, and cultural attributes of natural and cultural resources.

Alternatives that propose to utilize dredged material to alleviate flooding and shoreline erosion have potential CSRM benefits and the potential to offer ancillary benefits to natural resources. The PDT believes the net environmental impact of alternatives that consist of different combinations of the above-referenced measures will potentially have a net positive impact on the environment and improve the resiliency of coastal communities and ecosystems.

Other Social Effects (OSE) – The OSE account is a means of displaying and integrating into water resource planning information on alternative plan effects from perspectives that are not reflected in the other three accounts. The categories of effects in the OSE account include the following: Urban and community impacts; life, health, and safety factors; displacement; long-term productivity; and energy requirements and energy conservation.

Further detail regarding the System of Accounts analysis is detailed on the table below:

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Table 6 - System of Accounts Analysis

National Economic Development (NED)					
	Levee/Dike Plan	Beach Restoration Plan	Beach Restoration with Groin(s) Plan	Beach Restoration with Breakwater Plan	Beach Restoration with Groin(s), Breakwater, Living Shoreline & Wetland Plan
Cost Effectiveness	Value Engineering (VE) Study indicated high cost of levee construction with minimal increase in benefits at CSRM problem area (New Castle).	The benefits of beach restoration at the southern reach system (Pickering Beach, Kitts Hummock, Bowers Beach, South Bowers Beach, Big Stone Beach, Slaughter Beach, Prime Hook Beach and Lewes Beach) are greater than the associated dredged material placement costs. In addition, the benefits at each placement location are greater than the associated dredged material placement costs for all locations except for Big Stone Beach.	Groins can modify longshore sediment transport; however, they provide minimal direct protection from storm surge. Available data indicates that added CSRM benefits from groins are typically less than their added cost.	While breakwaters reduce wave energy and coastal erosion, they have minimal impact on inundation. Also, they are expensive to build as they require a large volume of stone.	Analysis indicated that the additional features, such as wetlands or living shorelines, would provide minimal additional CSRM compared to the added cost.
Federal Tax Revenues	Not likely to have significant impact.	Not likely to have significant impact.	Not likely to have significant impact.	Not likely to have significant impact.	Not likely to have significant impact.
Environmental Quality (EQ)					
Physiography & Geology	Not evaluated in detail due to lack of NED benefits and lack of appropriate material in dredged sediment to support levee/dike construction.	Beach restoration will help restore the natural physiography and habitat. Also, beach nourishment using compatible grain size materials does not adversely impact the geology of the study area.	The construction of a hardened structure, such as a breakwater or groin would not impact the area geology, but would alter the physiography of the beach.	The construction of a hardened structure, such as a breakwater or groin would not impact the area geology, but would alter the physiography of the beach.	The construction of a hardened structure, such as a breakwater or groin would not impact the area geology, but would alter the physiography of the beach.
Sediment Quality	Not evaluated in detail due to lack of NED benefits and lack of appropriate material in dredged sediment to support levee/dike construction.	Beach restoration will improve the sediment deficit in the Delaware Estuary and improve the overall health of the estuary.	The construction of a hardened structure, such as a breakwater or groin is not advised by the natural resources agencies as it impedes the natural transfer of sediments within the beach/intertidal habitat interface.	The construction of a hardened structure, such as a breakwater or groin is not advised by the natural resources agencies as it impedes the natural transfer of sediments within the beach/intertidal habitat interface.	The construction of a hardened structure, such as a breakwater or groin is not advised by the natural resources agencies as it impedes the natural transfer of sediments within the beach/intertidal habitat interface.
Vegetation & Wetlands	Not evaluated in detail due to lack of NED benefits and lack of appropriate material in dredged sediment to support levee/dike construction.	Beach restoration will enhance protection of the adjacent wetlands and enable dune vegetation to establish with resultant higher berm and dune elevations.	The construction of a hardened structure, such as a breakwater or groin is not advised by the natural resources agencies as it impedes the natural transfer of sediments within the beach/intertidal habitat interface.	The construction of a hardened structure, such as a breakwater or groin is not advised by the natural resources agencies as it impedes the natural transfer of sediments within the beach/intertidal habitat interface.	The construction of a hardened structure, such as a breakwater or groin is not advised by the natural resources agencies as it impedes the natural transfer of sediments within the beach/intertidal habitat interface.
Planktonic & Benthic Organisms	Not evaluated in detail due to lack of NED benefits and lack of appropriate material in dredged sediment to support levee/dike construction.	Beach restoration will involve the pumping of dredged material onto the beach above the mean high water line, thereby minimizing impacts to intertidal infaunal organisms. However, despite the resiliency of intertidal benthic fauna, the initial beachfill will result in some mortalities of existing benthic organisms.	The construction of a hardened structure, such as a breakwater or groin would permanently impact intertidal and beach habitat by obstructing the hydrodynamic connection between the two.	The construction of a hardened structure, such as a breakwater or groin would permanently impact intertidal and beach habitat by obstructing the hydrodynamic connection between the two.	The construction of a hardened structure, such as a breakwater or groin would permanently impact intertidal and beach habitat by obstructing the hydrodynamic connection between the two.
Fish	Not evaluated in detail due to lack of NED benefits and lack of appropriate material in dredged sediment to support levee/dike construction.	Beach restoration may temporarily adversely impact larval and juvenile fish by elevating turbidity levels within the nearshore zone. Beach restoration will not disrupt the natural shoreline transition zone from intertidal to beach berm and will have minimal to no impact on adult	The construction of a hardened structure, such as a breakwater or groin would permanently impact intertidal and beach habitat by obstructing the hydrodynamic	The construction of a hardened structure, such as a breakwater or groin would permanently impact intertidal and beach habitat by obstructing the hydrodynamic	The construction of a hardened structure, such as a breakwater or groin would permanently impact intertidal and beach habitat by obstructing the hydrodynamic

		fish that can leave the impact area during construction.	connection between the two.	connection between the two.	connection between the two.
Essential Fish Habitat	Not evaluated in detail due to lack of NED benefits and lack of appropriate material in dredged sediment to support levee/dike construction.	Dredging within the Main Channel has the potential to impact EFH several ways: direct entrainment of eggs and larvae, the creation of higher suspended sediment levels in the water column, reduced feeding success for site-feeding fish and reduced water oxygen levels. All of these impacts are temporary in nature, occurring during and briefly after the actual dredging period. Substrate conditions can often return to similar preconstruction conditions and the benthic community recovers through recolonization. With beach restoration via dredged material, the slurry of dredged material and water pumped onto the beach typically results in an increase in localized turbidity; however, the impacts of beach nourishment on turbidity plumes and elevated suspended solids tend to drop off rapidly seaward of the sand placement operation. Other studies support this finding that turbidity plumes and elevated TSS levels are typically limited to a narrow area of the swash zone downcurrent of the discharge pipe (Burlas *et al*., 2001). Fish eggs and larvae are the most vulnerable to increased sediment in the water column and are subject to burial and suffocation. Juvenile fish and adults are capable of avoiding sediment plumes. Increased turbidity due to placement operations will temporarily affect fish foraging behavior and concentrations of food sources are expected to return to the nearshore zone once placement operations cease due to the dynamic nature of nearshore benthic communities (Burlas *et al*., 2001). Turbidity impacts are anticipated to be minimized by the placement of the dredge pipe above the mean high water line during pump-out and development of the raised beach berm moving along the shoreline. Most shallow water coastal species will leave the area of disturbance at the immediate placement site.	The construction of a hardened structure, such as a breakwater or groin would permanently impact intertidal and beach habitat by obstructing the hydrodynamic connection between the two.	The construction of a hardened structure, such as a breakwater or groin would permanently impact intertidal and beach habitat by obstructing the hydrodynamic connection between the two.	The construction of a hardened structure, such as a breakwater or groin would permanently impact intertidal and beach habitat by obstructing the hydrodynamic connection between the two.
Wildlife	Not evaluated in detail due to lack of NED benefits and lack of appropriate material in dredged sediment to support levee/dike construction.	Beach restoration will provide added protection to interior shrub and forested habitats.	Beach restoration will provide added protection to interior shrub and forested habitats.	Beach restoration will provide added protection to interior shrub and forested habitats.	Beach restoration will provide added protection to interior shrub and forested habitats.
Threatened & Endangered Species	Not evaluated in detail due to lack of NED benefits and lack of appropriate material in dredged sediment to support levee/dike construction.	Beach restoration can provide positive benefits to listed species by restoring preferred beach habitat.	Beach restoration can provide positive benefits to listed species by restoring preferred beach habitat; however, the construction of a hardened structure, such as a	Beach restoration can provide positive benefits to listed species by restoring preferred beach habitat; however, the construction of a hardened structure, such as a	Beach restoration can provide positive benefits to listed species by restoring preferred beach habitat; however, the construction of a hardened structure, such as a

			breakwater or groin would permanently impact intertidal and beach habitat by obstructing the hydrodynamic connection between the two.	breakwater or groin would permanently impact intertidal and beach habitat by obstructing the hydrodynamic connection between the two.	breakwater or groin would permanently impact intertidal and beach habitat by obstructing the hydrodynamic connection between the two.
HTRW	Not evaluated in detail due to lack of NED benefits and lack of appropriate material in dredged sediment to support levee/dike construction.	Dredging within Reach E of the Main Channel and beach placement activities are not expected to result in the identification and/or disturbance of HTRW, as it has been found that coarse-grained material like sand in a high-energy environment is unlikely to be contaminated with HTRW.	Dredging within Reach E of the Main Channel and beach placement activities are not expected to result in the identification and/or disturbance of HTRW, as it has been found that coarse-grained material like sand in a high-energy environment is unlikely to be contaminated with HTRW.	Dredging within Reach E of the Main Channel and beach placement activities are not expected to result in the identification and/or disturbance of HTRW, as it has been found that coarse-grained material like sand in a high-energy environment is unlikely to be contaminated with HTRW.	Dredging within Reach E of the Main Channel and beach placement activities are not expected to result in the identification and/or disturbance of HTRW, as it has been found that coarse-grained material like sand in a high-energy environment is unlikely to be contaminated with HTRW.
Air Quality	Not evaluated in detail due to lack of NED benefits and lack of appropriate material in dredged sediment to support levee/dike construction.	Emissions of criteria pollutants, greenhouse gases, and other hazardous air pollutants would result from operation of the dredge pumps and coupled pump-out equipment, dredge propulsion engines, tugs, barges, and support vessels used in the placement and relocation of mooring buoys. In addition, air emissions would result from bulldozers, trucks, and other heavy equipment used in the construction of the berm and dune. Carbon monoxide and particulate emissions at the project site, during construction, may be considered offensive; but are generally not considered far-reaching. Exhaust from the construction equipment will have an effect on the immediate air quality around the construction operation but should not impact areas away from the construction area. These emissions will subside upon cessation of operation of heavy equipment.	Emissions of criteria pollutants, greenhouse gases, and other hazardous air pollutants would result from operation of the dredge pumps and coupled pump-out equipment, dredge propulsion engines, tugs, barges, and support vessels used in the placement and relocation of mooring buoys. In addition, air emissions would result from bulldozers, trucks, and other heavy equipment used in the construction of the berm and dune. Carbon monoxide and particulate emissions at the project site, during construction, may be considered offensive; but are generally not considered far-reaching. Exhaust from the construction equipment will have an effect on the immediate air quality around the construction operation but should not impact areas away from the construction area. These emissions will subside upon cessation of operation of heavy equipment.	Emissions of criteria pollutants, greenhouse gases, and other hazardous air pollutants would result from operation of the dredge pumps and coupled pump-out equipment, dredge propulsion engines, tugs, barges, and support vessels used in the placement and relocation of mooring buoys. In addition, air emissions would result from bulldozers, trucks, and other heavy equipment used in the construction of the berm and dune. Carbon monoxide and particulate emissions at the project site, during construction, may be considered offensive; but are generally not considered far-reaching. Exhaust from the construction equipment will have an effect on the immediate air quality around the construction operation but should not impact areas away from the construction area. These emissions will subside upon cessation of operation of heavy equipment.	Emissions of criteria pollutants, greenhouse gases, and other hazardous air pollutants would result from operation of the dredge pumps and coupled pump-out equipment, dredge propulsion engines, tugs, barges, and support vessels used in the placement and relocation of mooring buoys. In addition, air emissions would result from bulldozers, trucks, and other heavy equipment used in the construction of the berm and dune. Carbon monoxide and particulate emissions at the project site, during construction, may be considered offensive; but are generally not considered far-reaching. Exhaust from the construction equipment will have an effect on the immediate air quality around the construction operation but should not impact areas away from the construction area. These emissions will subside upon cessation of operation of heavy equipment.
Noise	Not evaluated in detail due to lack of NED benefits and lack of appropriate material in dredged sediment to support levee/dike construction.	Noise has also been documented to influence fish behavior (Thomsen *et al*., 2009). Fish detect and respond to sound utilizing cues to hunt for prey, avoid predators and for social interaction (LFR, 2004). It is likely that at close distances to the dredge vessel, the noise may	Noise has also been documented to influence fish behavior (Thomsen *et al*., 2009). Fish detect and respond to sound utilizing cues to hunt for prey,	Noise has also been documented to influence fish behavior (Thomsen *et al*., 2009). Fish detect and respond to sound utilizing cues to hunt for prey, avoid predators and for social	Noise has also been documented to influence fish behavior (Thomsen *et al*., 2009). Fish detect and respond to sound utilizing cues to hunt for prey, avoid predators and

		produce a behavioral response in mobile marine species, with individuals moving away from the disturbance, thereby reducing the risk of physical or physiological damage. Accordingly, any resulting effects would be negligible. It is unlikely that underwater sound from conventional dredging operations can cause physical injury to fish species (Reine *et al*., 2012).	avoid predators and for social interaction (LFR, 2004). It is likely that at close distances to the dredge vessel, the noise may produce a behavioral response in mobile marine species, with individuals moving away from the disturbance, thereby reducing the risk of physical or physiological damage. Accordingly, any resulting effects would be negligible. It is unlikely that underwater sound from conventional dredging operations can cause physical injury to fish species (Reine *et al*., 2012).	interaction (LFR, 2004). It is likely that at close distances to the dredge vessel, the noise may produce a behavioral response in mobile marine species, with individuals moving away from the disturbance, thereby reducing the risk of physical or physiological damage. Accordingly, any resulting effects would be negligible. It is unlikely that underwater sound from conventional dredging operations can cause physical injury to fish species (Reine *et al*., 2012).	for social interaction (LFR, 2004). It is likely that at close distances to the dredge vessel, the noise may produce a behavioral response in mobile marine species, with individuals moving away from the disturbance, thereby reducing the risk of physical or physiological damage. Accordingly, any resulting effects would be negligible. It is unlikely that underwater sound from conventional dredging operations can cause physical injury to fish species (Reine *et al*., 2012).
Other Social Effects (OSE)					
Cultural Resources	Not evaluated in detail due to lack of NED benefits and lack of appropriate material in dredged sediment to support levee/dike construction.	Those areas, specifically Woodland Beach (historic hotel site), Big Stone Beach (Lighthouse) and Lewes Beach (shipwreck) with potentially eligible historic properties can be successfully avoided during construction with the use of buffer areas.	Those areas, specifically Woodland Beach (historic hotel site), Big Stone Beach (Lighthouse) and Lewes Beach (shipwreck) with potentially eligible historic properties can be successfully avoided during construction with the use of buffer areas.	Those areas, specifically Woodland Beach (historic hotel site), Big Stone Beach (Lighthouse) and Lewes Beach (shipwreck) with potentially eligible historic properties can be successfully avoided during construction with the use of buffer areas.	Those areas, specifically Woodland Beach (historic hotel site), Big Stone Beach (Lighthouse) and Lewes Beach (shipwreck) with potentially eligible historic properties can be successfully avoided during construction with the use of buffer areas.
Environmental Justice	Not evaluated in detail due to lack of NED benefits and lack of appropriate material in dredged sediment to support levee/dike construction.	Beach restoration is not anticipated to result in any significant or negative human health or safety impacts. Also, it will not have a disproportionately high adverse effect on minority or low income populations and is in compliance with EO 12898.	Beach restoration is not anticipated to result in any significant or negative human health or safety impacts. Also, it will not have a disproportionately high adverse effect on minority or low income populations and is in compliance with EO 12898.	Beach restoration is not anticipated to result in any significant or negative human health or safety impacts. Also, it will not have a disproportionately high adverse effect on minority or low income populations and is in compliance with EO 12898.	Beach restoration is not anticipated to result in any significant or negative human health or safety impacts. Also, it will not have a disproportionately high adverse effect on minority or low income populations and is in compliance with EO 12898.
Regional Economic Development (RED)					
Local Economy	Not evaluated in detail due to lack of NED benefits and lack of appropriate material in dredged sediment to support levee/dike construction.	Beach restoration will reduce risks to homes and agricultural land.	Beach restoration will reduce risks to homes and agricultural land.	Beach restoration will reduce risks to homes and agricultural land.	Beach restoration will reduce risks to homes and agricultural land.
Social Structures	Not evaluated in detail due to lack of NED benefits and lack of appropriate material in dredged sediment to support levee/dike construction.	Beach restoration will enhance ecosystem services to humans by providing erosion control, water quality enhancement, storm risk management and habitat provision for wildlife and recreation.	Beach restoration will enhance ecosystem services to humans by providing erosion control, water quality enhancement, storm risk management and habitat provision for wildlife and recreation.	Beach restoration will enhance ecosystem services to humans by providing erosion control, water quality enhancement, storm risk management and habitat provision for wildlife and recreation.	Beach restoration will enhance ecosystem services to humans by providing erosion control, water quality enhancement, storm risk management and habitat provision for wildlife and recreation.

Quality of Life	Not evaluated in detail due to lack of NED benefits and lack of appropriate material in dredged sediment to support levee/dike construction.	Beach restoration will enhance ecosystem services to humans by providing erosion control, water quality enhancement, storm risk management and habitat provision for wildlife and recreation.	Beach restoration will enhance ecosystem services to humans by providing erosion control, water quality enhancement, storm risk management and habitat provision for wildlife and recreation.	Beach restoration will enhance ecosystem services to humans by providing erosion control, water quality enhancement, storm risk management and habitat provision for wildlife and recreation.	Beach restoration will enhance ecosystem services to humans by providing erosion control, water quality enhancement, storm risk management and habitat provision for wildlife and recreation.

As previously referenced, the alternatives were evaluated in two defined planning reaches within the Delaware River/Bay system. The "northern reach" is north of the river/bay boundary (Liston Point, DE), while the "southern reach" extends south from the river/bay boundary to the mouth of the Delaware Bay. The northern reach includes DRBC Zone 5, while the southern reach includes DRBC Zone 6.

Northern Reach

The Levee/Dike Plan was formulated for the New Castle problem area. Regarding New Castle (D2), a Value Engineering (VE) study was conducted to evaluate the viability of applying the levee/dike alternative to this area. The VE team consisted of the following technical disciplines: civil engineering, geotechnical engineering, hydrology and hydraulic engineering, cost engineering and planning. The D2 Levee/Dike Plan was measured against the P&G's evaluation criteria and determined to have low efficiency and acceptability, and medium effectiveness. The low efficiency rating was based on the following:

- Anticipation of a high cost of levee construction coupled with minimal increase in benefit pool by raising the existing levee(s) from 8 to 12 feet.
- Silt, sand and organic material comprise the bulk of dredged material available for use; however, this material is unsuitable for levee construction without improvement of the dredged material and additional imported impervious fill for the levee core.
- It is unclear whether utilities would need to be relocated. Depending on the utility, relocation can be expensive to very expensive.

The low acceptability rating was the result of:

- USACE does not commonly support the use of dredged material for levee construction.
- New Castle (D2) has historic buildings; therefore, there would likely be a cultural impact.
- The existing levee(s) were repaired in 2014 at a cost of $8M; thus, replacement of them may not be economically efficient.

A medium rating was assigned for the effectiveness because given the pervious nature of the available dredged material, the fill required for levee construction can only be partially supplied by dredged material. Levee core and possibly other sections would need to come from elsewhere, or be improved dredged material (e.g. soil mixing). The specified opportunity of dredged material utilization would not be well addressed, due to limited and/or lack of use of dredged material. Based on the efficiency, acceptability and effectiveness ratings, New Castle (D2) has been screened out from further consideration under this study.

The other 4 action alternatives included various combinations and permutations of beach restoration, including stand-alone beach restoration, beach restoration with groin(s), beach restoration with breakwater and beach restoration with groin(s), breakwater, living shoreline and wetland. However, during alternative comparison and evaluation, the PDT focused TSP development on dune/berm combinations for the stand-alone beach restoration alternative (without groins, breakwaters, wetlands or living shorelines) because preliminary analysis indicated that the additional features, such as wetlands or living shorelines, would provide minimal additional CSRM compared to the added cost. In addition, while breakwaters reduce wave energy and coastal erosion, they have minimal impact on inundation. Also, they are expensive to build as they require a large volume of stone. Groins can modify longshore sediment transport; however, they provide minimal direct protection from storm surge. Available data indicates that added CSRM benefits from groins are typically less than their added cost.

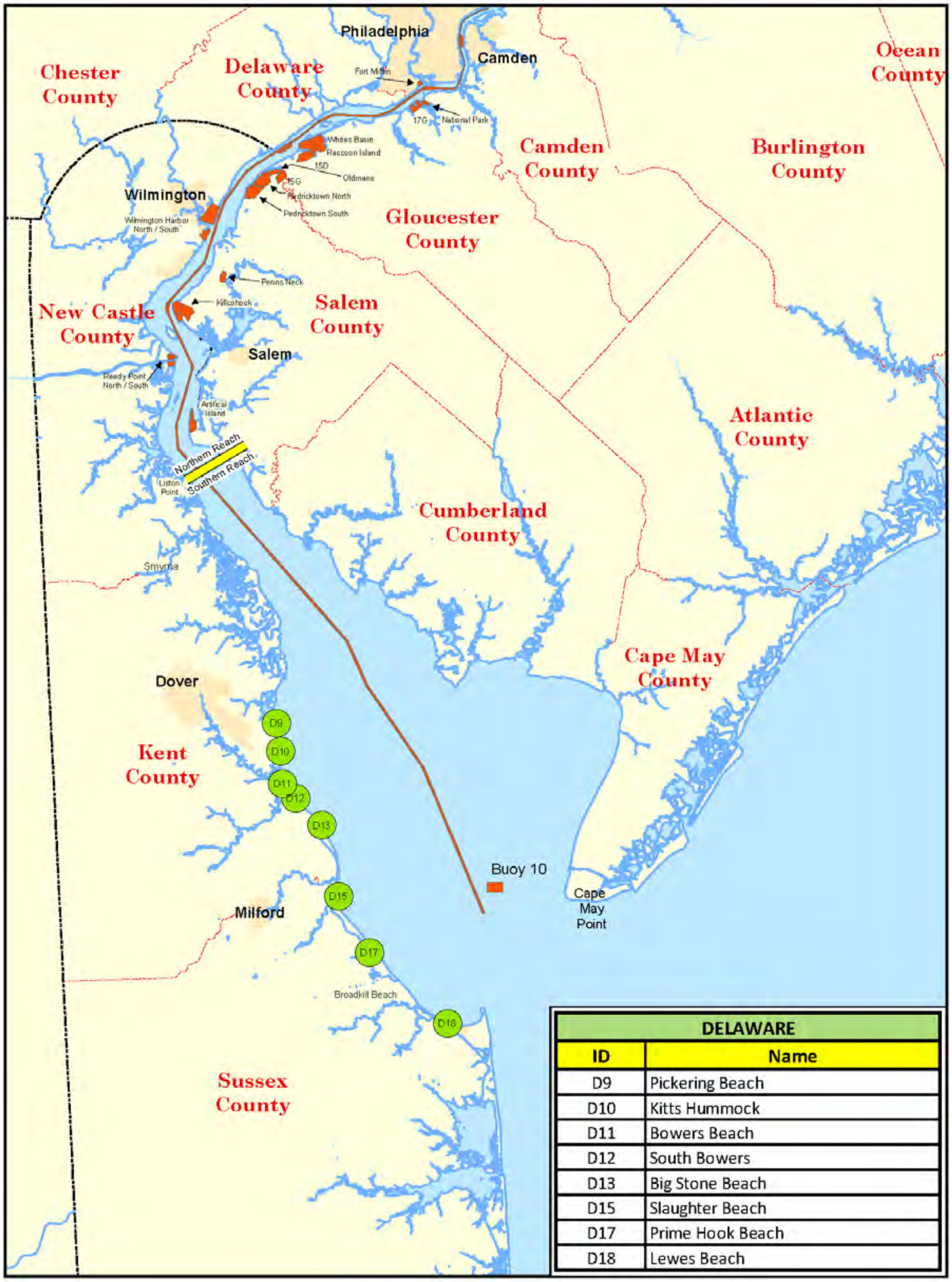
In the northern reach, 2 sites (Augustine Beach (D4), Bay View Beach (D5) were evaluated for beach restoration. Potential dredged material sand sources included the Artificial Island CDF, the Buoy 10 Open Water Disposal Site, and the Miah Maull and Brandywine ranges (Lower Reach E) of the southern end of the Delaware River (Philadelphia to the Sea) navigation channel. Given the relatively small structural inventories at these two communities and the large transportation distance and costs associated with transporting material from Buoy 10 or the Miah Maull/Brandywine ranges, these two sources were eliminated from consideration. The PDT focused on the Artificial Island CDF; however, given the need for a source of homogeneous beach-quality sand at the two communities and the heterogeneous nature of the material in the CDF, the PDT determined that Artificial Island was not a viable source. Therefore, Augustine Beach and Bay View Beach were screened out of the study.

The original intent was to use the two stage-probability curves generated by the NACCS numerical modeling as inputs to the HEC-FDA model to estimate the economic benefits of a beach restoration project in Augustine Beach and Bay View Beach. However, based on the aforementioned screening criteria (including, but not limited to the lack of a viable sand source), these two sites were screened out prior to conducting HEC-FDA modeling. The same site screening logic was applied to Woodland Beach (D6), which is located in the northern portion of the southern reach, because Woodland Beach was affected by similar CSRM damage mechanisms as Augustine Beach and Bay View Beach. Therefore, given the limited structural inventory and lack of a viable sand source, Woodland Beach was also screened out prior to conducting HEC-FDA modeling.

Southern Reach

In the rest of the southern reach of the study area, the PDT focused on a system consisting of eight sites (Pickering Beach (D9), Kitts Hummock (D10), Bowers Beach (D11), South Bowers Beach (D12), Big Stone Beach (D13), Slaughter Beach (D15), Prime Hook Beach (D17) and Lewes Beach (D18)). This area is subject to CSRM damages from inundation, waves and erosion and was consequently analyzed using Beach-fx.

Figure 4 – Planning Reach Delineation



In order to accomplish the economic benefits analysis, Beach-fx required the application of the model SBEACH. SBEACH was used to simulate the without project condition profile response to a larger number of storm conditions in order to build the response database used by Beach-fx in the economic analysis. Based on the summary of without project conditions provided by the SBEACH runs, the range of existing project dimensions along Delaware Bay (Broadkill Beach, Prime Hook National Wildlife Refuge and Lewes Beach) and the assumption that the with-project conditions will include periodic nourishment, with-project design templates were determined for input into Beach-fx. Based on the with-project design templates, estimated sand quantities for initial construction and periodic nourishment were determined within Beach-fx. Dredged material beach restoration source areas were identified and the costs associated with placing material from those source areas were also provided as inputs into Beach-fx.

Geotechnical analysis of available dredged material for beach restoration indicated the following potential source areas with available sand: Lower Reach E (Miah Maull and Brandywine Ranges) of the main Delaware River channel and the Buoy 10 open water disposal site. Lower Reach E and Buoy 10 were identified as potential source areas based on the following criteria:

- The sandy material in Lower Reach E and Buoy 10 has a similar grain size (approximately 0.30 mm) to the proposed beach destinations along the Delaware shoreline.
- Buoy 10 currently contains approximately 750,000 cubic yards of sandy material that could be used for initial construction of the proposed beach destinations.
- Lower Reach E (which was deepened to 45 feet in 2015/2016) is anticipated to have approximately 465,000 cubic yards of dredged material available annually that will need to be removed to maintain the 45 feet depth. The sandy material from the Lower Reach E was used to construct a beach at Broadkill Beach, a Delaware shoreline community adjacent to Prime Hook Beach.
- Prior to the deepening of Lower Reach E, sandy dredged material from this reach was placed in Buoy 10 for disposal.

For the aforementioned southern reach system, the PDT determined that the likely project dredged material source will be Lower Reach E (Miah Maull and Brandywine Ranges) of the main Delaware River channel. The project implementation would consist of a continuous dredging operation with one primary mobilization and continuous incremental preparatory costs to nourish the sites in the system. Project costs were based on the dredge mobilization and dredged material placement costs, as well as associated design and construction management costs. The following assumptions were made for the material placement methodology:

- Generic medium Hopper Dredge (3,800 cubic yard capacity) to excavate and transport dredged material to a mooring barge (unloader)
- Unloader to transfer sand via a pipeline to the CSRM problem area
- Bulldozers to spread the sand along the shoreline of the CSRM problem area

In addition, the costs of transporting material to the DMU project site were compared against the Federal standard practice of dredged material disposal at the least cost, environmentally acceptable disposal location (Buoy 10). The current Federal standard for dredged material disposal from Miah Maull and Brandywine ranges is dredging via a hopper dredge and bottom dumping at Buoy 10. Buoy 10 is approaching full capacity and is in the process of being permitted for additional capacity, which will potentially extend its viability for dredged material disposal for approximately the first 10 years of the proposed project life. Beyond this 10 year threshold, the Federal standard will likely involve the placement of dredged material at Artificial Island CDF, located approximately 40 miles upstream from the dredge location.

For initial construction through the first 10 years of the project life, project costs are based on the difference between placement at the DMU project locations (with-project condition) and placement at Buoy 10 (without-project condition). As referenced above, the without project condition changes after year 10 due to limited capacity at Buoy 10; therefore, the with-project condition is compared against disposal at Artificial Island CDF for years 11 to 50 of the project. As referenced above, the likely project implementation would consist of a continuous dredging operation with one primary mobilization; therefore, the mobilization cost is shared by the sites in the southern reach system. The resulting variables for project mobilization and unit placement costs are outlined in the tables below:

Table 7 – Project Mobilization Cost Summary

Dredged Material Placement Site	Mobilization Cost (Project Years 1-10)	Mobilization Cost (Project Years 11-50)
Pickering Beach	$18,974,284	$15,469,407
Kitts Hummock	$18,974,284	$15,469,407
Bowers Beach	$18,974,284	$15,469,407
South Bowers Beach	$18,974,284	$15,469,407
Big Stone Beach	$18,974,284	$15,469,407
Slaughter Beach	$18,974,284	$15,469,407
Prime Hook Beach	$18,974,284	$15,469,407
Lewes Beach	$18,974,284	$15,469,407

Throughout the 50-year project lifecycle, the dredged material unit placement cost was based on the difference between without project condition (dredged material placement via the Federal standard) unit placement costs and the with project condition (dredged material placement at the proposed DMU project location) unit placement costs. The difference between these unit placement costs were attributed to the DMU project. For example, if costs to place dredged material via the Federal standard for the ongoing Delaware River – Philadelphia to the Sea Navigation Project are $10 per cubic yard, and the costs to transport the same material to a DMU project site for CSRM are $15 per cubic yard, then the cost to the navigation project is $10 per cubic yard and the only cost applied to the DMU project is the additional cost above the Federal standard, $5 per cubic yard. The unit placement costs for each dredged material placement site are summarized in the table below:

Table 8 - Dredged Material Unit Placement Cost

Dredged Material Placement Site	Unit Placement Cost (Project Years 1-10)	Unit Placement Cost (Project Years 11-50)
Pickering Beach	$35.39/cubic yard	$10.96/cubic yard
Kitts Hummock	$32.40/cubic yard	$7.97/cubic yard
Bowers Beach	$30.16/cubic yard	$5.73/cubic yard
South Bowers Beach	$33.14/cubic yard	$8.71/cubic yard
Big Stone Beach	$34.07/cubic yard	$9.65/cubic yard
Slaughter Beach	$30.60/cubic yard	$6.18/cubic yard
Prime Hook Beach	$27.73/cubic yard	$3.30/cubic yard
Lewes Beach	$32.79/cubic yard	$8.36/cubic yard

Note: The cost values in Table 8 cover a 50-year period of analysis with a base year of 2020.

3.5 PLAN SELECTION

The system-wide benefits were compared against the aforementioned project cost to determine the BCR and net benefits of the system. In addition, the project cost was compared against the benefits at each individual dredged material placement location in the system to determine the BCR and net benefits at each placement location. The NED benefit categories included the following: reduction in damage to structures and content, local costs foregone, emergency costs foregone, and incidental recreational benefits. Current results indicate that the benefits of beach restoration at the above-referenced system are greater than the associated dredged material placement costs. In addition, the benefits at each placement location are greater than the associated dredged material placement costs for all locations except for Big Stone Beach.

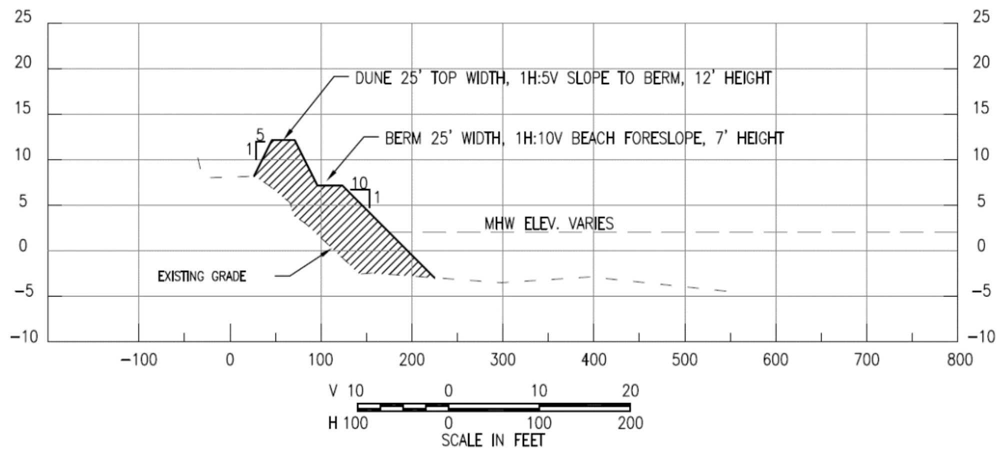
3.6 DESCRIPTION OF THE RECOMMENDED PLAN

3.6.1 Plan Components

The tentatively selected plan (TSP) consists of dune and berm construction at 8 dredged material placement locations in the southern reach of the study area. The 8 dredged material placement locations span approximately 29 miles along the Delaware Bay and include (from north to south): Pickering Beach, Kitts Hummock, Bowers Beach, South Bowers Beach, Big Stone Beach, Slaughter Beach, Prime Hook Beach and Lewes.

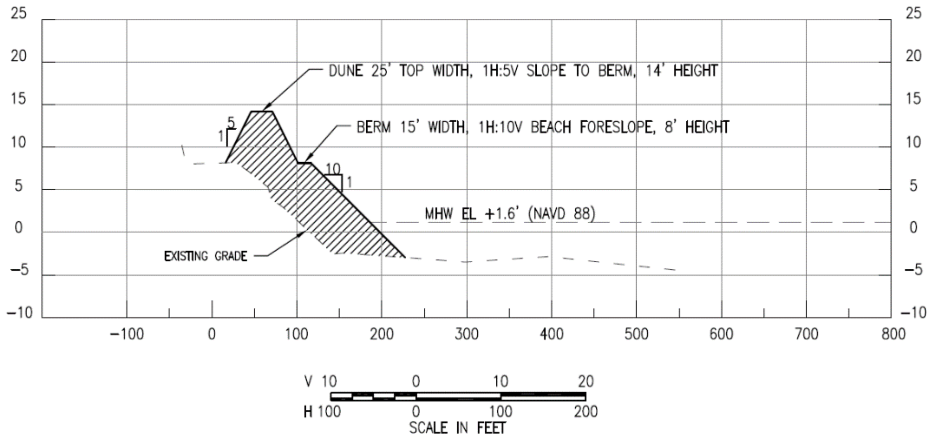
Based on the summary of existing conditions at each site, the range of existing project dimensions along Delaware Bay (Broadkill Beach, Prime Hook National Wildlife Refuge and Lewes), the assumption that the design purpose is to provide storm damage reduction benefits and the assumption that the design will include periodic nourishment, the PDT developed the with-project template. At 7 of the 8 dredged material placement locations, excluding Lewes, the proposed design template features a berm of 25' width at a height of 7' (NAVD 88) with a foreslope of approximately 400' length on a slope of 1V:10H extending bayward to depth of closure of -5.0' (NAVD 88). The berm is topped with a dune whose crest width is 25' at a height of 12' (NAVD 88). The dune transitions both bayward to the berm and landward to existing grade on a slope of 1V:5H., as indicated on Figure 7.

Figure 5 - Dredged Material Placement Locations Design Template (Excluding Lewes)



For Lewes Beach, the design template was intended to expand the linear footprint of an existing authorized project 10,100’ to the southeast. The authorized project consists of a dune and berm extending from Roosevelt Inlet approximately 900 feet southeast with a 500 feet taper. Initial construction included the reconstruction of the adjacent terminal groin for Roosevelt Inlet for the purpose of navigation and the aforementioned beachfill that consisted of a 15’ wide berm (NAVD 88) extending bayward at a slope of 1V:10H above MHW, and a dune with a 25’ crest width with an elevation of 14’ (NAVD 88) for the purpose of coastal storm damage reduction. The Lewes Beach portion of the TSP proposes to utilize the design template of the existing Lewes project in the remaining 10,100’ stretch of the community.

Figure 6 - Dredged Material Placement Locations Design Template (Lewes)



Varying volumes of dredged material are required at each of the 8 placement locations, depending on the length of shoreline to be nourished and the existing beach profile, as summarized on Table 9 below:

Table 9 - Projected Dredged Material Volumes for Initial Construction

Dredged Material Placement Location	**Volume of Dredged Material (Initial Construction)**
Pickering Beach	63,771 cubic yards
Kitts Hummock	158,321 cubic yards
Bowers Beach	117,149 cubic yards
South Bowers Beach	52,935 cubic yards
Big Stone Beach	42,278 cubic yards
Slaughter Beach	246,564 cubic yards
Prime Hook Beach	114,341 cubic yards
Lewes Beach	100,000 cubic yards

Note: Initial construction and associated nourishment volumes may change due to the project optimization process and to ensure consistency with the Coastal Barrier Resources Act (CBRA)

Based on the volume projections for initial construction at each of the 8 placement locations, a total of approximately 900,000 cubic yards of dredged material would be required for initial construction. As referenced in Section 3.4, the proposed source area (Lower Reach E) is anticipated to have approximately 465,000 cubic yards of dredged material available annually that will need to be removed to maintain the 45 feet depth. The anticipated dredging cycle for Lower Reach E is every two years to remove and place 930,000 cubic yards (465,000 x 2) of dredged material. The projected quantity and dredging cycle were based on the feasibility report completed in support of the Delaware River Main Channel Deepening project. Actual dredged material quantities will be verified prior to construction; therefore, the PDT recognizes the possibility that there may be greater and/or lesser quantities available (than currently projected) at the time of construction. If there is less dredged material available than anticipated at the projected date of initial construction (2020), Buoy 10 may serve as a back-up source for initial construction as it contains sand (approximately 750,000 cubic yards) previously dredged from

Lower Reach E during operation and maintenance of the Delaware River, Philadelphia to the Sea navigation project. The PDT recognizes that the use of Buoy 10 as a back-up source would necessitate a benthic habitat assessment and ultimately a Supplemental Environmental Assessment (EA).

A 4-year periodic nourishment cycle is anticipated to maintain optimal coastal storm risk management. This nourishment cycle is in line with the proposed operation and maintenance (O&M) dredging to be performed in Lower Reach E; however, it will be further refined during plan optimization.

3.6.2 Real Estate Requirements

Based on the information available, the current TSP requires three (3) types of easements/instruments for the combined projects. Currently, all mobilization and construction activities, including lay down and storage of contractor materials and equipment, is assumed to be located within the project area Limit of Construction for the entire project. Since at least one of the project areas contains a private road leading to a portion of the project area, a Road/Access Easement (Standard Estate No. 11) is anticipated to be required for at least one area. Two project areas include land owned by the United States, under the purview of the United States Fish and Wildlife Service (USFWS). Use of this property requires a non-standard estate in the form of a Memorandum of Agreement plus a Special Use Permit.

The standard Perpetual Beach Storm Damage Reduction Easement (Standard Estate No. 26) is required for the construction of the beach berm and dune system on the beachfront properties that are above the mean high water line or that include riparian grants, including any owned by the local municipalities. Properties requiring Standard Estate No. 26 include parcels located below the mean high water line currently subject to riparian grants. Easements must be acquired over the areas below the mean high water line covered by riparian grants for construction, operation and maintenance work required by the Non-Federal Sponsor and the Government over the life of the project. The third estate/instrument required is for lands in the project area currently owned by the United States Fish and Wildlife Service.

3.6.3 Economic Summary

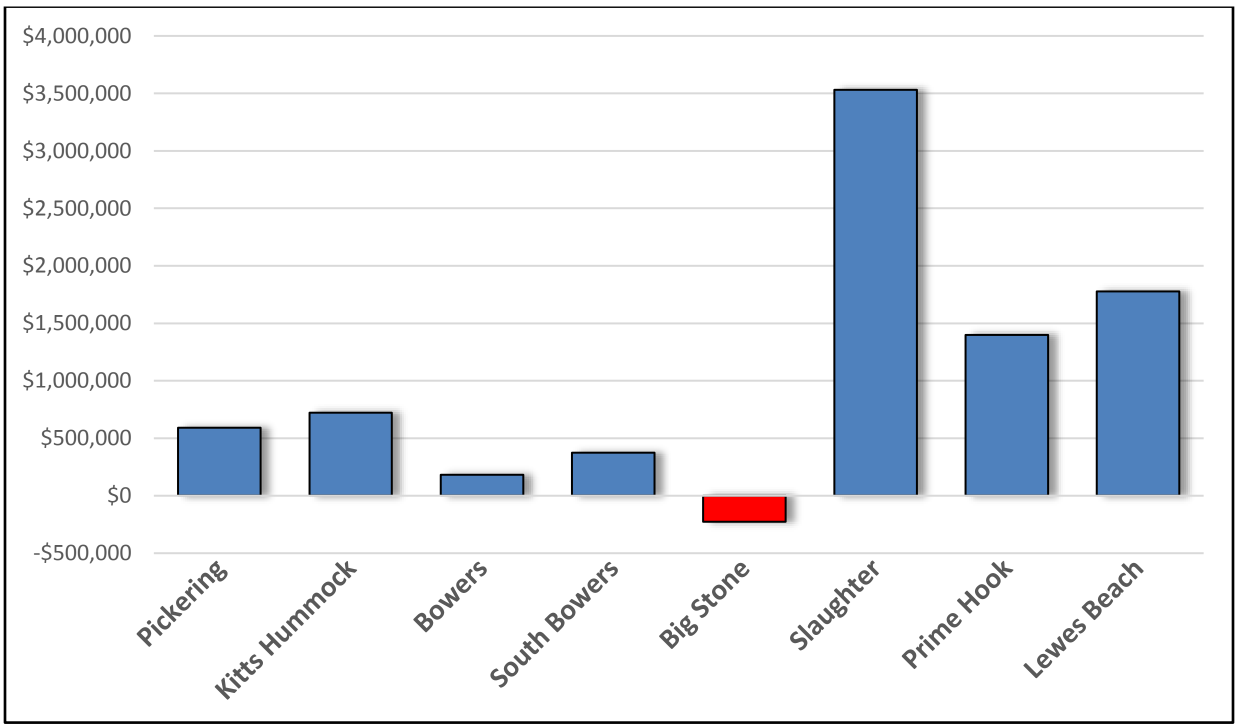
While the southern reach system and 7 of the 8 associated dredged material placement sites have benefits exceeding costs, both the system and the 8 placement sites will undergo an optimization process that will ultimately determine the final footprint of the recommended plan and its associated costs and benefits. Therefore, the BCRs and associated net benefits listed in the table above are subject to change as the tentatively selected plan is optimized. This optimization process will help determine viability of the southern reach system and the final number of dredged material placement sites in the recommended plan.

Table 10 – Summary of Costs & Benefits

Site	Damages Reduced	Total Estimated Project Cost	Total Net Benefits	Average Annual Net Benefits	BCR
Pickering	$32,653,678	$17,080,359	$15,573,319	$590,978	1.91
Kitts Hummock	$37,612,661	$18,575,604	$19,037,057	$722,420	2.02
Bowers	$9,009,131	$4,176,748	$4,832,383	$183,380	2.16
South Bowers	$15,357,442	$5,498,240	$9,859,202	$374,138	2.79
Big Stone	$11,408,499	$17,375,109	-$5,966,610	-$226,421	0.66
Slaughter	$107,266,146	$14,188,758	$93,077,388	$3,532,109	7.56
Prime Hook	$47,605,197	$10,746,416	$36,858,781	$1,398,720	4.43
Lewes Beach	$60,161,076	$13,348,255	$46,812,821	$1,776,457	4.51
Total	**$321,073,830**	**$100,989,490**	**$220,084,340**	**$8,351,779**	**3.18**

Note: The cost and benefit values in Table 9 cover a 50-year period of analysis with a base year of 2020.

Figure 7 - Summary of Average Annual Net Benefits



3.6.3.1 Residual Risk

Damages prevented constitute the CSRM benefits of the TSP. Benefits are computed using the formula Without Project Damages – With Project Damages = CSRM Benefits. Residual risk refers to the storm damages a study area can be anticipated to experience post project implementation. This is computed using Without Project Damages – CSRM Benefits = Residual Risk. Additional benefits, such Benefits During Construction (BDC), Local Costs Foregone and Recreation Benefits may also be present, but were not quantified at this time. The table below provides a summary of damages prevented, which increase as residual risk decreases. The southern reach system had 50.39% damages prevented, while the individual placement sites varied from 22.92% to 70.78% damages prevented. The damages prevented will be subject to optimization of the recommended plan and will ultimately change before finalization of the feasibility report.

Table 11 - Summary of CSRM Damages Prevented

Site	Without Project Condition			With Project Condition			Damages Prevented			
	Structure Damage	Content Damage	Total Damage	Structure Damage	Content Damage	Total Damage	Structure Damage	Content Damage	Total Damage	% Damages Avoided
Pickering	$29,968,085	$17,205,511	$47,173,596	$9,329,161	$5,190,757	$14,519,918	$20,638,924	$12,014,754	$32,653,678	69.22%
Kitts Hummock	$38,280,543	$15,261,048	$53,541,591	$11,371,521	$4,557,409	$15,928,930	$26,909,022	$10,703,639	$37,612,661	70.25%
Bowers	$28,708,504	$10,601,459	$39,309,963	$22,124,102	$8,176,730	$30,300,832	$6,584,402	$2,424,729	$9,009,131	22.92%
South Bowers	$23,243,311	$8,688,508	$31,931,818	$12,116,853	$4,457,523	$16,574,376	$11,126,458	$4,230,985	$15,357,442	48.09%
Big Stone	$11,479,727	$4,637,530	$16,117,257	$3,413,364	$1,295,394	$4,708,758	$8,066,363	$3,342,136	$11,408,499	70.78%
Slaughter	$122,658,313	$50,851,971	$173,510,283	$46,370,897	$19,873,240	$66,244,137	$76,287,416	$30,978,731	$107,266,146	61.82%
Prime Hook	$135,057,740	$52,607,902	$187,665,642	$101,806,555	$38,253,890	$140,060,445	$33,251,185	$14,354,012	$47,605,197	25.37%
Lewes Beach	$64,484,402	$23,495,210	$87,979,613	$20,592,404	$7,226,133	$27,818,537	$43,891,998	$16,269,077	$60,161,076	68.38%
Total	**$453,880,624**	**$183,349,139**	**$637,229,763**	**$227,124,857**	**$89,031,076**	**$316,155,933**	**$226,755,767**	**$94,318,063**	**$321,073,830**	**50.39%**

Note: The damage and damages prevented values in Table 10 cover a 50-year period of analysis with a base year of 2020.

3.6.3.2 Risk & Uncertainty

As stated in Appendix A, Beach-fx is an event-based Monte Carlo life cycle simulation that uses historic storms to calculate damages over the course of a project life cycle. The model links the predictive capability of coastal evolution modeling with project area infrastructure information, structure and content damage functions, and economic valuations to estimate the costs and total damages under various shore protection alternatives while accounting for risk and uncertainty. The model output can then be used to determine the net benefits of each project alternative. Storm damage is defined as the ongoing monetary loss to contents and structures incurred as a direct result of wave attack, erosion, and inundation caused by a storm of a given magnitude and probability. The model also computes permanent shoreline reductions. These damages and associated costs are calculated over the project period of analysis based on storm probabilities, tidal cycle, tidal phase, beach morphology, and many other factors. Data on historic storms, beach survey profiles, and beach reactions to specific storm events can be found in the Engineering Appendix C.

For the Future Without Project (FWOP) Condition and Future With Project (FWP) Condition, the structure inventory and values are the same as the existing condition barring any structure that are deemed condemned by Beach-fx over the period of analysis. This conservative approach neglects any increase in value accrued from future development even though Kent County and Sussex County have seen population density and structure assessment values increase in recent years. Use of the existing inventory is preferable due to uncertainty and limitations in projecting future development.

Damage Functions

Damage functions are user-defined curves that are applied within the model to determine the extent of storm-induced damages attributable to any specific combination of damage element type and foundation type. There are six types of damage functions which include erosion, inundation, and wave attack for both structure and content. For example, there is a specific set of six damage functions for single-family residential one story Damage Elements with a slab foundation and a separate, unique set of damage functions for single-family residential one story Damage Elements with a pile foundation. This analysis used a total of 48 damage functions to calculate storm-induced damages.

Damage is determined as a percentage of overall structure or content value using a triangle distribution of values, which looks at minimum, maximum and most likely value. For erosion functions, damage is dependent upon the extent to which a structure's footprint has been compromised and for inundation and wave attack functions, damage is determined by the storm-surge heights in excess of first-floor elevation.

Damage Functions were developed using the North Atlantic Coast Comprehensive Study (NACCS) Resilient Adaption to Increasing Risk: Physical Depth Damage Function Summary Report.

Future Without Project Condition (FWOP) Damages

The FWOP net present value damages are a combination of the CSRM damages experienced at each individual project site. Damages are measured by both structure and content and averaged over 300 iterations (with the exception of Prime Hook at 100 iterations). Values are in Present Worth using the FY2017 Federal Discount Rate. All results are currently shown at the Historic (Low) Relative Sea Level Change (RSLC) rate, but will include Intermediate and High rates post-optimization.

Table 12 - Future Without Project Condition Damages by Site

Site	Structure Damage	Content Damage	Total Damage	% of Total
Pickering	$29,968,085	$17,205,511	$47,173,596	7.4%
Kitts Hummock	$38,280,543	$15,261,048	$53,541,591	8.4%
Bowers	$28,708,504	$10,601,459	$39,309,963	6.2%
South Bowers	$23,243,311	$8,688,508	$31,931,818	5.0%
Big Stone	$11,479,727	$4,637,530	$16,117,257	2.5%
Slaughter	$122,658,313	$50,851,971	$173,510,283	27.2%
Prime Hook	$135,057,740	$52,607,902	$187,665,642	29.5%
Lewes Beach	$64,484,402	$23,495,210	$87,979,613	13.8%
Total	$453,880,624	$183,349,139	$637,229,763	-

Note: The future without project condition damage values in Table 11 cover a 50-year period of analysis with a base year of 2020.

3.6.4 Environmental Compliance

The table below provides a summary of the environmental compliance status to date. Additional details regarding the environmental compliance are provided in Section 6.2.2.

Table 13 - Summary of Environmental Compliance

Item	Compliance
Anadromous Fish Conservation Act	N/A
Archaeological and Historic Preservation Act, as amended, 16 U.S.C. 469, et seq.	Full
Clean Air Act of 1977, as amended, 42 U.S.C. 7609, et seq.	Full
Clean Water Act, as amended, (Federal Water Pollution Control Act), 33 U.S.C. 1251, et seq.	Full
Coastal Barrier Resources Act and Coastal Barrier Improvement Act of 1990	Full
Coastal Zone Management Act, 16 U.S.C. 1451, et seq.	Full
Endangered Species Act, 16 U.S.C. 1531, et seq.	Full
Estuary Protection Act, 16 U.S.C. 1221, et seq.	Full
Farmland Protection Policy Act of 1981	N/A
Federal Water Project Recreation Act, 16 U.S.C. 460-12, et seq.	N/A
Fish and Wildlife Coordination Act, 16 U.S.C. 661, et seq.	Full
Land and Water Conservation Fund Act, 16 U.S.C. 460/ -460/-11, et seq.	N/A
Magnuson-Stevens Fishery Conservation and Management Act of 1976	Full
Marine Mammal Protection Act of 1972	Full
Marine Protection, Research and Sanctuary Act, 33 U.S.C. 1401, et seq.	N/A
Migratory Bird Treaty Act and Migratory Bird Conservation Act	Full
National Environmental Policy Act, 42 U.S.C. 4321, et seq.	Full
National Historic Preservation Act, 54 U.S.C. 300101 et seq.	Full
Rivers and Harbor Act, 33 U.S.C. 401, et seq.	Full
Submerged Lands Act of 1953	Full
Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970	N/A
Watershed Protection and Flood Prevention Act, 16 U.S.C. 1001, et seq.	N/A
Wild and Scenic Rivers Act, 16 U.S.C. 1271, et seq.	N/A
Executive Order 11988, Floodplain Management, May 24, 1977 (42 CFR 26951; May 25, 1977)	Full
Executive Order 11990, Protection of Wetlands, May 24, 1977 (42 CFR 26961; May 25, 1977)	N/A
Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations, February 11, 1994	N/A
Executive Order 13045, Disparate Risks Involving Children	N/A

Note: The compliance categories used in this table were assigned based on the following:

- Full Compliance (Full) – Having met all requirements of the statute, Executive Order (EO) or other environmental requirements for the current stage of planning
- * indicates coordination ongoing and will be completed prior to signature of FONSI.

3.6.5 Environmental Operating Principles

The United States Army Corps of Engineers Environmental Operating Principles were developed to ensure that Corps of Engineers missions include totally integrated sustainable environmental practices. The Principles provided corporate direction to ensure the workforce recognized the Corps of Engineers role in, and responsibility for, sustainable use, stewardship, and restoration of natural resources across the Nation and, through the international reach of its support missions.

Since the Environmental Operating Principles were introduced in 2002 they have instilled environmental stewardship across business practices from recycling and reduced energy use at Corps and customer facilities to a fuller consideration of the environmental impacts of Corps actions and meaningful collaboration within the larger environmental community.

The concepts embedded in the original Principles remain vital to the success of the Corps and its missions. However, as the Nation's resource challenges and priorities have evolved, the Corps has responded by close examination and refinement of work processes and operating practices. This self-examination includes how the Corps considers environmental issues in all aspects of the corporate enterprise. In particular, the strong emphasis on sustainability must be translated into everyday actions that have an effect on the environmental conditions of today, as well as the uncertainties and risks of the future. These challenges are complex, ranging from global trends such as increasing and competing demands for water and energy, climate and sea level change, and declining biodiversity; to localized manifestations of these issues in extreme weather events, the spread of invasive species, and demographic shifts. Accordingly, the Corps of Engineers is re-invigorating commitment to the Environmental Operating Principles in light of this changing context.

The Environmental Operating Principles relate to the human environment and apply to all aspects of business and operations. They apply across Military Programs, Civil Works, Research and Development, and across the Corps. The Principles require a recognition and acceptance of individual responsibility from senior leaders to the newest team members. Re-committing to these principles and environmental stewardship will lead to more efficient and effective solutions, and will enable the Corps of Engineers to further leverage resources through collaboration. This is essential for successful integrated resources management, restoration of the environment and sustainable and energy efficient approaches to all Corps of Engineers mission areas. It is also an essential component of the Corps of Engineers' risk management approach in decision making, allowing the organization to offset uncertainty by building flexibility into the management and construction of infrastructure.

The **Environmental Operating Principles** are:

- Foster sustainability as a way of life throughout the organization.
- Proactively consider environmental consequences of all Corps activities and act accordingly.
- Create mutually supporting economic and environmentally sustainable solutions.
- Continue to meet our corporate responsibility and accountability under the law for activities undertaken by the Corps, which may impact human and natural environments.
- Consider the environment in employing a risk management and systems approach throughout the life cycles of projects and programs.
- Leverage scientific, economic and social knowledge to understand the environmental context and effects of Corps actions in a collaborative manner.

- Employ an open, transparent process that respects views of individuals and groups interested in Corps activities.

Over the past 50 years, there has been a progressive decline in the average annual volume of sediment removed from the Delaware River/Bay system by dredging with no reductions in maintained depths or any significant reduction in dredging projects requiring maintenance. Fringing marshes along the shorelines have experienced significant lateral retreat. Inadequate importation of suspended sediment (and confined upland placement of dredge material), SLC, frequent severe storms, ship wakes, and to some extent, land subsidence, are believed to be the main causal factors.

The above-referenced TSP will provide improved CSRM for the Delaware Bay shoreline by utilizing dredged material to alleviate shoreline erosion and flooding. This TSP supports the Corps Environmental Operating Principles by providing an economic and environmentally sustainable solution that enhances shoreline resilience and sustainability by placing dredged sediment in the estuary system.

There is a potential for this TSP to enhance resiliency and sustainability of the natural coastal environment by retaining sediment in the system, and thereby providing habitat protection and/or restoration. Specifically, the importation and deposition of new sediments is essential to the long-term sustainability of coastal wetlands. Wetlands serve as a first line of defense against coastal flooding. Due to land conversion and degradation, less than 5% of pre-settlement acreage of freshwater wetlands remains in the Delaware Estuary. The U.S. EPA estimates that 35% of Delaware Bay's rare species and 70-90% of the estuary's fish and shellfish depend on wetland habitats. These critical habitats are under constant threat of storm damage and inundation.

Tidal wetlands provide some of the most productive natural ecosystems in the world, and are widely recognized for their important ecological functions. The services they provide include flood protection for coastal communities, maintenance of water quality, habitat for hundreds of species of fish and wildlife, and carbon sequestration. Normally, tidal wetlands can build vertically (accrete) in order to compensate for subsidence and/or SLC. This accretion occurs through the accumulation of organic matter (peat) from autochthonous production as well as the importation and trapping of suspended sediments washing in with tidal or storm flows by salt marsh vegetation.

The loss of shoreline fringing wetlands has exacerbated flooding and erosion problems. Once inundated, long-term vegetation dies off leaving mudflats, eroded banks, and open water areas that can no longer accrete sediments and keep pace with SLC. Coastal marshes provide naturally for greater resilience to future storm damage. In combination with utilizing dredged material to build up eroded shorelines, mitigation opportunities exist to establish "living shorelines," which serve to further reduce losses of tidal marshes. Fringing shellfish beds, such as oysters or mussels, serve as natural breakwaters to trap sediments and absorb wave energy. Oysters and mussels build their own habitats and provide habitat for other marine intertidal species, while armoring the substrate and binding to vegetation.

3.6.6 Actions for Change

On 24 August 2006, the commander of the United States Army Corps of Engineers signed and released the "12 Actions for Change," a set of actions that USACE will focus on transform its priorities, processes and planning. The "12 Actions for Change" fall within three overarching themes: effectively implement a comprehensive systems approach, communication and reliable public service/professionalism:

- Theme 1: Comprehensive Systems Approach

  As referenced above, the alternatives were evaluated in two defined planning reaches (northern reach and southern reach) within the Delaware River/Bay system. Based on the likely project implementation consisting of a continuous dredging operation (in the southern reach) with one primary mobilization and continuous incremental preparatory costs to nourish the sites in the system, the dredged material placement sites were evaluated both individually and as a comprehensive system.

- Theme 2: Communication

  The North Atlantic Coast Comprehensive Study: Resilient Adaptation to Increasing Risk (NACCS) identified the Delaware River/Bay and Inland Bay shorelines as "High Storm Impact" areas from Hurricane Sandy. Under the purview of the NACCS, there was significant coordination with state, county and local community agencies and representatives of non-profit organizations to identify specific flood-prone problem areas within the "High Storm Impact" zone. The CSRM problem areas evaluated in this study were identified through assistance from the NACCS coordination.

- Theme 3: Reliable Public Service and Professionalism

  The feasibility study has had full vertical team coordination throughout the plan formulation process and quality control for both technical and policy reviews.

3.7 IMPLEMENTATION REQUIREMENTS

3.7.1 Institutional Requirements

Project implementation assumes authorization in a Water Resources Development Act (WRDA). After project authorization, the project will be eligible for construction funding. It will be considered for inclusion in the President's budget based on national priorities, magnitude of the Federal commitment, economic and environmental feasibility, level of local support, willingness of the non-Federal sponsor to fund its share of the project cost and the budget constraints that may exist at the time of funding.

Once Congress appropriates Federal construction funds, USACE and the non-Federal sponsor would enter into a Project Partnership Agreement (PPA). This PPA would define the Federal and non-Federal responsibilities for implementing, operating and maintaining the project.

Following the signing of the PPA and the design approval, USACE would officially request the sponsor to acquire the necessary real estate. The advertisement of the construction contract would follow the certification of the real estate acquisition and right-of-entry. The final acceptance and transfer of the project to the non-Federal sponsor will follow the delivery of an operation and maintenance manual and as-built drawings.

3.7.2 Cost Apportionment

The sponsor is responsible for the LERRD which is included in the sponsor's share of the construction cost. Items included in the LERRD total include the land to construct the project and the relocation of utilities. Costs for HTRW cleanup is not a Federal responsibility and is not included in the total project cost. The TSP has no identified HTRW in the construction footprint.

Table 14 - Estimated Schedule of Federal and Non-Federal Expenditures

	Non-Federal Sponsor Contribution	Federal Contribution	Total Project Cost
LERRD	$11,177,990	N/A	$11,177,990
Cash	$24,168,332	$65,643,169	$89,811,500
Total	$35,346,322	$65,643,169	$100,989,490

3.7.3 Environmental Requirements

Requirements for Section 404 of the Clean Water Act of 1972, as amended, will be met prior to any construction activity. The completed 404(b)(1) guidelines form is included in Appendix D.

A Section 401 Water Quality Certification and a consistency determination under the Coastal Zone Management Act will be obtained from the State of Delaware prior to project construction.

3.7.4 Views of Non-Federal Sponsor

The non-Federal sponsor fully supports the TSP.

4 AFFECTED ENVIRONMENT

The study area is located within the Delaware River watershed within the state of Delaware and includes the inland bays region of Delaware's ocean coast (Figure 1). The north/south boundaries of the study area extend from Delaware/Pennsylvania state line to the Delaware/Maryland state line at Fenwick Island, DE. Given the alignment of the state boundary between Delaware and New Jersey, the study area also includes some land located on the east bank of the Delaware River which is contiguous with New Jersey (*i.e.* portions of Kilcohook and Artificial Island dredged material disposal areas).

4.1 ENVIRONMENTAL SETTING OF THE STUDY AREA

The study area addresses flood prone areas along the mainstem Delaware River and Delaware Bay, and also the tidal reaches of the tributaries within this part of the estuary that contribute to tidal and fluvial flooding. These include: Brandywine Creek, Christina River, Chesapeake and Delaware Canal, Smyrna River, Leipsic River, St. Jones River, Murderkill River, Cedar Creek, Simons River, Mahon River, Little River, Mispillion River, Broadkill River, Canary Creek, and the Lewes and Rehoboth Canal.

Specifically, the Delaware River is a principal corridor for commerce that has sustained the region since America's colonial period and reached a zenith during World War II and thereafter. Today, it continues to be a major strategic port for national defense and economic interests. The Estuary supports the 4th largest urban center in the nation and contains the world's largest freshwater port. The Estuary also sustains a wealth of natural and living resources, such as drinking water for millions of people, extensive tidal marshes that sustain vibrant ecosystems, and shoreline habitats for horseshoe crabs and migratory shorebirds, and both freshwater and saltwater habitats for shellfish (Kreeger *et al*., 2010).

4.2 PHYSICAL ENVIRONMENT

4.2.1 Land Use

DRBC Region 5 includes urban Wilmington, New Castle and Delaware City. Wilmington is characterized by mixed industrial and commercial use and urban residential development. Major roads include Interstate 495 and Interstate 95. There are seven ports, one power plant and three rail bridges. New Castle is located further south and is characterized by mixed industrial and commercial use and urban residential development with extended areas of wetland shoreline. Major roads include the Delaware Memorial Bridge (Interstate 295). There are two rail bridges. South of New Castle, Delaware City borders the Delaware River and lies approximately two miles north of the Chesapeake and Delaware Canal (C&D). The C &D has a 1.8 mile branch channel which enters the Delaware River at Delaware City. Delaware City is characterized by a mix of residential and commercial development.

The Bay Region of the study area (DRBC Zone 6) includes the bayshore communities of Woodland Beach, Pickering Beach, Kitts Hummock, Bowers Beach, South Bowers Beach, Big Stone Beach, Slaughter Beach and Lewes Beach. Most of the Delaware Bay shoreline in this region is characterized by broad marshes with a narrow barrier of sand along the beach. The barrier is widest and most well-developed near the mouth of the bay south of the Prime Hook National Wildlife Refuge (PHNWR).

The Inland Bays Region includes bays that are connected to the Atlantic Ocean by Indian River Inlet. The region includes Dewey Beach, Joy Beach/Old Landing, Long Neck, Oak Orchard, the South Side of Indian River Bay, Fenwick Island, Mallard Lakes, Bethany Beach and South Bethany. The Inland Bay communities are characterized as medium density urban residential and beach community development.

The shoreline for these areas consists of beaches, bluffs, wetlands, bulkheads, docks and urban development. The major road in this region is Delaware State Route 1 which intersects the local arteries such as State Routes 9 and 13 near the Dover Air Force Base. Further south on Little Assawoman Bay lies Fenwick Island. This area is characterized by medium density urban residential and beach community development. The shoreline for this area varies with beaches, bluffs, wetlands and urban development. Delaware State Route 1 is the major artery in this region.

4.2.2 Physiography and Geology

The shorelines of the Delaware River/Bay and Inland Bays are characterized by flat, low-lying coastal plains. Elevations range from 5 to 10 feet in the lower portion of the estuary to 20 feet in the vicinity of Wilmington.

Geologically, the Delaware Estuary is situated near the border of two subdivisions: the Appalachian Piedmont province and the Atlantic Coastal Plain province. The Piedmont Plateau lies along the eastern edge of the Appalachian Mountains and runs from New Jersey to Alabama. The rocks of the Piedmont are old, hard and crystalline. They extend downward and toward the Atlantic Ocean, forming a platform that supports the Coastal Plain. The Piedmont Plateau borders the western side of the estuary between Philadelphia and Wilmington. At Wilmington, the Piedmont shifts to the west of the estuary, eventually running through Baltimore, Maryland and Washington D.C. The Coastal Plain physiographic province borders the entire eastern side of the Delaware Estuary, as well as the western side of the estuary below Wilmington. The rocks of the coastal plain are much younger than those of the Piedmont, and are largely unconsolidated sediments. The Coastal Plain sediment layers are mainly comprised of sands and clays that dip to the southeast, and generally thicken oceanward. The older formations are at or near the surface in the vicinity of the estuary, and are progressively deeper towards the Atlantic Ocean. The unconsolidated sediments consist of pervious and impervious layers that form a series of aquifers and aquicludes.

4.2.3 Sediment Quality

Extensive sediment quality sampling and analyses have been conducted within the Delaware Estuary, primarily in association with the USACE Delaware River Main Stem Channel Deepening and Maintenance Dredging projects in the uppermost portions of the navigation project (USACE, 1992, 1997). Most of this sediment testing has occurred within the current project area reaches.

Sediment samples collected from the Main Stem Delaware River included bulk sediment analyses, elutriate sediment analyses, Toxicity Characteristic Leaching Procedure (TCLP) analyses, biological effects based sediment testing, and high resolution PCB congener analyses (USACE, 2009). The mean and range of contaminant concentrations were provided for each reach of the proposed project area. Mean contaminant concentrations fell within ranges considered to be background for soils and sediments in New Jersey. Maximum concentrations that exceed background appear to be in isolated samples, and are, therefore, limited in spatial distribution.

Due to continued concerns raised during the Main Channel Deepening (MCD) Feasibility study regarding sediment chemical quality and the potential adverse effects on aquatic resources, further bulk sediment and elutriate analyses were conducted (USACE, 1997). The majority of contaminant parameters evaluated were not detected in channel sediments. Bulk analysis did not identify high concentrations of organic contaminants; PCBs were detected in two samples (Bellevue and Liston Ranges); 4 pesticides (all below 0.1 ppm) were detected in the Bellevue, Liston and Mifflin Ranges; and polycyclic aromatic hydrocarbons (PAHs) were detected in several channel bends between Philadelphia Harbor and Artificial Island. Of the remaining volatile and semi-volatile organic contaminants evaluated, only methylene chloride, acetone, 2-butanone, styrene and phthalates were detected at quantifiable levels (all below 0.1 ppm). Heavy metals were found to be widely distributed throughout the MCD project area, with concentrations in predominantly sandy bay sediments lower than up-river sediments. The presence of heavy metals in channel sediments is attributed to the urban and industrialized nature of the upper estuary. Refer to the 1997 Supplemental EIS (USACE, 1997) for a more detailed discussion of the sediment quality analyses and potential impacts to human health and biological effects testing.

Two additional sets of bulk sediment data were collected from the channel (Versar, 2003, 2005). A total of 45 sediment cores were collected from between Philadelphia and the Chesapeake and Delaware Canal and analyzed for inorganics, pesticides, PCBs, volatile and semi-volatile organic compounds. In these reaches of the river, the results were compared to Residential Direct Contact criteria developed by the State of New Jersey, and used to evaluate the quality of dredged material. The most common parameters detected in sediments were inorganic metals. Concentrations of inorganics in all 45 samples were below New Jersey residential criteria except for thallium and arsenic. Two samples had thallium concentrations (5.33 ppm and 7.24 ppm) above the residential criterion of 5 ppm. Two samples had arsenic concentrations (51.4 ppm and 37.4 ppm) above the residential criterion of 19 ppm. Thallium and arsenic, along with antimony, were the only inorganic parameters to exceed New Jersey criteria in previous sampling efforts. The most frequently detected organic parameters in the upper river were PAHs. PAHs are primarily formed through combustion of fossil fuels and are expected to be found in highly industrialized and populated regions (USACE, 2009).

The Port of Wilmington, at the confluence of the Delaware and Christina Rivers in New Castle County is located within the turbidity maximum zone of the estuary where suspended sediment levels are high (*i.e.* the transition zone between the tidal freshwater zone upstream of Marcus Hook, PA and the saline zone below Artificial Island (US EPA, 1996). In excess of 400 vessels and 200 barges call on the port annually, and necessitate annual maintenance dredging. Located in a heavily industrialized portion of the river, aquatic sediments in Wilmington Harbor have been analyzed extensively prior to dredging operations (Costa and Sauer, 1994; DNREC, 1999, Burton *et al.*, 1997; and Burton, 2000). Surficial sediments of the tidal Delaware River in the vicinity of the Port of Wilmington contain elevated concentrations of several metals, chlorinated pesticides, PCBs and PAHs. The highest concentrations occur above Marcus Hook, PA, river mile 80, and relatively low below Artificial Island, river mile 52. The Port of Wilmington region is an intermediate section of the river (river mile 72) where sediments can be broadly characterized as containing moderately elevated contaminant levels (USACE, 2009).

A multi-agency Sediment Quality Committee compiled a database of 932 *in situ* bulk chemistry sediment in 2012 (RSMT, 2013). Samples were analyzed for the purpose of evaluating dredged material for use in aquatic habitat restoration. The data was evaluated for the following contaminants of concern (COC): arsenic, cadmium, cobalt, copper, lead, mercury, total chlordane, dieldrin, 4,4’-DDT/DDD/DDE, benzo(a)pyrene, total PCBs, and total dioxin/furan. The Committee considered guidelines that are currently in use in the Delaware Estuary to evaluate sediment quality, including Pennsylvania, New Jersey and Delaware state regulatory criteria for the evaluation of fill (soil, dredged material, *etc*.) at upland sites; sediment quality guidelines used for ecological effects screening purposes; state and DRBC water quality criteria, state criteria used to develop fish advisories; and eco-effects data for toxicity, bioaccumulation, and community health indices.

Statistical analyses of the mean COC concentrations in each DRBC Water Quality Zone identified significant differences between DRBC zones. The Committee concluded that sediments suitable for "unrestricted" upland beneficial uses are usually interspersed among samples acceptable for "limited/restricted" upland beneficial uses throughout the Delaware Estuary. However, the data suggest that dredged material from DRBC Zone 6 (Delaware Bay) is most suitable for "unrestricted" upland beneficial use projects. Dredged material from DRBC Zones 2 through 5 and the tributaries appear to be suitable for either "unrestricted" or "limited/restricted" upland beneficial uses.

Explorations and test data from eleven (11) individual USACE and Philadelphia Regional Port Authority (PRPA) investigations were compiled into a single geotechnical data report by Gehagan & Bryant Associates, Inc. (GBA) dated October 2010. These investigations between Philadelphia and the sea were conducted between the early 1960s and 2010 for local project feasibility studies and the DRMCD. From this collection of data, it was estimated that most materials in the main channel of Reach E consisted of sandy materials. In 2012, GBA conducted a supplemental geotechnical subsurface investigation for USACE Philadelphia District and the PRPA. GBA collected vibracore samples of the riverbed sediment at 51 discrete locations in the main channel. An extensive geotechnical laboratory testing program was performed, results of which indicated that the bulk of material encountered was sand. Results show that 92% of all samples were predominantly sand (sand fraction greater than 50%). Only 12% of grain size samples had silt and clay contents greater than 50%. The findings of this supplemental investigation essentially confirmed previous findings and assumptions regarding the sediment grain sizes in the channel.

The Philadelphia District has placed sand dredged from Lower Reach E (the Brandywine and Miah Maull ranges of the Main Channel) in Buoy 10 in 2011, 2006 and 2005. In 2014, 11 sediment grab samples were collected in and around the Buoy 10 open water disposal site. All samples were analyzed for grain size and ranged from 96.1% to 99.8% sand. The remaining component were shell fragments. Vibracores were collected from Buoy 10 in 2007 and 2014 and predominantly indicate similar results as the grab samples; however, there are some coarser sediments (gravel) in pockets approximately 7 to 10 feet below the surface that may reduce total available quantity. The munitions and explosives of concern (MEC) screening process will prevent most of the coarser material from getting into the dredged material. The current estimate of sand remaining within the Buoy 10 boundaries is approximately 750,000 cy.

4.2.4 Climate and Climate Change

The Partnership for the Delaware Estuary (PDE) is a nonprofit organization that manages the Delaware Estuary Program, one of 28 estuaries recognized by the U.S. Congress for its national significance under the Clean Water Act. The PDE evaluated climate change effects within the Delaware Estuary (Kreeger *et al*., 2010).

Sea Level Change (SLC) due to climate change has been predicted to be greater in the Mid-Atlantic Region than points north and south on the eastern seaboard. PDE's Climate Adaptation Workgroup looked at the results of 14 different climate models to first test their accuracy in predicting past conditions for the region and averaged them together to postulate a locally relevant future scenario. The team then evaluated the vulnerabilities of the Delaware Estuary's tidal wetlands, drinking water, and bivalve shellfish to changes in physical and chemical conditions associated with climate change. Some aspects of a changing climate may not be as severe here than in other watersheds while other changes may be more problematic.

For example, modest rises in temperature could lengthen growing seasons or boost productivity for some signature species and help them compete with invasive species or keep pace with SLC. PDE's scientific team found that the length of the growing season is predicted to increase by about 15 days by mid-century, and by up to 30 days by 2100 for the Delaware Estuary. Additionally, approximately 20 fewer frost days per year are predicted by mid-century and 40 fewer frost days by the end of the century under a higher emissions scenario. The models show high confidence that average annual temperatures will increase by the end of the 21st century by 2-4 degrees C. More warming is expected in summer months. This conclusion is consistent with predictions by the Union of Concerned Scientists which estimated that Pennsylvania summer temperatures could increase by 2-7 degrees C, depending on the emissions scenario (UCS, 2008; Field *et al*., 2007).

Annual mean precipitation is predicted to increase by 7-9% by the end of the 21st century (median projection). Higher increases are expected during winter months (Najjar, 2009; GCRP, 2009). Three quarters of the models predict substantial increases in the frequency of extreme precipitation events including heavy precipitation and consecutive dry days. The U.S. Global Climate Research Program (GCRP) also predicted increases in extreme weather events and associated risks from storm surges (GCRP, 2009) (Table 14).

Table 15 – Delaware Estuary Watershed Climate Predictions: Present to 2100

Climate Condition		Model Evaluation: Biases & Issues	21st Century Prediction	Confidence Levels
Temperature	Monthly Mean	Slight cool bias in winter and summer	Warming: 1.9 – 3.7°C median rise by late century; Substantially greater warming in summer months	High
	Inter-annual Variability	Slightly too much variability, but better with winter than summer	Warming: 1.9 – 3.7°C median rise by late century; Substantially greater warming in summer months	High
	Intra-monthly Variability	Models' mean reproduces correctly, but there is a large spread among the individual models	Warming: 1.9 – 3.7°C median rise by late century; Substantially greater warming in summer months	High
	Extreme Temp >80 F	Underestimates	Downscaled models show substantial increases	High
Precipitation	Monthly Mean	Wet bias in winter and spring and a dry bias in summer	Increase in Precipitation: 7 - 9% median increase by late century; Substantial increase in winter months	Medium
	Inter-annual Variability	Does not predict summer peak and winter minimum seen in observed conditions	Increase in Precipitation: 7 - 9% median increase by late century; Substantial increase in winter months	Medium
	Intra-monthly Variability	Mean reasonably captures, but too low in the summer	Increase in Precipitation: 7 - 9% median increase by late century; Substantial increase in winter months	Medium
Extreme Precipitation	Short Term Drought	Slight low bias	Substantial increases, but less than ¼ of models show declines	Medium
	Heavy Precipitation	Slight low bias	Substantial increases, but less than ¼ of models show declines	Medium
Growing Season Length		Predicts accurately	Substantial increase by end of century	High
Number of Frost Days		Somewhat high	Substantial decline	High

The Delaware Estuary has the largest freshwater tidal prism in the world. The freshwater tidal region extends about 70 river miles, and the salinity in areas more seaward changes very gradually. This feature makes the Delaware Estuary unique among large American estuaries because of the array of ecosystem services supplied to human and natural communities tied to the extended salinity gradient, such as the supply of drinking water for people and rare natural communities (Kreeger *et al*., 2010). Increasing sea level may result in larger tidal volumes bringing salt water further up the estuary. Some of the salinity increase could be offset by anticipated increases in precipitation. Sea level rise could increase the tidal range in the Delaware system (Walters, 1992), similar to expectations for the Chesapeake Bay (Zhong *et al*, 2008).

The Mid-Atlantic region is anticipated to experience SLC greater than the global average (GCRP, 2009). Some regional variation in sea level results from gravitational forces, local land subsidence, wind, and water circulation patterns. Water circulation patterns are expected to change in the region by approximately 10 cm over this century (Yin *et al*., 2009). Two other factors play prominent roles influencing SLC locally: land subsidence and sediment accretion. Delaware has been settling since the last Ice Age, causing a steady loss of elevation. Subsidence is expected to continue through the next century at an average of 1-2 mm of land elevation loss per year (Engelhart *et al*., 2009). Sediment accretion is a natural process whereby suspended sediments within the Delaware River, Bay, and tributaries settle and accumulate along the shoreline such as on mudflats and in wetlands. Accretion cannot occur on developed surfaces where erosion typically occurs or if the system is sediment starved from diversion processes (such as dredging and upland placement operations). These factors play a significant role in either accelerating or decreasing the rate of SLC and loss of habitat. The net increase in sea level compared to the change in land elevation is the rate of relative sea level rise (RSRL). Kreeger *et al*. (2010) estimate relative sea level rise for the Delaware Estuary watershed by the end of the century at 0.8 to 1.7 m.

4.3 WATER RESOURCES

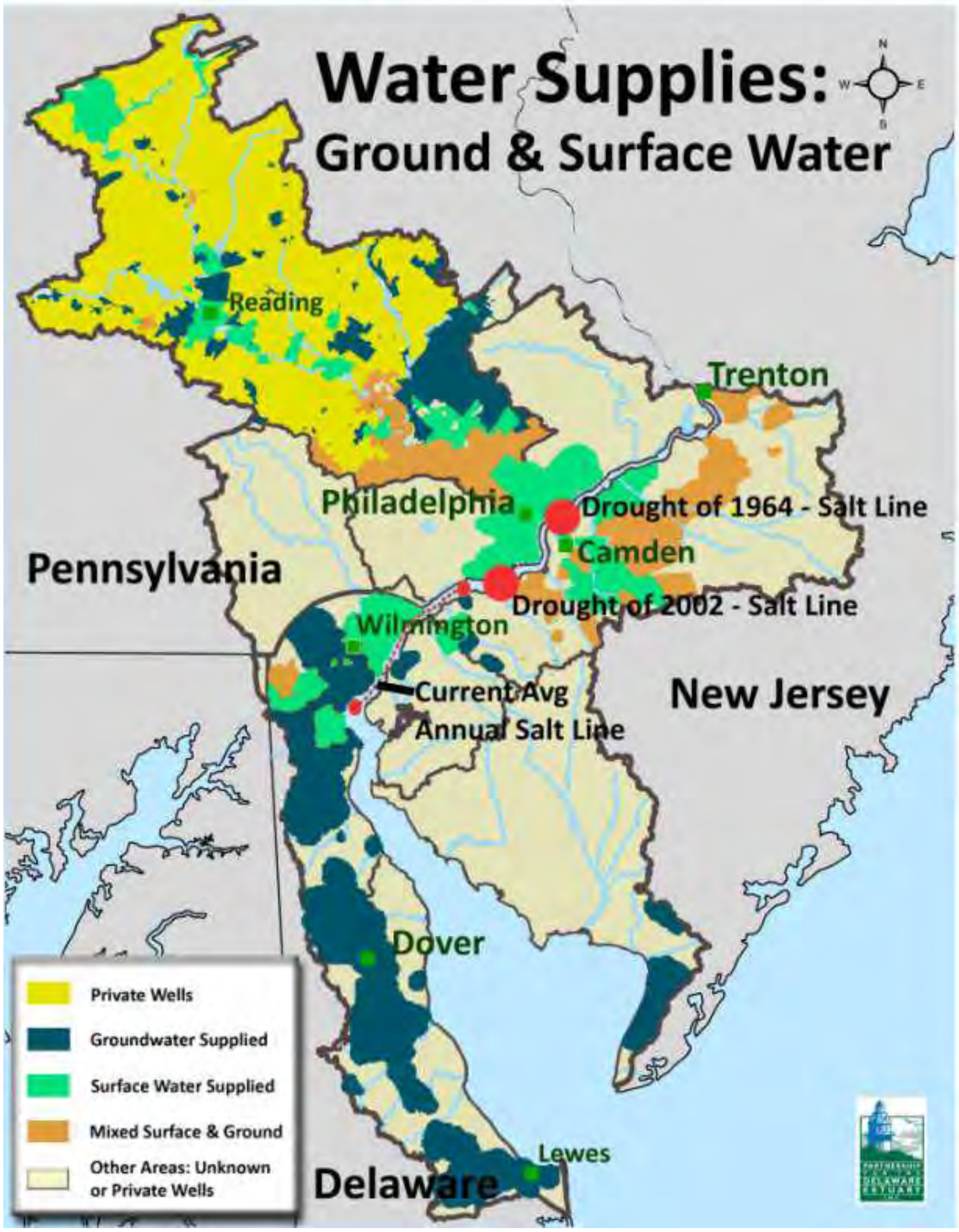
4.3.1 Groundwater Quality and Public Water Sources

Groundwater is contained within aquifers, which are porous geologic formations that store or transmit groundwater. The significant aquifers underlying the state of Delaware are the Potomac, Magothy, Monmouth, Rancocas, Frederica, Cheswold, and Columbia. The Potomac and Magothy aquifers are exposed at various locations at or near the surface in a narrow band along the sides of the Delaware River. The Pleistocene formations: Cape May and the Columbia overlie areas of the Cretaceous aquifers and cover nearly all of Delaware and portions of southern New Jersey. They are predominantly composed of sands and gravels. In areas where windows of sandy materials outcrop in the clays of the Potomac-Raritan-Magothy formation, a hydraulic connection will exist between the shallow water table aquifers in the Cape May and Columbia formations and the underlying Cretaceous aquifers.

In some locations, the Potomac-Raritan-Magothy or Cape May and Columbia formations are in direct contact with Delaware River water. Consequently, a direct hydraulic connection exists, such that when large groundwater withdrawals have locally reversed natural aquifer flow patterns, induced aquifer recharge of river water results. Infiltration from the Delaware River, particularly when salinity levels are high, is a major concern relative to maintaining groundwater quality. The quality of the Magothy-Raritan is closely linked to the quality of the Delaware River.

Groundwater resources represent 58% of Delaware's total available water supply. Surface water withdrawals are negligible compared to groundwater use in Kent and Sussex Counties. However, surface water use in New Castle County far outweighs groundwater pumpage. The population centers of Wilmington and Newark are located in or near the Piedmont Province, and groundwater is far less abundant in the crystalline rocks of the Piedmont than in Coastal Plain sediments. Therefore, these cities take most of their water from surface water sources. Figure 10 shows a map of the watershed and service areas of community water supplies. Major cities in the northern part of the estuary get the majority of their water supplies from surface water or a mix of surface and ground water. Most of southern Delaware relies exclusively on ground water.

Figure 8 - Water Supplies: Ground & Surface Water



The quality of all of Delaware's groundwater resources is generally good, although local problems exist. The Potomac and Magothy formations are usually high in iron. Nitrate contamination has been a problem near St. Georges in the Monmouth and Pleistocene deposits. A high chloride concentration is typical within two miles of Delaware Bay and within one mile of tidal streams (USACE, 1992). The most widespread groundwater quality problem in Delaware has been saline encroachment.

4.3.2 Surface Water Quality

Advances in the treatment of municipal and industrial waste and changes in manufacturing and processing techniques over the past 40 years have led to improved surface water quality in many parts of the Delaware River Basin. One indication of this improvement is the return of shad runs to the Delaware River. The presence of toxic compounds, however, still leads to consumption advisories for many fish species, and nutrient loadings adversely affect water quality and the health of ecological communities. Many of the water quality issues in the Delaware Estuary can be related to the high human population density and related activities associated with urban, industrial, and agricultural land use. Most concerns are related to human health (*i.e.* the quality of domestic water supply, the safety of water contact recreation, and the safety of eating game fish) and the health of ecological communities (USACE, 2009).

The project area spans from the lower Delaware River region in northern Delaware to the bay mouth, and including portions of the Delaware Inland Bays in Sussex County. Water quality in these reaches varies from fair in the uppermost portions to good in the lower Delaware Bay region. The uppermost reach is considered a transition zone between urbanized upstream areas and rural Delaware Bay. This zone is also the transitional area between the freshwater habitats upstream and more saline areas downstream.

The DRBC is responsible for managing the water resources within the entire Delaware River Basin. Pursuant to Section 305(b) of the Clean Water Act, the DRBC prepares biennial assessments of water quality for the Delaware River. As referenced above, the study area falls into DRBC's Zone 5, which extends from the Pennsylvania-Delaware-New Jersey border at Marcus Hook to Liston Point, Delaware (River Miles 78.8 to 48.2), and Zone 6 which extends (River Miles 48.2 to 0.0). The DRBC considers all readily available data sets in its assessments, such as the U.S. Environmental Protection Agency (EPA) STORET database, the U.S. Geological Survey (USGS) NWIS database, the National Oceanographic and Atmospheric Administration (NOAA) PORTS database, as a few examples. The reports provide an assessment of waters in the Delaware River and Bay for support of various designated uses in accordance with Section 305(b) of the Clean Water Act and identifies impaired waters, which consist of waters that do not meet Delaware River Basin Commission's (DRBC) Water Quality Regulations (18 CFR 410).

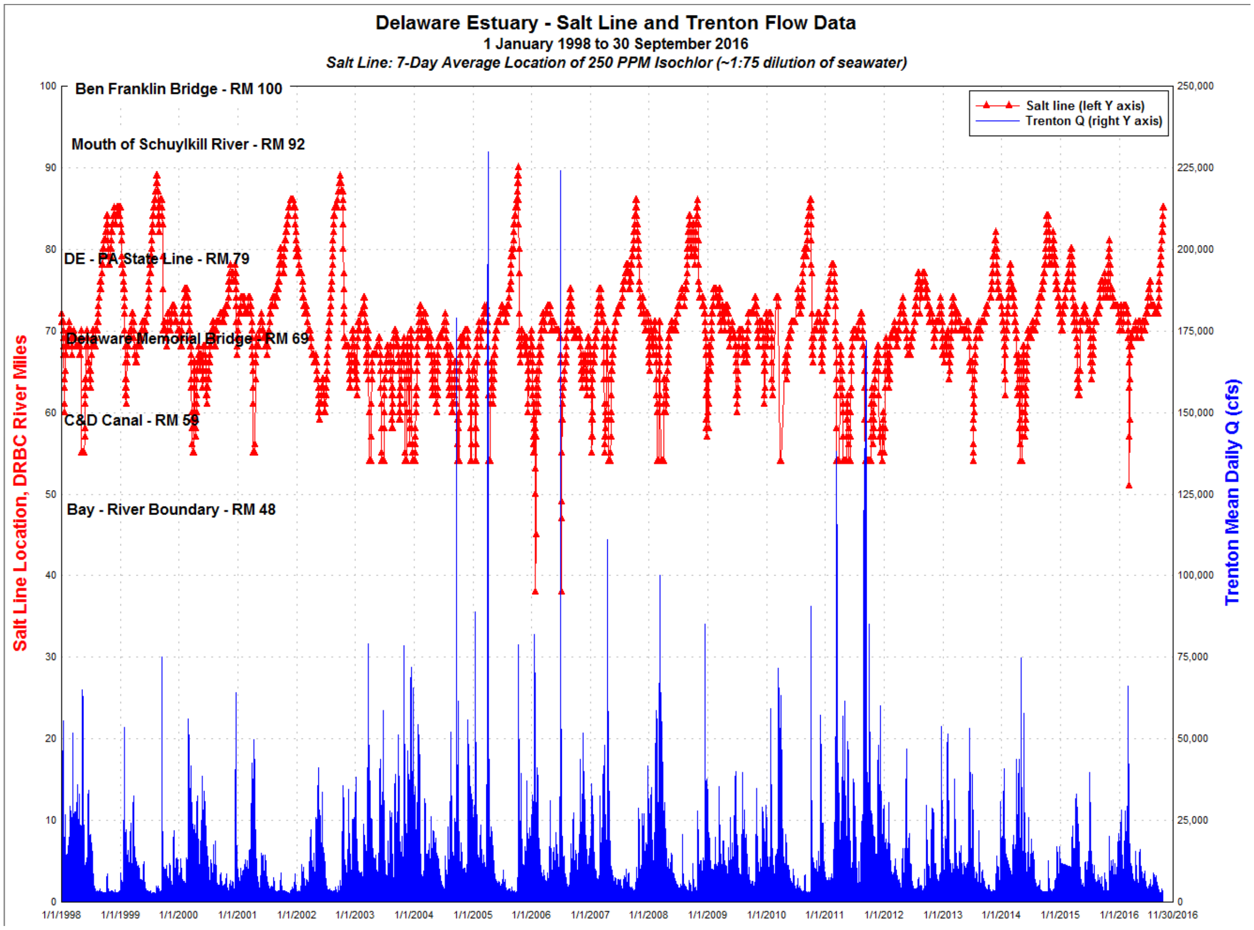
The composite aquatic life assessment for 2012 yields a result of "Not Supporting" for aquatic life (DRBC, 2012). It is important to note, however, that this result is largely driven by DRBC's requirement to categorize as not meeting criteria with 1 exceedance plus 1 confirmatory exceedance and based primarily on fewer than 10% exceedances of criteria. It has been extensively documented that water quality of the Delaware Estuary, particularly upstream in the tidal Delaware River, has greatly improved over the past 50 years since implementation of the 1961 Delaware River Basin Compact and the 1970s Federal Clean Water Act Amendments. Dissolved oxygen levels have increased while phosphorus and nitrogen levels have decreased (Kauffman *et al*., 2009).

Salinity. Salinity within Delaware Estuary waters is important for its effects on habitat suitability for living resources (fish, shellfish, plant life, *etc*.), and its impact on human uses of the water of the estuary (industrial and municipal water supply withdrawals, groundwater recharge, *etc*.). A longitudinal salinity gradient exists with salinity higher at the mouth and downbay and decreases in the upstream direction. The distribution of salinity in the Delaware estuary exhibits significant variability on both spatial and temporal scales; at any given time, salinity reflects the opposing influences of freshwater inflow from tributaries (and groundwater) versus saltwater inflow from the Atlantic Ocean.

The four longitudinal salinity zones within the Delaware Estuary, starting at the bay mouth are: *polyhaline* (18 - 30 ppt) from the mouth of the bay to the vicinity of the Leipsic River (RM 34); *mesohaline* (5 - 18 ppt) from the Leipsic River to the vicinity of the Smyrna River (RM 44); *oligohaline* (0.5 - 5 ppt) from the Smyrna River to the vicinity of Marcus Hook (RM 79), and *fresh* (0.0 - 0.5 ppt) upriver. Although these zones are useful to describe the long-term average distribution of salinity in the estuary, the longitudinal salinity gradient is dynamic and subject to short and long-term changes caused by variations in freshwater inflows, tides, storm surge, weather (wind) conditions, *etc*. These variations can cause a specific salinity value (isohaline) to move upstream or downstream by as much as 10 miles in a day due to semi-diurnal tides, and by more than 20 miles over periods ranging from a day to weeks or months due to storm and seasonal effects on freshwater inflows.

The long-term average salt line location hovers in the vicinity of the Delaware Memorial Bridge (RM 69-70). From 1998 to the present, the salt line data (*i.e*. the 7-day average location of 250 ppm isochlor) shows that it has nearly reached as far north as RM 90 (the mouth of the Schuylkill River) about three times and has flushed downstream below RM 59 (the C&D Canal entrance) about five times, due to sustained high flows at Trenton, New Jersey (Figure 11).

Figure 9 - Delaware Estuary: Salt Line and Trenton Flow Data



4.4 BIOLOGICAL RESOURCES

4.4.1 Vegetation and Wetlands

In the upper reaches of the estuary, including northern Delaware, vegetation is predominantly riparian and includes emergent and forested wetland species such as American beech (*Fagus grandifolia*), American sycamore (*Platanus occidentalis*), black birch (*Betula lenta*), black cherry (*Prunus serotina*), black gum (*Nyssa sylvatica*), boxelder (*Acer negundo*), common persimmon (*Diospyros virginiana*), eastern cottonwood (*Populus deltoids*), eastern red cedar (*Juniperus virginiana*), hackberry (*Celtis occidentalis*), hickory (*Carya* spp.), pin oak (*Quercus palustris*), red maple (*Acer rubrum*), sweetgum (*Liquidambar styraciflua*), tuliptree (*Liriodendron tulipifera*), and willow (*Salix nigra*). Upland forests in this area are typically transitional and dominated by oak (*Quercus* spp.). Non-native flora, including common reed (*Phragmites australis*), mile-a-minute vine (*Persicaria perfoliatum*), and purple loosestrife (*Lythrum salicaria*).

As previously mentioned in Section 4.4.3, salinity is a key factor in the distribution of vegetation species in an estuarine environment. Plant location is dependent upon their salinity tolerance. Freshwater species tend to be located along the coastline above Wilmington as well as inland, while species that are more salt-tolerant occur in coastal areas downriver and downbay. Historically, the Delaware River and all tidal tributaries were fringed with wetlands. The Delaware Estuary's large tidal freshwater prism runs from Trenton, New Jersey to around Wilmington, Delaware. Tidal wetlands provide essential spawning, foraging, and nesting habitats for both land and aquatic species. Wetlands absorb contaminants, nutrients, and suspended sediments from the water column, and help buffer the impact of storm surge and flooding. The values of these ecosystems went largely unrecognized in the past, and most of these wetlands on both shores have been eliminated through development. Losses are most severe in the urban corridor. Freshwater riverine wetland plant species commonly found upriver include arrow arum (*Peltandra virginica*), spikerush (*Eleocharis palustris*), pickerelweed (*Pontederia cordata*), blue flag (*Iris versicolor)*, American threesquare (*Scirpus americanus)* and common reed (*Phragmites australis*).

The Delaware Vegetation Communities Guide follows the format of the National Vegetation Classification System (NVCS). The State of Delaware covers 1,524,864 acres of which 1,231,394 acres are terrestrial and 293,470 are water. Some of the larger of the 130 vegetation communities identified in the state include agricultural fields, cultivated lawn, and salt marsh (Coxe, 2009).

Wetlands are considered one of the most productive ecosystems in the world and play an important role in the maintenance of water quality. Dense vegetation filters sediment nutrients from the water and provides coastal resiliency to storms and erosion. Wetlands provide habitat and food for a variety of wildlife and tidal marshes in particular are vital as nursery areas for economically valuable fish and crustaceans. In the Delaware Estuary, tidal wetlands are flooded twice daily by tides and this tidal fluctuation maintains their high productivity. Nontidal wetlands typically occur in freshwater zones such as lakes and upriver streams. As much as 25% of the state of Delaware is covered by wetlands with over 320,000 acres inventoried. Tidal wetlands comprise 23% of the state's wetlands while non-tidal wetlands comprise the remainder (Tiner *et al*., 2011).

Representative wetland plant species follow the salinity gradient. Typical freshwater marsh species include common threesquare (*Scirpus americanus*), dotted smartweed (*Polygonum punctatum*), common spikerush (*Eleocharis palustris*), wild rice (*Zizania palustris*), pickerelweed (*Pontederia cordata*), and arrow arum (*Peltandra virginica*). Saltwater marsh species include smooth cordgrass (*Spartina alterniflora*), salt hay (*Spartina patens*), spikegrass (*Distichlis spicata*), and marsh elder (*Iva frutescens*).

New Castle County has about 47,000 acres of tidal wetlands within the project area and most are located south of the Chesapeake and Delaware (C&D) Canal. Between the Christina River and Silver Run, the wetlands are generally small patches dominated by common reed (Phragmites australis). Marshes are larger in size south of Silver Run and the predominant plant is cordgrass. South of Blackbird Creek, salt hay and spikegrass are more dominant along the Delaware Bay shoreline, with cordgrass more commonly found on the inland side of marshes. Salt hay and spikegrass grow along the lower two miles of the Smyrna River, while cordgrass is found along the tidal stream portion as far west as the town of Smyrna. There are numerous shallow groundwater-fed ponds in southern New Castle County with freshwater marshes.

Kent County has approximately 123,000 wetland acreage. Wetland vegetation extends the entire length of the county's 35-mile Delaware Bay shoreline. Marshes are largest in the vicinity of Bombay Hook (23,000 acres) and further south in four marsh-oriented state conservation areas including Little River, St. Jones River, and Mispillion River.

Sussex County has approximately 150,000 acres of wetlands landward of the Delaware Bay's western shore. Dominant plants in salt marshes include smooth cordgrass, salt hay and spike grass. A cordgrass marsh south of the Broadkill River extends 6 miles inland.

4.4.2 Planktonic and Benthic Organisms

The diversity of phytoplankton is high in the Delaware Estuary due to the presence of freshwater, brackish, and marine environments. Several hundred species occur along the length of the estuary. The most prominent are diatoms (Class Bacilliariophyceae) (Pennock and Herman, 1988). In the upper reaches of the estuary, phytoplankton have lower diversity and are limited by water quality (*i.e.* the area of higher anthropogenic influences and the turbidity maximum). Chlorophytes (green algae) and diatoms were the predominant groups (ANSP, 1981).   This phytoplankton community is indicative of an enriched and turbid system, while many of the species are considered pollution tolerant (*e.g*. *Phizoclonium*, *Oscillatoria*, and *Cladophoroglomata*). Upper estuary phytoplankton exhibit a period of accumulation during the summer months. In the middle estuary region, the accumulation peaks generally occur in spring, and transient blooms in September and November.   Despite lower turbidity and non-nutrient limiting conditions in the lower bay during summer months, chlorophyll concentrations remain relatively low. Small green and brown algae make up much of the summer phytoplankton population in the lower bay (Pennock and Harman, 1988).

Zooplankton occupy a critical position in the food web. These small drifting animals feed on phytoplankton and provide a large food source for larger aquatic animals. The ANSP (1981) found that the zooplankton found in the upper reaches of the project area consisted primarily of ciliates (Codonella) and heliozoan protozoa (Actinosphaerium, Staurophyra) and rotifers (Keratella). The zooplankton community in these upper portions of the estuary showed a high dominance of a few taxa and populations were not particularly abundant. In the lower more saline reaches, 30 different species of zooplankton have been identified, with more than 85% of them Copepods. Other common species include *Halicyclops fosteri*, *Eurytemora affinis*, and *Acaryia tonsa*. Mysid shrimp (*Neomysis americana*) also provide a significant food source for fish. Ecologically important crustaceans include the grass shrimp (*Palaemonetes* spp.), fiddler crab (*Uca* spp.), and blue crab (*Calinectes sapidus*). The wedge rangia (*Rangia cuneata*) is an important bivalve filter feeder in soft bottom habitats, and the coffee-bean snail (*Melampus bidentatus*) serves as a detrial/algal razer in marshes. Other abundant forms included crabs and shrimp larvae, mollusk larvae, barnacle larvae, and fish eggs and larvae (Pennock and Herman, 1988).

The distribution of benthic macroinvertebrates within the Delaware Estuary is determined by salinity, sediment type, and current velocity. In the upper reaches where waters are brackish to fresh, Oligochaeta and Hirundinea were the most abundant, although blue crabs have also been found in this stretch of the river (PECO, 1977). The ANSP (1981) concluded that the predominant macroinvertebrate fauna are sparse in this portion of the upper estuary, citing low species diversity due to the more industrialized character of the river. The species most dominant were amphipods (Gammarus); isopods (Cyathura, Chiridotea); and tubificid worms (Limnodrilus).

In contrast to upper estuary sites, species diversity is greater, with more taxa contributing significantly to the biota, in the more saline bay region. Over 30 taxa of polychaetes, mollusks, and crustaceans were found. Important species include the polychaete *Sabellaria vulgaris*, the mysid shrimp Neomysus Americana, amphipods Unciola and Acanthohaustorius, and the snail Nassarius trivittatus. Decapod crustaceans in the lower bay include several species of crab (Ovalipes, Panopeus, Cancer, Libinia) and the sand shrimp (Crangon septemspinosa) (RMC, 1988).

The sandbuilder worm (*Sabellaria vulgaris*) occurs along temperate shorelines, including in the Mid-Atlantic, but only in dense, reef-like structures in the lower portion of the Delaware Estuary (Brown and Miller, 2011). Similar to oysters, sabellariid tube-building worms create structural habitat for a variety of benthic invertebrates, higher diversity than surrounding sediments, and provides an additional stabilizing force along beaches (Wells, 1970; Gore *et al*., 1978; Dubois *et al*., 2002). Intertidal aggregations have been found between Slaughter Beach and Cape Henlopen, extending parallel to the shoreline (Amos, 1966; Wells, 1970; Curtis, 1973, 1975).

A recent benthic macroinvertebrate assessment was completed in the lower bay for the Prime Hook National Wildlife Refuge (Scott, 2014). Sediment and biomass analyses were conducted for 56 benthic samples collected from three areas located about 1.0 to 1.5 miles offshore of the refuge in Sussex County. The majority of the samples contained sand with very little silt or clay and species that typically inhabit sandy substrates were prevalent (*e.g.* haustorid amphipods and a small tanaid crustacean). Additionally, species common in higher saline waters of the bay, such as the polychaete worms *Heteromastus filiformis, Streblospio benedicti*, and *Neanthese succinea* were present at many of the sampling sites. In trawl surveys of epi-benthic species (17 benthic sampling locations), a 2-foot oyster dredge was towed for between 2-5 minutes at each station. Nine taxa were collected during the tows and the knobbed whelk (*Busycon carica*) was the most abundant species collected.

The Eastern oyster (*Crassostrea virginica*) is a keystone species of the Delaware Bay from the mouth up to the Bombay Hook Wildlife Refuge (near Leipsic, Delaware in the upper bay), with the southernmost of these beds occurring in the mid-bay region. Delaware oyster seed beds cover about 1,331acres (Wilson *et al*., unpub.). Oysters have also been a valuable food source and part of the Mid-Atlantic's cultural history for centuries. Oyster populations dropped significantly in the 1950s due primarily to the prevalence of an oyster disease (MSX). Populations recovered slightly during the 1970s and 1980s only to be hit again by a second disease (Dermo). Since 1989, the condition of the bay's oysters has deteriorated despite careful management and a limited controlled fishery.

Blue crabs have been reported to occur above Wilmington but are more common in the higher salinity waters of the bay. The blue crab (*Callinectes sapidus*) inhabits nearshore coastal and estuarine habitats. Delaware Bay is the northernmost range of blue crab distribution (Helser and Kahn, 2001). Generally the crabs reside in shallow lower salinity waters in spring and summer and higher salinity deeper waters in winter.

Another of the Delaware Estuary's notable species is the horseshoe crab (*Limulus polyphemus*). The crabs spend the bulk of their lives on the bay and ocean bottom but gather on bay beaches during the high tides of the full and new moons in May and June. Beach morphology (*i.e.* sediment type and grain size) affects oxygen, temperature, and moisture gradients, which in turn, affect egg survivability. Horseshoe crabs appear to favor sandy beaches with a gentle slope (Botton and Loveland, 1987). In addition to the intertidal zone used for spawning, horseshoe crabs use the adjacent shallow waters and tidal flats as nursery habitat for juvenile life stages. Horseshoe crab eggs provide a critical food resource to migrating shorebirds, and are economically valued as bait for the American eel and conch fisheries, and in the manufacture of medical testing products.

4.4.3 Fish

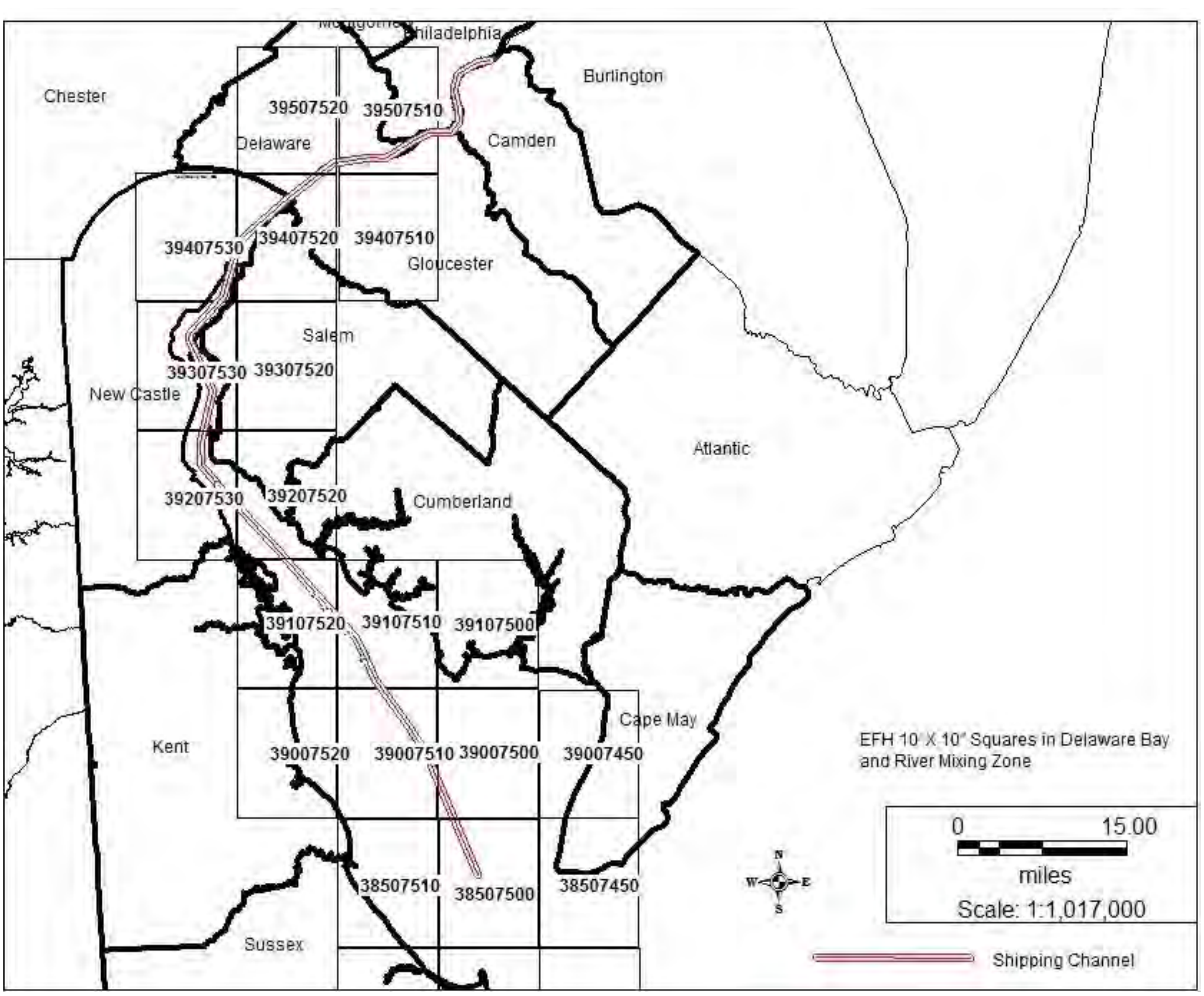
The Delaware Estuary also supports over 200 fish species, both residents and migrants: freshwater species, freshwater species that occasionally enter brackish water; estuarine species that remain in the estuary their entire life cycle, anadromous and catadromous species passing through different salinity reaches of the estuary, marine species which regularly spend time in the estuary, marine species that utilize the estuary as a nursery and/or spawning area; and adventitious visitors of oceanic origin (ANSP, 1981). River herring (*Alosa* spp.) are anadromous species that live in the ocean but migrate upbay to spawn in freshwater reaches of the river. Some commercially and recreationally important fisheries include striped bass (*Morone saxatilis*), weakfish (*Cynoscion regalis*), summer flounder (*Paralichthys dentatus*), croaker (*Micropogonias undulates*), and menhaden (*Brevoortia tyrannis*) (McHugh, 1981). There are at least 31 species that are commercially harvested from the Delaware Estuary. Catadromous species, such as the American eel (*Anguilla rostrata*), spend their lives within the estuary, but migrate to the ocean to spawn. Species such as the spottail shiner (*Notropis hudsonius*) and the channel catfish (*Ictalurus punctatus*) are year-round residents of fresh and brackish waters and do not migrate to any significant degree to spawn. Species such as the Atlantic silverside (*Menidia menidia*) and bluefish (*Pomatomus saltatrix*) spend their lives in higher salinity waters and spawn in the bay. Atlantic menhaden (*Brevoortia tyrannus*) and the Atlantic croaker (*Micropogon undulates*) spawn offshore and use the bay as a nursery area.

Other notable fish inhabitants include several species of sharks skates and rays, including sand tiger (*Carcharias taurus*) and sandbar (*Carcharhinus* plumbeus) sharks, the cow-nosed stingray (*Rhinoptera* bonasus) and clear-nose skate (*Raja eglanteria*). The lower portion of the Delaware Bay has been designated as a Habitat Area of Particular Concern (HAPC) for sandbar shark. Pregnant females enter the bay between late spring and early summer, give birth and depart shortly after while neonates (young of the year) and juveniles (ages 1 and over) occupy nursery grounds until migration to warmer waters in the fall (Rechisky and Wetherbee, 2003). Neonates return to their natal grounds as juveniles and remain there during the summer. Tagging studies done by Merson and Pratt (2001) found that sandbar sharks use the southwestern portion of the bay as pupping grounds and the entire bay for summer feeding nursery area.

4.4.3.1 Essential Fish Habitat

Under provisions of the reauthorized Magnuson-Stevens Fishery Conservation and Management Act of 1996, the Delaware Estuary, spanning from the northern part of the state of Delaware south to the bay mouth, is designated as Essential Fish Habitat (EFH) for species with Fishery Management Plans (FMP's) and their important prey species. The area includes fifteen 10 minute x 10 minute squares. The map depicted in Figure 12 shows the locations within the Delaware Estuary that the National Marine Fisheries Service (NMFS) identifies as the mixing zone.

Figure 10 - Delaware Estuary Mixing Zone Essential Fish Habitat



The study area contains EFH for various life stages for 25 species of managed fish and shellfish. Table 15 presents the managed species and their life stage that EFH is identified for these fifteen 10 x 10 minute squares covering the potential affected area.

Table 16 – Summary of Essential Fish Habitat Designated Species & Their Life Stages

Managed Species	Eggs	Larvae	Juveniles	Adults	Spawning Adults
Redfish (Sebastus fasciatus)	n/a				
Red Hake (Urophycis chuss)				X	
Windowpane flounder (Scopthalmus aquosus)	X	X	X	X	X
Atlantic sea herring *(Clupea harengus)*			X	X	
American plaice (Hippoglossoides platessoides)			X		
Bluefish (Pomatomus saltatrix)			X	X	
Long finned squid *(Loligo pealei)*	n/a	n/a			
Short finned squid *(Illex ilecebrosus)*	n/a	n/a			
Atlantic butterfish *(Peprilus tricanthus)*		X	X	X	
Summer flounder (Paralicthys dentatus)			X	X	
Scup (Stenotomus chrysops)			X	X	
Black sea bass (Centropristus striata)			X	X	
Surfclam (Spisula solidissima)	n/a	n/a			
Ocean quahog (Artica islandica)	n/a	n/a			
Spiny dogfish (Squalus acanthias)	n/a	n/a			

Managed Species	Eggs	Larvae	Juveniles	Adults	Spawning Adults
King mackerel (Scomberomorus cavalla)	X	X	X	X	
Spanish mackerel (Scomberomorus maculatus)	X	X	X	X	
Cobia (Rachycentron canadum)	X	X	X	X	
Clearnose skate (*Raja eglantteria*)			X	X	
Little skate (Leucoraja erinacea)			X	X	
Winter skate (Leucoraja ocellata)			X	X	
Sand tiger shark (Carcharias taurus)		X neonates*		X	
Dusky shark (Carcharhinus obscurus)		X neonates*			
Sandbar shark (Carcharhinus plumbeus)		X neonates* (HAPC)	X (HAPC)	X (HAPC)	

Notes:

1.) N/A indicates species either have no data available on designated life stages, or those life stages are not present in the species reproductive cycle.
2.) Neonates* indicates sharks do not have a larval stage.

4.4.4 Wildlife

Reptiles and Amphibians. The American toad (*Bufo americanus*) and the leopard frog (*Rana pipens*) are amphibian residents of the study area. Reptiles include the common snapping turtle (*Chelydra serpentina)*, eastern garter snake (*Thamnophi sirtalis*), diamondback terrapin (*Malaclemys terrapin*), and smooth green snake (*Opheodrys vernalis*).

Across their range, diamondback terrapin (*Malaclemys terrapin*) populations are in decline (USFWS, 2016). The state of Delaware lists the diamondback terrapin as a species of greatest conservation need within their State Wildlife Action Plan. The USFWS lists the species as an Appendix II species under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). The diamondback terrapin is the only North American turtle that lives exclusively in brackish waters associated with estuaries, coastal bays and salt marshes. Terrapins are heavily dependent on shoreline conditions to satisfy its habitat requirements. The terrapin spends most of it life in the water, but it must come ashore for nesting. Nesting normally occurs at bare or sparsely vegetated, unshaded, sandy areas above the level of the normal high tides (Palmer and Cordes, 1988; Roosenburg, 1990; Burger and Montevecchi, 1975). Nesting season extends from the beginning of June until the end of July, and terrapins often aggregate in the waters adjacent to the nesting beaches during the nesting season (Roosenburg, 1993).

The primary habitats of hatchlings and juveniles up to about the third year appear to be marshes and tidal flats (Roosenburg *et al.*, 2004; Draud *et al.*, 2004). At this stage, they avoid open water, but instead actively seek to hide under vegetation or debris in an apparent attempt to avoid being preyed upon (Lovich *et al.*, 1991; Burger, 1976; Pitler, 1985; Gibbons *et al.*, 2001). It appears necessary that such wetland habitat be located in proximity to the nesting sites, and most terrapin nesting studies have indeed reported the presence of adjacent marshes (Roosenburg 1991; Burger and Montevecchi, 1975; Feinberg and Burke, 2003; Butler *et al.*, 2004; Chambers, 2000; Szerlag and McRobert, 2006; Aresco, 1996).

<u>Birds</u>. Many species of birds common to the Delaware Estuary are inhabitants of the wetlands and tidewaters. Other species use wetlands and beaches during their migrations. The Delaware Estuary is situated on the Atlantic Flyway and an important migratory route for many species of shorebirds and waterfowl. Migratory shorebirds such as the ruddy turnstone (*Arenaria interpres*), short-billed dowitcher (*Limnodromus griseus*), semi-palmated sandpiper (*Calidris pussilla*), sanderlings (*Calidris alba*), and the imperiled red knot (*Calidrus canutus*) fly from southern Argentina each spring and stop at the Delaware Bay to rest and feed on amphipods, chironomids, and horseshoe crabs (Chipley *et al*., 2003). The total number of shorebirds counted in aerial surveys in Delaware Bay over a 6-week migration period from May to mid-June range from 250,000 to more than 1,000,000 birds. Birds observed in tidal marsh habitats are estimated at 700,000.

Waterfowl common to the area include mallard (*Anas platyrhynchos*), American black duck (*Anas rubripes*), northern pintail (*Anas acuta*), and wood duck (*Aix sponsa*). Canada geese (*Branta Canadensis*) and snow geese (*Chen caerulescens*) frequent the region during fall, winter, and spring. Saltmarshes are frequented by clapper rail (*Rallus longirostris*), seaside sparrow (*Ammodramus maritimus*), saltmarsh sparrow (*Ammodramus caudacutus*), redwinged blackbird (Agelaius phoeniceus)and willet (*Tringa semipalmata*). Wading bird species common to the area include the snowy egret (*Leucophoyx thula*), glossy ibis (*Plegadis falcinellus*), and great blue heron (*Ardea herodias*). Over a dozen raptors reside or migrate through the study area, such as the red-tailed hawk (*Buteo lineatus*), broad-winged hawk (*Buteo platypterus*), northern harrier (*Circus cyaneus*), American kestrel (*Falco sparverius*), osprey (*Pandion* *haliaetus*) and sharp-shinned hawk (*Accipiter striatus*). Typical owls include the barn owl (*Tyto alba*), great horned owl (*Bubo virginianus*) and long-eared owl (*Asio otus*).

Mammals. Many species of mammals inhabit the shoreline, tidal marshes, and interior forests. Common to the study area are white tail deer (*Odocoileus viiginianus*), red fox (*Vulpes vulpes*), raccoon (*Procyon lotor*), long-tailed weasel (*Mustela frenata*), striped skunk (*Mephitis mephitis*), river otter (*Lutra canadensis*), muskrat (*Ondatra zibethicus*), gray squirrel (*Sciurus carolinensis*), eastern chipmunk (*Tamia striatus*), eastern cottontail (Sylvilagus floridanus), Virginia opossum (Didelphis virginiana), white-footed mouse (*Peromyscus leucopus*), meadow vole (*Microtus pennsylvanicus*), and marsh rice rat (*Oryzomys palustris*).

4.4.5 Threatened and Endangered Species

Endangered species are those whose prospects for survival are in immediate danger because of a loss or change of habitat, over-exploitation, predation, competition or disease. Threatened species are those that may become endangered if conditions surrounding the species begin or continue to deteriorate. Species may be classified on a Federal or State basis. The Delaware Estuary is within the historic range of 22 Federally-listed threatened or endangered species: 17 animals and 5 plants (Table 16).

Table 17 – Delaware Estuary Threatened & Endangered Species

Status	Species
T	Bat, Northern long-eared (*Myotis septentrionalis*)
E	Piping Plover (*Charadrius melodus*)
T	Knot, red (*Calidris canutus rufa*)
T	Sea turtle, green: except where endangered (*Chelonia mydas*)
E	Sea turtle, hawksbill Entire (*Eretmochelys imbricata*)
E	Sea turtle, Kemp's ridley Entire (*Lepidochelys kempii*)
E	Sea turtle, leatherback Entire (*Dermochelys coriacea*)
E	Loggerhead Turtle (*Caretta caretta*)
E	Sturgeon, shortnose Entire (*Acipenser brevirostrum*)
E	Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*)
T	Turtle, bog (=Muhlenberg) northern (*Clemmys muhlenbergii*)
E	Whale, fin Entire (*Balaenoptera physalus*)

E	Whale, humpback Entire (*Megaptera novaeangliae*)
E	Whale, North Atlantic Right Entire (*Eubalaena glacialis*)
E	Sei Whale (*Balaenoptera borealis*)
E	Sperm Whale (*Physeter macrocephalus*)
T	Amaranth, seabeach (*Amaranthus pumilus*)
T	Beaked-rush, Knieskern's (*Rhynchospora knieskernii*)
E	Dropwort, Canby's (*Oxypolis canbyi*)
T	Pink, swamp (*Helonias bullata*)
T	Pogonia, small whorled (*Isotria medeoloides*)

On May 4, 2015, the USFWS designated the northern long-eared bat (*Myotis septentrionalis*) as a threatened species under the Endangered Species Act (ESA). In more recent years, the Federally-listed and State-listed endangered piping plover (*Charadrius melodus*) have been occasionally sited on sandy beaches of the lower bay but is not known to have nested along the bayshore. The Service proposed in 2006 to list the *rufa* subspecies of the red knot (*Calidris canutus rufa*) due to the high magnitude of imminent threats to the subspecies, and as of September 2013 the Service listed the red knot as a threatened species throughout its range, including Delaware.

Piping plover. Outside of the study area, the oceanfront beaches of southern Delaware support a small breeding population of the Federally threatened piping plover (*Charadrius melodus*). Over the last several years during the nesting season, 10 or fewer breeding pairs have been present and have been restricted to Cape Henlopen State Park (especially the Point of Cape Henlopen and the Gordon’s Pond area). Earlier records have shown sporadic nesting with Delaware Seashore State Park which extends southward to the vicinity of the Indian River Inlet (USFWS, 2016).

The Atlantic Coast piping plover breeding population nests prefers wide, flat, sparsely vegetated barrier beach habitats. These habitats include abundant moist sediment areas that are associated with dune blowouts, washover areas, sand spits, unstabilized and recently closed inlets, ephemeral pools and sparsely vegetated dunes. Locations suitable for breeding are also limited because these ground nesting birds are especially sensitive to human-related disturbance and predation. In Delaware the birds begin arriving in mid-March to set up territories and perform courtship behavior. Egg laying begins mid-April. The birds may renest one or more times if their nest is lost prior to hatching. Hatching takes place from mid-May to mid-July. Generally the young would be completely fledged by September 1 and often earlier in July or August. Piping plover chicks are somewhat unusual in that they must leave the nest shortly after hatching in order to begin foraging for food. Since the chicks are flightless, suitable feeding areas must be located within a reasonable walking distance of the nest site. Feeding areas include the wet portion of the beach, wrack lines, moist washover areas, and shorelines and flats associated with coastal lagoons and ponds. If the vegetation is too dense, the chicks may be deterred from reaching the feeding areas. The wave overwash that occurs during storms can be beneficial by creating low moist feeding areas and by keeping the vegetation from becoming too dense (USFWS, 2016).

<u>Red Knot</u>. The Delaware Bay shoreline is known to be a major stopover site for the Federally threatened red knot, during their northward migration in the spring. The red knots perform an unusually long distance migration from their primary wintering areas in southern South America to their breeding areas in the Canadian Arctic. While the red knots normally feed primarily on small bivalves, their spring migration has evolved so that the Delaware Bay area has become their primary stopover location due to the extraordinary abundance of horseshoe crab eggs. The eggs are considered to be a key factor that allows red knots to gain sufficient body condition to complete the migration and accomplish their breeding activity. The reduced availability of horseshoe crab eggs at the Delaware Bay stopover due to commercial harvest of the crabs is believed to have been a primary cause for the decline of the red knot population that was observed in the early 2000s.

In Delaware during the spring migration, the birds are heavily concentrated along the shoreline reach between Broadkill Beach and Bombay Hook National Wildlife Refuge. Large numbers typically arrive in mid-May and depart by the end of the first week in June. Most of their time is spent feeding on horseshoe crab eggs which are available on the intertidal beaches, although they also make comparatively limited use of the exposed mud flats and pans within the adjacent marshes and impoundments for roosting. Red knots are relatively uncommon along Delaware Bay during the southward fall migration, which peaks in August, and along the Delaware ocean coast during both spring and fall migration periods (USFWS, 2016).

<u>Sea turtles</u>. There are five Federally-listed threatened or endangered sea turtles that occasionally enter the Delaware estuary including the endangered Kemp's ridley turtle (*Lepidochelys kempii*), leatherback turtle (*Dermochelys coriacea*) and hawksbill turtle (*Eretmochelys imbricata*), and the threatened green turtle (*Chelonia mydas*) and loggerhead turtle (*Caretta caretta*). With the exception of the loggerhead these species breed further south from Florida through the Caribbean and the Gulf of Mexico. The loggerhead may have historically nested on coastal barrier beaches. No known nesting sites are within the project area. All of these species, with the exception of the hawksbill turtle, are listed in the State of Delaware.

<u>Whales</u>. There are six species of Federally-endangered whales that have been observed along the Atlantic coast that, on occasion, have traveled into the Delaware Bay. These include the sperm whale (*Physeter catodon*), fin whale (*Balaenoptera physalus*), humpback whale (*Megapter novaeangliae*), blue whale (*Balaenoptera musculus*), sei whale (*Balaenoptera borealis*) and North Atlantic right whale

(*Balaena glacialis*). These are migratory animals that travel north and south along the Atlantic coast. All six species are also listed by the state of Delaware.

Shortnose sturgeon. The shortnose sturgeon (*Acipenser bevirostrum*) is a Federally-listed endangered species, and occurs primarily in the upriver freshwater portion of the Delaware Estuary. Interbasin movements have been documented for shortnose sturgeon between the Delaware River and Chesapeake Bay via the C&D Canal (NMFS, 2011).

Atlantic sturgeon. In 2010, the NMFS proposed to list three Distinct Population Segments (DPSs) of the Atlantic sturgeon (*Acipenser oxyrhinchus oxyrinchus*) in the Northeast Region. The New York Bight DPS, which includes Atlantic sturgeon whose range extends into coastal waters of Long Island, the New York Bight, and the Delaware Bay, from Chatham, MA to the Delaware-Maryland border of Fenwick Island, as well as wherever these fish occur in coastal bays, estuaries, and the marine environment from the Bay of Fundy, Canada to the Saint Johns River, FL. In 2012, NMFS issued rulings listing five DPSs of Atlantic sturgeon as threatened or endangered under the ESA. All five of these DPSs may occur within waters of the Delaware Bay. Atlantic sturgeon are anadromous, spending a majority of their adult life phase in marine waters, migrating upriver to spawn in freshwater reaches of the Delaware River, then migrating to lower estuarine brackish areas during juvenile growth phases. Adults migrate along the ocean coast of New Jersey and Delaware.

In addition to the Atlantic and shortnose sturgeons, sea turtles, and whales, the NMFS has jurisdiction over other listed species that are more likely to occur in the lower reaches of the estuary. Some marine mammals may be classified as threatened or endangered species, but all fall under the jurisdiction of the Marine Mammal Protection Act. The marine mammal species that are commonly encountered in the Delaware Estuary are bottlenose dolphin (*Tursiops truncatus*), harbor porpoise (*Phocoena phocoena*), harbor seal (*Phoca vitulina concolor*), and gray seal (*Halichooerus grypus*). Additional species not commonly sighted but which may incidentally utilize the estuary are pygmy sperm whale (*Kogia breviceps*), long-finned pilot whale (*Globicephala melaena*), harp seal (*Cystophora cristata*), and ringed seal (*Poca hispida*).

Raptors. Although the bald eagle (*Haliaeetus leucocephalus*) and the peregrine falcon (*Falco* peregrines) have been recently removed from the Federal endangered species list, these raptors do occur in the project area. The bald eagle is still protected under the Bald and Golden Eagle Protection Act and both birds are protected under the Migratory Bird Treaty Act.

The following is a list of the state endangered species of Delaware:

Birds

- Pied-billed Grebe[BR] (Podilymbus podiceps)
- Northern Harrier[BR] (Circus cyaneus)
- Broad-winged Hawk[BR] (Buteo platypterus)
- Black-Crowned Night-Heron (Nycticorax nycticorax)

- Yellow-Crowned Night-Heron (Nyctanassa violacea)
- American Kestrel (Falco sparverius)
- Red Knot (Calidris canutus)
- Piping Plover (Charadrius melodus)
- Short-eared Owl [BR] (Asio flammeus)
- American Oystercatcher (Haematopus palliatus)
- Black Rail (Laterallus jamaicensis)
- Upland Sandpiper (Bartramia longicauda)
- Black Skimmer (Rynchops niger)
- Henslow's Sparrow (Ammodramus henslowii)
- Common Tern[BR] (Sterna hirundo)
- Forster's Tern[BR] (Sterna forsteri)
- Least Tern (Sterna antillarum)
- Cerulean Warbler (Setophaga cerulea)
- Hooded Warbler [BR] (Setophaga citrina)
- Swainson's Warbler(Limnothlypis swainsonii)
- Sedge Wren (Cistothorus platensis)

Note: BR (Breeding Population only)

Reptiles

- Leatherback Turtle (*Dermochelys coriacea*)
- Kemp's Ridley Turtle (*Lepidochelys kempii)*
- Green Turtle (*Chelonia mydas*)
- Loggerhead Turtle (*Caretta caretta*)
- Bog Turtle (*Clemmys muhlenbergii*)
- Corn Snake (*Elaphe guttata guttata*)
- Eastern Scarlet Snake (*Cemophora coccinea*)
- Redbelly Watersnake (*Nerodia erythrogaster)*

Amphibians

- Eastern Mud Salamander (*Pseudotriton montanus montanus)*
- Eastern Tiger Salamander (*Ambystoma tigrinum tigrinum*)
- Barking Treefrog (*Hyla gratiosa*)

Mammals

- Little Brown Bat (*Myotis lucifugus*)
- Northern Long-eared Bat (*Myotis septentrionalis*)
- Delmarva Fox Squirrel (*Sciurus niger cinereus*)

- Blue Whale (*Balaenoptera musculus*)
- Fin Whale (*Balaenoptera physalus*)
- Humpback Whale (*Megaptera novaengliae*)
- North Atlantic Right Whale (*Eubalaena glacialis*)
- Sei Whale (*Balaenoptera borealis*)
- Sperm Whale (*Physeter macrocephalus*)

Fish

- Glassy Darter(*Etheostoma vitreum*)
- Blueridge Sculpin (*Cottus caeruleomentum*)
- Bridled Shiner (*Notropis bifrenatus*)
- Ironcolor Shiner (*Notropis chalybaeus*)
- Atlantic Sturgeon (*Acipenser oxyrhynchus*)
- Shortnose Sturgeon (*Acipenser brevirostrum*)
- Blackbanded Sunfish (*Enneacanthus chaetodon*)

Mollusks

- Yellow Lampmussel *(Lampsilis cariosa*)
- Eastern Lampmussel (*Lampsilis radiata*)
- Dwarf Wedgemussel (*Alasmidonta heterodon*)
- Eastern Pondmussel (*Ligumia nasuta*)
- Brook Floater (*Alasmidonta varicosa*)
- Triangle Floater (*Alasmidonta undulata*)
- Tidewater Mucket (*Leptodea ochracea*)

Insects

- Little White Tiger Beetle (*Cicindela lepida*)
- White Tiger Beetle (*Cicindela dorsalis*)
- Seth Forest Scavenger Beetle (*Hydrochus spangleri*)
- Burgundy Bluet (*Enallagma dubium*)
- Pale Bluet (*Enallagma pallidum*)
- Baltimore Checkerspot (*Euphydryas phaeton*)
- Banner Clubtail (*Gomphus apomyius*)
- Laura's Clubtail (*Stylurus laurae*)
- Midland Clubtail (*Gomphus fraternus*)
- Sable Clubtail (*Gomphus rogersi*)
- Black-tipped Darner (*Aeshna tuberculifera*)
- Taper-tailed Darner (*Gomphaeschna antelope*)
- Black Dash (*Euphyes conspicua*)

- Frosted Elfin (*Incisalia irus*)
- Treetop Emerald (*Somatochlora provocans*)
- Bethany Beach Firefly (*Photuris bethaniensis*)
- Hessel's Hairstreak (*Mitoura hesseli*)
- King's Hairstreak (*Satyrium kingi*)
- Aralia Shoot Borer Moth (*Papaipema araliae*)
- Dark Stoneroot Borer Moth (*Papaipema duplicatus*)
- Maritime Sunflower Borer Moth (*Papaipema maritima*)
- Pitcher Plant Borer Moth (*Papaipema appassionata*)
- Yellow Stoneroot Borer Moth (*Papaipema astuta*)
- Elfin Skimmer (*Nannothemis bella*)
- Rare Skipper (*Problema bulenta*)
- Brown Spiketail (*Cordulegaster bilineata*)
- Sely's Sundragon (*Helocordulia selysii*)
- Marbled Underwing (*Catocala marmorata*)
- Ulalume Underwing (*Catocala ulalume*)
- Mulberry Wing (*Poanes massasoit massasoit*)
- Chermock's Mulberry Wing (*Poanes massasoit chermocki)*

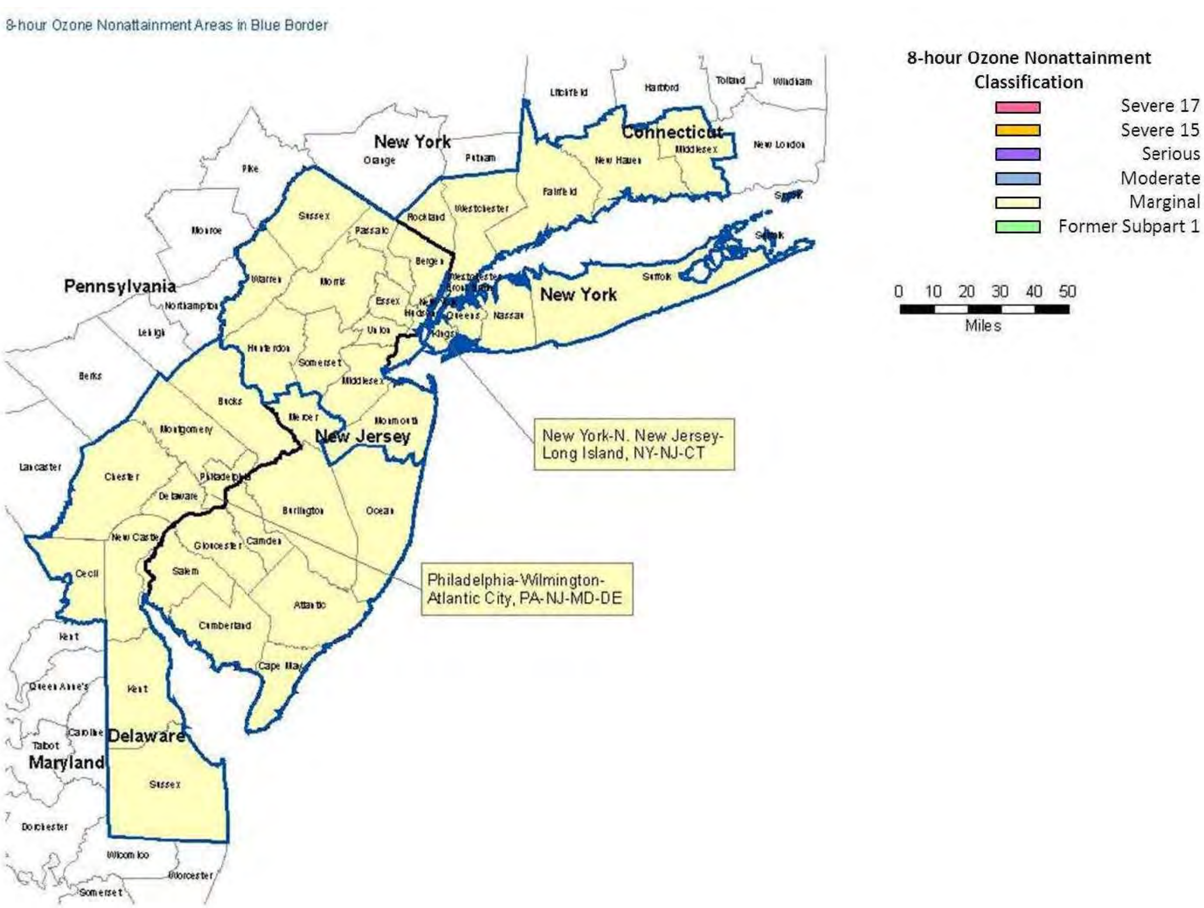
Source:
http://www.dnrec.delaware.gov/fw/NHESP/information/Pages/Endangered.aspx
For information on rare, endangered and threatened flora, refer to the Delaware Natural Heritage Program webpage: http://www.dnrec.state.de.us/fw/rareplant2001.htm.

4.5 AIR QUALITY

Ambient air quality is monitored by the Delaware Department of Natural Resources and Environmental Control's (DNREC) Division of Air and Waste Management and is compared to the National Ambient Air Quality Standards (NAAQS) throughout the state, pursuant to the Clean Air Act of 1970. Six principal "criteria" pollutants are part of this monitoring program, which include ozone (O3), carbon monoxide (CO), sulfur dioxide (SO2), nitrogen dioxide (NO2), particulate matter (PM10 and PM 2.5), and lead (Pb). Sources of air pollution are broken into stationary and mobile categories. Stationary sources include power plants that burn fossil fuels, factories, boilers, furnaces, manufacturing plants, gasoline dispensing facilities, and other industrial facilities. Mobile sources include vehicles such as cars, trucks, boats, and aircraft.

The Clean Air Act requires that all areas of the country be evaluated and then classified as attainment or non-attainment areas for each of the National Ambient Air Quality Standards. Areas can also be found to be "unclassifiable" under certain circumstances. The 1990 amendments to the act required that areas be further classified based on the severity of non-attainment. The classifications range from "Marginal" to "Extreme" and are based on "design values." The design value is the value that actually determines whether an area meets the standard. For the 8-hour ozone standard for example, the design value is the average of the fourth highest daily maximum 8-hour average concentration recorded each year for three years. Their classification with respect to the 8-hour standard is shown in Figure 11. Ground-level ozone is created when nitrogen oxides (NOx) and volatile organic compounds (VOC's) react in the presence of sunlight. NOx is primarily emitted by motor vehicles, power plants, and other sources of combustion. VOC's are emitted from sources such as motor vehicles, chemical plants, factories, consumer and commercial products, and even natural sources such as trees. Ozone and the pollutants that form ozone (precursor pollutants) can also be transported into an area from sources hundreds of miles upwind. The project area is located within the 8-hour Ozone Nonattainment area shown in Figure 13. The entire state of Delaware is in non-attainment and is classified as being "Marginal."

Figure 11 - Non-Attainment Areas for Ozone



4.6 NOISE

Communities adjacent to the Delaware Estuary shoreline are more extensively developed in the upper portion of the estuary along the Delaware River, primarily as residential and commercial properties. Noise in this area is mostly due to traffic along main road corridors. In the bay region of the estuary, roads are located further inland and noise generated is significantly less. Dover Air Force Base is located approximately 4 miles inland from the Delaware Bay in Dover, Delaware. The base generates significant noise from its aircraft during pilot training exercises and missions.

4.7 HAZARDOUS, TOXIC AND RADIOACTIVE WASTE

The PDT contracted with Environmental Data Resource, Inc. (EDR) to produce environmental database, mapping and aerial photograph searches for the 8 (Pickering Beach, Kitts Hummock, Bowers Beach, South Bowers Beach, Big Stone Beach, Slaughter Beach, Prime Hook Beach and Lewes) proposed dredged material placement areas. Database searches were conducted for reports within a one mile radius of addresses located in the approximate centers of the proposed dredged material placement areas. Each notation for each database find was reviewed to determine which were considered closed by the appropriate authority. In cases where the review with inconclusive, the result was considered to be open. The United States Geological Survey, public and private wells are considered to be open. Each remaining address for the database searches was then reviewed for distance from the beachfill area, up or down gradient of the beachfill area, and potential for impact to the planned nourishment of the beaches by pumping.

Facilities with potential for HTRW impacts located within approximately ¼ mile of each dredged material placement location were subjected to further case review and evaluation for potential impacts to the proposed beachfill projects. No reported facilities were found to have the potential to adversely affect the proposed beachfill projects. The USACE project team has elected to have EDR continue to monitor the selected location and EDR will provide updates electronically should any new environmental records become available.

4.8 CULTURAL RESOURCES

Background research indicates that the majority of the Delaware beaches have been previously assessed for cultural resources. Specifically, potential eligible historic properties have been noted at Woodland Beach (historic hotel site), Big Stone Beach (Lighthouse), and Lewes Beach (shipwreck).

4.9 SOCIOECONOMIC

Delaware is 96 miles long and varies from 9 to 35 miles wide. Chief products are manufacturing, mining, fishing industry and agriculture. Delaware ranks 5th in the nation in percentage of cropland, with a total of 39% of state lands cultivated (Atkins, 2009) and leads the nation in the percentage of protected farmland through agricultural easements.

Numerous seaside resorts and small towns are located along the Delaware bayshore. Half of Delaware's 25 mile of coastal beach habitats are State Parks. Tourism in Sussex County alone employs over 10,000 people with abundant beaches, marinas, inland bays, quaint historic towns and golf courses. Two National Wildlife Refuges (NWRs) occur on the bayshore (Bombay Hook and Prime Hook). NWRs enrich people's lives in a variety of ways, and ecotourism derives many monetary and quality of life benefits from the conservation of wildlife and natural habitats surrounding the bayshore communities with public beach access.

Caudill and Henderson (2005) evaluated the economic benefits of Prime Hook NWR to local communities. Prime Hook NWR visitors do not pay entrance fees; however, the state requires the purchase of hunting and fishing licenses. Visitors obtain services and purchases from local businesses for food, lodging and other recreational services. The location of the Refuge in Sussex County is within driving distance of large urban areas including Washington D.C., Philadelphia and Baltimore. In 2004, the Refuge had 106,525 visitors. Table 17 quantifies the local economic effects associated with recreational use of the Refuge in 2004. These values represent employment income, tax revenue dollars and the impact of ecotourism within the three county area by Prime Hook NWR visitor spending. Numbers of annual visitors to the Refuge has continued to climb since 2004.

Table 18 – Local Economic Effects of Prime Hook NWR (2004)

	Residents	Non-Residents	Total
Final Demand	$346,000	$1,110,200	$1,456,600
Jobs	3.0	9.8	12.8
Job Income	$99,400	$320,000	$419,400
Total Tax Revenue	$69,700	$221,300	$291,000

Sexton *et al.* (2007) reported visitor and community attitudes and preferences by way of surveys (1,859) for visitors to the Refuge and area residents. Most refuge visitations are by repeat visitors, with approximately 72% of total visitors from the local area. Wildlife observation was listed as the primary reason for both groups of visitors. Consumptive users primarily engaged in hunting (80%) and fishing (30%) and non-consumptive visitors engaged in the following activities: bird-watching (73%), nature/wildlife viewing (64%), hiking/nature trails (56%), and special education events and tours (collectively 68%). Both residents and non-resident visitors alike expressed strong support for the services and features of the Prime Hook NWR. In addition to the economic benefits of Delaware's NWRs, the project area residential bayfront communities all offer public access and parking areas for recreational activities such as beachcombing, birding, kayaking and fishing.

Demographic data ranks Delaware's human population (830,364) as 45th in the nation. Sussex County is the second most populated county (215,622 people). Residents are predominantly Caucasian persons not of Hispanic origin (75.1%) followed by 12.4% African Americans and 9% Hispanic (U.S. Census Bureau). The poverty rate in 2014 was 13.3%. More than a quarter of all Sussex County homes were occupied for seasonal or recreational use. With 173,533, Kent County is the least populated county in the state. The largest Kent County racial/ethnic group is Caucasian (64.1%) followed by 23.4% African American and 6.4% Hispanic. Approximately 12.9% of Kent County residents live in poverty. New Castle County is the most populated county in the state with 556,779 people. Approximately 60.4% of residents are Caucasian, followed by 23.5% African American and 9.1% Hispanic.

5 EFFECTS ON SIGNIFICANT RESOURCES

5.1 PHYSICAL ENVIRONMENT

5.1.1 Land Use

The communities along the Delaware River/Bay shoreline have a long history of economic activity provided by the Delaware River and Bay. The economies of the towns have changed over the years from ship building and oyster harvesting to fishing and crabbing. The shoreline communities have changed from rural communities to suburbs of the surrounding cities of Wilmington and Philadelphia. Some of the communities in the southern part of the study area have become retirement communities. DNREC has launched an effort called the Delaware Bay Shore Initiative to promote the natural resources surrounding the communities in the Bay Shore and increase the ecotourism to support these communities. The No Action alternative does not provide CSRM and will allow for increasing erosional impacts and coastal storm risk to infrastructure. The action alternatives involving the construction of hardened structures impede the natural shoreline interface between the intertidal zone and the upland sandy beach and can accelerate erosion in other adjacent areas. The TSP to provide CSRM with beach nourishment will help the shoreline communities be resilient against future storms and help provide economic sustainability, recreational use and restore natural habitat.

5.1.2 Physiography and Geology

Under the No Action Plan, storms will continue to erode the shoreline, exposing the underlying peat and reducing available sandy beach habitat for wildlife and CSRM for developed stretches. A loss of the barrier beach could result in flood inundation to interior salt marshes, forests and neighboring farmland.

In the lower Delaware Bay, the rate of erosion and landward migration of the shoreline at the Prime Hook NWR was evaluated from 1937 to 2012 via historic aerial images (Psuty *et al.*, 2010). The rate of erosion has accelerated from 3 ft/yr between 1937 and 1954 to 10 ft/yr between 1997 and 2012. Shoreline position has been monitored on the ground every spring and fall since 2011. Between spring 2011 and spring 2014, the shoreline retreated approximately 27 feet in most areas, which represents a continued shoreline erosion rate of about 10 ft/yr. However, the total shoreline retreat in many areas along the southern bayshore over that time was approximately 30 to 60 ft/yr, which is roughly 20 ft/yr (Psuty *et al.*, 2010).

Alternative plans entailing the construction of a hardened structure, such as a breakwater or groin would not impact the area geology, but would alter the physiography of the beach. The TSP entails restoring the berm and dune system fronting the developed sections of the bayshore with periodic nourishment to provide improved CSRM, while restoring the natural physiography and habitat. In addition, beach nourishment using compatible grains size materials does not adversely impact the geology of the study area.

5.1.3 Sediment Quality

Delaware Estuary sediment quality is described in the 1992 EIS (USACE, 1992), 1997 SEIS (USACE, 1997), the 2009 EA (USACE, 2009), the 2011 EA (USACE, 2011) and the 2013 EA (USACE, 2013) for the DRMCD project. This information is incorporated by reference.

The 1997 SEIS (USACE, 1997) sediment quality data included bulk sediment analysis, elutriate sediment analysis, Toxicity Characteristic Leaching Procedure (TCLP) analysis, biological effects based sediment testing and high resolution PCB congener analysis for the DRMCD project. Based on a review by the EPA, the tests showed no toxicity or bioaccumulation of any significance. The USFWS commented that the results of the chemical analysis indicated that contaminated loads in the sediments tested are low. These chemical analyses investigated sediments extending approximately 102.5 river miles from Philadelphia to the mouth of the Delaware Bay. Chemical contaminants are more likely to occur in the upper reaches of the estuary where smaller grain size sediments are found (chemical constituents bind to smaller grain size sediments) than in the lower reaches of the Delaware Bay where the proposed beneficial use sediments occur.

This feasibility report focuses on sediment quality data for the Main Channel from the Miah Maull and Brandywine Ranges within lower Reach E only (the proposed maintenance dredged material source area for the TSP). For the DRMCD project, the sediments tested within this ranges exhibited large grain sizes and no contaminants were detected in these samples. The sediment grain size samples obtained in 2008 as part of the Delaware Estuary Program DEBI (Delaware Estuary Benthic Inventory) indicated that the percent sand in Lower Reach E was 81-100%.

Prior to the deepening operations in 2015, sediment grain size data for Reach E bottom sediments collected by USACE between 1991 and 2013 (176) samples were re-evaluated to identify the sub-reaches where economic loading would be permitted during dredging. Economic loading refers to the practice of filling a hopper dredge beyond overflow to achieve a higher density load (discussed in greater detail in Section 5.2.2). The 2013 EA (USACE, 2013) considered both the environmental effects of economic loading (*i.e.* turbidity) and the economic benefits and concluded that economic loading could be conducted in Delaware Bay with minimal adverse environmental impacts and significant economic benefits.

Reach E was divided into 9 subsections. For sub-Reach E-7 through E-9, the weighted average for coarse-grained material was estimated to be approximately 93 percent, with a confidence interval of 90 percent that another sample collected within E-7 through E-9 would be between 90 and 95 percent coarse grained material. Coarse grained material is defined as the portion of the sample that includes sand (passing the #4 to #200 screen) and gravel (passing the #3 to #4 screen). Fine grained material is defined as the portion of the sample that passes the #200 screen and includes silts and clays. The grain size distribution for the sediment samples collected within Reach E ranged from 17 to 98% coarse grained material. Two sub-reaches, sub-Reach E-2 and E-5 has coarse grained material percentages of 17 and 51%, respectively; therefore, economic loading was not conducted in these two sub-reaches (USACE, 2013).

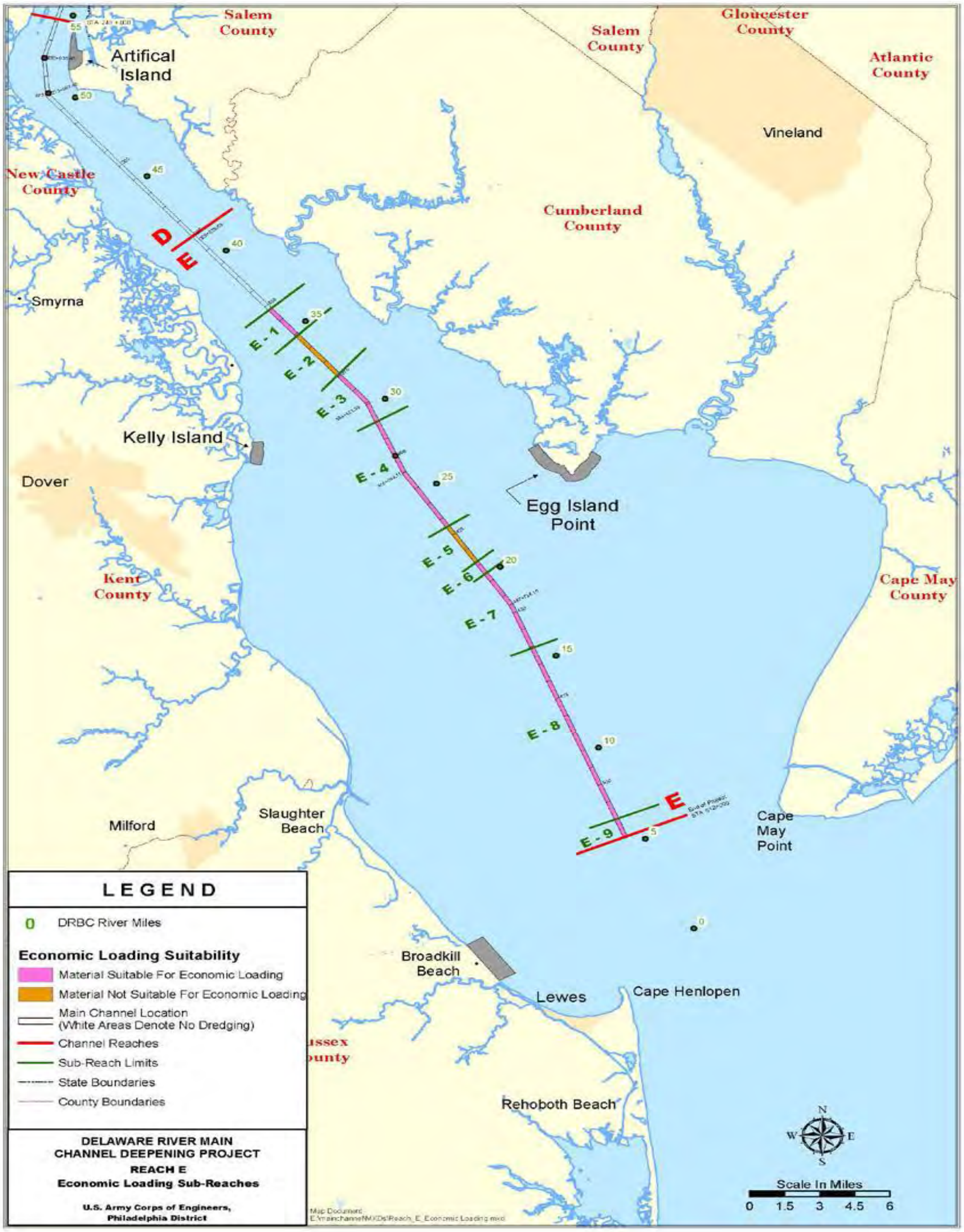
For the No Action Alternative, future maintenance dredging sand from Lower Reach E will be placed at Buoy 10 open water disposal site for approximately 10 more years, based on the projected capacity remaining at Buoy 10. Beyond this, dredging sand from Lower Reach E will be placed at Artificial Island CDF, per the Federal Standard for the least-cost, environmentally acceptable disposal location. Although this is the least-cost method of disposing maintenance dredging material from lower Reach E, there is no significant economic or environmental benefit from this practice.

Sediments are a critical component of the estuarine system as they constitute the substrate for most hydraulic, geochemical and biogenic processes that affect the overall "health" of the estuary. The estuary acts as a sink for sediments eroded from the watershed above the head of tide. The seawardmost portion of the estuary (the bay) is also a sink for sandy sediment transported in from the ocean primarily by tidal hydraulic processes.

The latest published sediment budget for the Delaware Estuary indicates that the bed of the estuary has eroded at a rate that exceeds the average annual rate at which new sediment is supplied from the watershed (*i.e.* upland fluvial input). Additionally, maintenance dredging coupled with disposal at CDFs is the principal mechanism by which sediment is removed from the estuary. Decreasing dredged quantities from the main channel over time (1937 – 2009) are indicative of this imbalance (Gebert and Searfoss, 2012).

Under the TSP, the use of sandy sediment dredged lower Reach E for beach nourishment will provide a tangible economic benefit (*i.e.* coastal storm risk management benefit) to the study are shoreline. Sand placed on Delaware Bay beaches will reduce flood risk to developed Bayfront communities and coastal habitats.

Figure 12 - Reach E Sub-Reaches



5.1.4 Climate and Climate Change

The U.S. Climate Change Science Program (USCCSP, 2009) evaluated coastal sensitivity to SLC and climate change scenarios, with a focus on the mid-Atlantic region. Sea level trends are recorded by tide stations, which measure the height of the water relative to a known land elevation (benchmark). The long-term tide gauge data recorded during the past century shows an average global sea level rise of approximately 1-2 mm/yr. The rate of sea level rise recorded at the tide gauge in Lewes, DE is 3.2 mm/yr (NOAA, 2009). This change in local mean sea level in Delaware is greater than the global sea level rate (*i.e.* eustatic). Land subsidence in Delaware is causing the land in Delaware to slowly sink (DNREC, 2012).

Most erosion along the Delaware Bay shoreline is caused by waves generated by local winds, especially during storms. Wave exposed shorelines within estuaries and coastal bays are likely to see higher rates of erosion with sea level rise increases (Rosen, 1978; Stevenson and Kearney, 1996). Sea level rise has this effect because it allows waves to impact the shoreline at a higher elevation (National Research Council, 2007). Erosion rates on non-ocean tidal shorelines may be significantly higher than on the more exposed ocean coast (French, 1990). One reason for this is that the non-ocean beaches lack exposure to the long period swell waves that return sand to ocean beaches (Nordstrom, 1980). Since erosion of estuarine and bay beaches is typically storm-driven (French, 1990), if the storm activity increases, this would compound the effect of rising sea level. The No Action Plan will have no impact on sea level rise. While sea level rise is believed to be an underlying driving force, there are many other factors that directly affect shoreline erosion including the material composition of the shoreline, bank height, supply of sandy material in the littoral zone, wave energy exposure, tidal range and human influences (Rosen, 1977 & 1980; Stevenson and Kearney, 1996; Perry, 2008). These factors often make it difficult to clearly discern the effect of sea level rise.

While there are many types of shorelines in estuaries, beaches tend to be the most common type and are prominent in the proposed project area. These beaches, which are smaller than on the ocean coast, may occur along the upland edge or as so-called “fetch limited” barriers (Lewes *et al.*, 2005). Their presence also tends to reduce erosion of uplands and wetlands by absorbing wave energy. Beaches tend to be relatively resilient to sea level rise since they are able to migrate landward as the shoreline retreats and wetlands accrete sediment and build in elevation. However, the combination of sea level rise and increased storm activity could cause more of the sand to be lost offshore. Riverine sediment input to the estuary is a sediment source to the estuary shoreline; however, the Delaware Estuary is known to be in sediment deficit due to significant shoreline stabilization in the upper reaches and decades of removal of bottom sediments by dredging and placement into upland confined disposal facilities. Since bank erosion and riverine input may serve as an important sediment source to bay shorelines, beneficial use of dredged material serves to put sediment back into the system where the shoreline is sediment starved.

It is difficult to predict the impact of climate change on aquatic endangered species (*i.e.* sea turtles and sturgeon) as there is significant uncertainty in the rate and timing of climate change as well as the effects it may have on these species. Sea turtles may be affected by increasing sand temperature at nesting beaches which may result in increased female to male sex ratio among hatchlings. Sea level rise could result in a reduction in available nesting beach habitat and increase the risk of nest inundation, and changes in abundance and distribution of forage species. Changes in water temperature could lead to a northward shift in the sea turtle range; however, the anticipated changed in sea temperatures within the next 50 years is not expected to be greater than 1.5 to 2.0 and not deemed significant enough to contribute towards shifts in range or distribution of sea turtles (NMFS, 2014) or warm enough for successful egg rearing. Nesting north of Virginia is relatively rare and would not occur in the project area.

Rising sea level may result in moving the salt line upstream, and potentially reducing available freshwater habitat for spawning, larvae and younger juvenile Atlantic sturgeon. Increased rainfall, as predicted by some climate models, may increase runoff and scour, thereby exacerbating poor water quality conditions but possibly counteracting a northern encroachment of the salt wedge. Atlantic sturgeon prefer water temperatures up to approximately 28 degrees C. Increased droughts (or increased withdrawals for human use) and low flow conditions are additional potential impacts unrelated to the proposed project that can impact all Atlantic sturgeon life stages by reducing suitable habitat and reducing water quality conditions.

Beaches in areas where development has occurred can become trapped between the development on the land side and rising sea level on the water side, leaving little room for normal landward migration and sediment dynamics (Defeo *et al.*, 2009). The net result of these effects will probably be a net reduction in beach habitat. Erosion on beaches fronting houses particularly affect estuarine beach dependent species such as shorebirds, terns, horseshoe crabs and diamondback terrapins. While CSRM is the primary driver of this feasibility study, the ancillary environmental benefits to returning dredged estuarine sediments to the system through beach nourishment are significant.

A study by Galbraith *et al.* (2002) illustrates the potential effect of sea level rise on prime migratory shorebird habitat. The study used the SLAMM version 4 to investigate the effect of sea level rise on beach and intertidal flat habitat at Delaware Bay and four other sites on the west and Gulf coasts known for their importance to migrating or wintering shorebirds. Delaware Bay supports the second largest spring concentration of migrating shorebirds in the Western Hemisphere and is a critical stopover site for the red knot. Under a conservative scenario where a global sea level rise of 0.34 mm by 2100 is adjusted with tidal gage records, the model predicted a 20 percent loss of Delaware Bay beach and intertidal flat habitat by 2050 and a 57 percent loss by 2100 (USFWS, 2016). The preferred alternative to conduct beach nourishment operations best mimics the natural shoreline habitat while affording additional defense against sea level rise. While hardened structure alternatives temporarily offer defense against sea level rise, they create adverse impacts to the natural hydrodynamic interface of the beach and the intertidal zones. The beach nourishment alternative lowers the risk of flooding to the developed bayshore communities by providing an elevated beach berm and vegetated dune buffer but likewise will not affect sea level rise.

5.2 WATER RESOURCES

Under the No Action Plan, inundation of flood waters on the Delaware bayshore causes excessive erosion during storms, thereby reducing water quality and clarity, which is further exacerbated by additional losses of vegetated land cover. A robust dune and beach sand berm is the first line of defense against adjacent marsh inundation. Marsh vegetation has the capacity to improve and maintain water quality through filtration, nutrient uptake and sediment trapping capacities. Large tracts of healthy marsh are particularly important surrounding bayfront residential communities to serve to absorb surface water and accrete sediments.

With the preferred alternative, physical and biological impairments to water quality can result from the proposed project due to increases in turbidity from dredging and placement operations. Increased turbidity results from the resuspension of sediments during operations and is temporary, but can impact primary productivity and respiration of organisms in the immediate project area. Increased turbidity can also impact prey species' predator avoidance ability due to decreased clarity in the water column. Impacts to water quality may occur at both the beach placement areas, as well as during excavation operations within the channel. Increased suspended sediment in the water can reduce dissolved oxygen (Johnston, 1981). This can be more of a concern during summer months when water temperatures are warmer and less capable of holding dissolved oxygen (Hatin et al, 2007). The nature, degree and extent of the suspended sediment plume in the water is controlled by a variety of factors including sediment particle size, solids concentration, dredge type, discharge rate, water temperature and hydrodynamic forces (*i.e.* waves, currents) causing horizontal mixing.

Dredge draghead movement can create a turbidity plume in the bay at the dredging site. Turbidity levels decrease exponentially with increasing distance from the dredge due to settling and dispersion. Plume concentrations, particularly when the material is predominantly large grained sand particles, is expected to return to background levels quickly in most cases. The vast majority of re-suspended sediments resettle close to the dredge within one hour (Anchor Environmental, 2003). Overall, water quality impacts are anticipated to minor and temporary.

Of the three major types of dredges available (hopper, cutter suction and mechanical), hopper dredges are the most likely to be used to dredged the Main Channel in lower Reach E because of the exposed conditions in the Delaware Bay and the relatively long distances between the Delaware River Federal channel and dredged material placement sites.

Figure 13 - Hopper Dredge

Hopper dredges are self-propelled ships equipped with propulsion machinery, hoppers for dredged material storage and dredge pumps. Dredged material is hydraulically raised through trailing dragarms which "vacuum" water and sediment in contact with the channel bottom and is discharged into the hoppers. The material is stored in the hoppers through transportation to the placement site. While most hopper dredges are equipped with bottom doors or split hulls for release of material at open water sites, they can also be equipped for pump-out of material to the beach nourishment beneficial use sites. During the dredging process, sediments are mixed with water to create slurry, which is typically about 25 percent solids and 75 percent water, and the slurry is pumped into the hopper. As the hopper fills with the slurry, the sediments begin to settle to the bottom of the hopper, creating a bottom layer of higher-density sediment with a top layer of lower-density supernatant. Coarse grained sediments (sediments with high percentages of sand/gravel) and consolidated clay sediments settle to the bottom faster than fine grained sediments (unconsolidated silts and clays).

A hopper dredge filled with such a large amount of water and a relatively smaller amount of sediment per load is economically inefficient. However, the proportion of solids in each load can be increased if the low-density supernatant is allowed to overflow the hopper and flow back into the water body and the sediment in the incoming slurry continues to settle to the bottom of the hopper. Depending on the composition of the dredged sediments, the proportion of solids retained in each hopper load can increase to as much as 70 to 90 percent.

The practice of filling a hopper beyond overflow to achieve a higher density load is referred to as economic loading. The result is fewer loads required to transport the same amount of dredged material, which decreases the overall operating time, and hence, the project cost. Economic loading is most effective when dredging coarse grained sediments or consolidated clay sediments due to higher settling velocities. Conversely, there is less potential for benefits from economic loading of fine-grained sediments due to lower settling velocities.

In considering economic loading, potential environmental effects must be reviewed as overflow of the supernatant may result in increased water column turbidity when compared to non-overflow dredging. Therefore, the relationship between dredge production, density of the hopper load, and the rate of material overflow are important variables in maximizing the efficiency of the dredging operation while minimizing environmental impacts.

Economic Loading during Main Channel Deepening. Reach E of the Delaware River Main Channel Deepening project extends from approximately River Mile 5 to River Mile 41.5. Economic loading was performed in some sub-reaches within Reach E where average channel sediments were determined to be greater than or equal to 90 percent coarse grained material.

The U.S. Army Engineer Research and Development Center (ERDC) conducted a field evaluation of hopper dredge overflow in the Delaware River for the U.S. Army Corps of Engineers (USACE) Philadelphia District (USACE, 2013). The study considered both the environmental effects of economic loading and the economic benefits and concluded that economic loading could be conducted in the Delaware Bay with minimal adverse environmental impacts and significant economic benefits. The study showed that coarse grained material settles at a rapid rate, facilitating a significant gain in material within the hopper with overflow as compared to without overflow.

A Section 401 Water Quality Certificate under the Clean Water Act of 1977 (PL 95-217), as amended, is required from the state of Delaware, and a Department of the Army permit under Section 10 of the Rivers and Harbors Act and under Section 404 of the Clean Water Act are required for the proposed project. Pursuant to Section 404 of the Clean Water Act, the impacts associated with the discharge of fill material into waters of the United States are discussed in Appendix D.

5.3 BIOLOGICAL RESOURCES

5.3.1 Vegetation and Wetlands

The majority of wetlands within the vicinity of the proposed project areas are estuarine intertidal emergent wetlands, with additional estuarine intertidal scrub-shrub and forested wetlands occurring intermittently. Coastal salt marshes are intertidal ecosystems occurring on soft sediments on which the vegetation is dominated by flowering plants, graminoids, forbs, and low shrubs. Salt marshes develop between terrestrial and marine environments, resulting in biologically diverse communities adapted for harsh environmental conditions including desiccation, flooding, and extreme temperature and salinity fluctuations. These wetlands are characterized by a mix of marsh vegetation comprised of salt marsh cordgrass (*Spartina alterniflora*), salt grass (*Distichlis spicata*), salt hay (*Spartina patens*), and black needlerush (*Juncus roemerianus*). Common tree and shrub species include high tide bush (*Iva frutescens*), loblolly pine (*Pinus taeda*), Virginia pine (*P. virginiana*), and eastern red cedar (*Juniperus virginiana*). Marshes act as nurseries to a wide variety of organisms, some of which are notably threatened or marketed as important fisheries species (USFWS, 2016). The No Action alternative is expected to exacerbate the loss of beach vegetation and excessive inundation of neighboring wetlands with erosion of the barrier beachfront. The preferred alternative of beach nourishment will enhance protection of adjacent wetlands and enable dune vegetation to establish with the resultant higher berm and dune elevations. The preferred plan entails planting American beach grass on the dune. Alternatives involving the construction of a hardened structure are not advised by the natural resource agencies as it impedes the natural transfer of sediments within the beach/intertidal habitat interface.

5.3.2 Planktonic and Benthic Organisms

With the No Action alternative, low quality intertidal habitat would continue to exist at the beach placement sites due to severe erosion and exposed peat. With the TSP that entails dredging and placement operations, infaunal organisms within the placement zone will be impacted by burial. Alternatives including a hardened structure would permanently impact intertidal and beach habitat by obstructing the hydrodynamic connection between the two. Most of the organisms inhabiting these dynamic zones are highly mobile and respond to stress by displaying large diurnal, tidal and seasonal fluctuations in population densities (Reilly and Bellis, 1983). Under the TSP, the material would be pumped onto the beach above the mean high water line, thereby minimizing impacts to intertidal infaunal organisms. Despite the resiliency of intertidal benthic fauna, the initial effect of beachfill will result in some mortalities of existing benthic organisms. The ability of a nourished area to recover depends on grain size compatibility of the material pumped on the beach (Parr and Lacy, 1978). Macrofaunal recovery is usually rapid after pumping operations cease. Recovery of the macrofaunal community may occur within one or two seasons because borrow material grain sizes are expected to be compatible with natural beach sediments. The abundance and species assemblage were generally not different from pre-nourishment samples after three months. Recolonization depends on the availability of larvae, suitable conditions for settlement, mobile organisms from nearby beaches, vertical migration of organisms through the placed material, and mortality. The benthic community can, however, be somewhat different from the original community.

At the proposed dredging location within lower Reach E of the Main Channel, the primary ecological impact of dredging is removal of existing benthic organisms. This has an immediate localized effect on the benthic macroinvertebrate community. Survival of organisms during dredging varies widely (Peterson *et al*., 2000). Mechanical disturbance of the substrate generates suspended sediments and increases turbidity near the dredging operation. In addition to the physical disruption of the habitat, recolonization of the benthic community can be rapid, typically taking from a few months to a few years (Brooks *et al*., 2006; Maurer *et al*., 1981a,b; 1982, Maurer *et al.,* 1986; Saloman *et al*., 1982; Van Dolah *et al*., 1984). Recovery of infaunal communities after dredging has been shown to occur through larval transport, along with juvenile and adult settlement, but can vary based on several factors including seasonality, habitat type, size of disturbance, and species' life history characteristics (*e.g*., larval development mode, sediment depth distribution) (Shull, 1997; Thrush *et al*., 1996; Zajac and Whitlatch, 1991). Initial recolonization is dominated by opportunistic taxa whose reproductive capacity is high, and flexible environmental requirements allow them to occupy disturbed areas (Boesch and Rosenberg, 1981; McCall, 1977).

Highly mobile organisms, such as amphipods, can escape to the water column and can directly resettle after dredging operations are completed (Conner and Simon, 1979). Mobile polychaetes are intermediate of amphipods and bivalves in their capacity to resettle directly after dredging. Bivalves are the least mobile organisms, although pelagic larvae of these species can result in high recruitment. Larval recruitment and horizontal migration from adjacent, unaffected areas initially recolonize the disturbed area (Van Dolah *et al*., 1984; Oliver *et al*., 1977). Anderson *et al.* (2010) evaluated benthic organisms within Delaware Bay relative to major physical habitats of the seafloor, such as depth, sediment size, topography, and salinity. Salinity and sediment type were primary factors in benthic species composition. Annelids were the predominant benthic species inhabiting the project area as well as the Delaware Bay as a whole. Some benthic studies have demonstrated only subtle changes in sediment characteristics with a slight shift in corresponding benthic community composition post-dredging (Scott, 2012). No long term effects are expected as salinity would not change and the benthic community that naturally exists in the area is present throughout the middle and lower bay region and dominated by species with opportunistic life histories that exhibit rapid recruitment capabilities.

Blue crabs. Adult blue crabs (*Callinectes sapidus*) migrate to higher salinity waters of the lower Delaware Bay in the December through March timeframe to overwinter. The crabs burrow into sediments of the deep channel as water temperatures decline and are not likely to be in the shallow waters of the project placement area during the cooler months of the year. During warmer months of the year, blue crabs are active within the shallow waters of the bay, but crabs in between molts have the mobility to move out of the area of disturbance at the dredge site. Impacts to overwintering blue crabs in the channel can be reduced by dredging in the late summer and fall while the crabs are mobile and can leave the impact area.

Horseshoe crabs. Shallow water intertidal flats of Delaware Bay are prime spawning habitat for horseshoe crabs (*Limulus polyphemus*). Shallow water areas with low wave action and sand or mud substrate are also important nursery areas for juvenile horseshoe crabs for their first two years. Horseshoe crab eggs and larvae are a food source for migratory birds and several fish species. The 17 phases of instars of the horseshoe crab are food for finfish, loggerhead turtles, American eels (*Anguilla rostrata*), and blue crabs. The use of seasonal windows (April 15 to August 31) will reduce adverse effects to horseshoe crabs by avoiding dredging during the spring and summer seasons when horseshoe crabs are most numerous in the shallow inshore areas. Beach nourishment will provide improved habitat for horseshoe crab spawning along the beach face. Restoring eroded beaches where horseshoe crabs spawn is important for both the crabs themselves and numerous other species that depend on the crabs for food. The current beach berm template is designed to have suitable grain size (>0.3 mm), slope (1H:5V) and deep enough (+7 feet) to promote horseshoe crab spawning habitat.

5.3.3 Fish

Under the No Action scenario adult fish occurring in the nearshore zone of the bay would not be impacted. If erosion of the barrier beach continues, larval and juvenile fish stages are also likely to be adversely impacted if area salt marshes incur lower habitat quantity and quality through loss of wetlands. Juvenile life stages rely on salt marshes as nursery areas. Healthy productive wetlands also provide increased diversity of prey species for fish relative to barren mudflats. With the proposed dredging and placement project, larval and juvenile fish may be temporarily adversely impacted by elevated turbidity levels within the nearshore zone. The proposed placement of sand on the beach would not disrupt the natural shoreline transition zone from intertidal to beach berm and will have minimal to no impact on adult fish that can leave the impact area during construction.

The marine habitat along the lower Delaware Bay coast in Delaware has been designated as "Habitat Areas of Particular Concern" by the NMFS. Pratt (1999) believes that there will be a great potential to impact shark pups and their food source of benthic organisms in the nursery areas along the Delaware Bay Coast, especially offshore from Broadkill Beach to Slaughter Beach, if sand is deposited near the beach (in areas 3-12 feet depth zone) during the nursery season. Potential impacts may include, but not be limited to: changing the habitat characteristics, depth, profile, odor, turbidity and fauna of the area. Indirect adverse impacts include the loss of forage food items. Prey species, principally crabs and fish of many species, may be disrupted directly by the presence of physical activity in the area and indirectly by the covering of vulnerable food web organisms with sand. The NMFS recommends that dredging be avoided during the 1 May to 30 September period to prevent potential impacts to newborn and juvenile sharks. After this time period, the young sharks have reached a larger size where they would be more able to avoid the sand placement operations. Since this environmental window, in combination with environmental windows for other coastal species (*e.g.* horseshoe crab, winter flounder, blue crab) result in a remaining available dredging and placement period for the dredging operation the USACE requires the dredging contractor to adhere to the following construction operation:

A sand dike, 200 to 300 feet in length, is constructed with existing beach material above mean high water (MHW) to contain dredged material that is pumped landward of it. The dike will be long enough that most dredged material will drop out on the beach and not return to the bay as a slurry. As material is deposited along the beach, the dike may be repositioned seaward to contain the required tilling above MHW for that section of beach. The slurry is also controlled by the dike along the shoreline. No dredged material will be hydraulically placed below MHW during the restricted period. The dike will be extended down the beach as the area behind the dike is tilled and the dredged pipe is lengthened. The dredged material that has been deposited will be built into the dune and beach berm. It is expected that little of this material will be re-deposited by wave action during the spring/summer window period since weather is generally mild. After September 30, some dredged material will be graded into the bay to widen the beach. The dredge pipe will be placed on pontoons for a minimum of 1000 feet, extending offshore to avoid disrupting young sandbar sharks mobility close to the shoreline. The remainder of the pipeline back to the dredge can rest on the bay bottom.

Both the beach placement sites within the shallow intertidal areas and the Main Channel lower Reach E dredging location incur limited and short-term impacts on finfish. Most early developmental stages are typically found more often in tidal creeks and backwater areas. Most bottom dwelling and pelagic fishes in Delaware Bay are highly mobile and should be capable of avoiding turbidity impacts of dredging and placement during operations. Due to suspension of food particles in the water column, some finfish are attracted to the turbidity plume.

The primary impact to fisheries is the disturbance of benthic and epibenthic communities. As mentioned in Section 5.3.2, the loss of benthos smothered during berm construction and removed during dredging temporarily disrupts food resources in the impact areas (Hackney *et al*., 1996). Due to rapid recolonization by macroinvertebrates typical of highly dynamic environments, the effect is short-term. Depending on the time of year, benthos food resources can recolonize from dredged areas within a year via larval recruitment as well as from immigration of adults from adjacent, undisturbed areas (Burlas *et al*., 2001; Posey and Alphin, 2002; Byrnes *et al*., 2003). Recovery is most rapid if dredging is completed before seasonal increases in larval abundance and adult activity in the spring and early summer (Herbich, 2000). Opportunistic benthic species are adapted to exploit suitable habitat when it becomes available post-dredging.

5.3.3.1 Essential Fish Habitat

Essential Fish Habitat (EFH) is defined as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity" and covers all habitat types utilized by a species throughout its life cycle. The Magnuson-Stevens Fishery Conservation and Management Act (Public Law 104-267) requires all Federal agencies to consult with National Marine Fisheries Service (NMFS) on all actions, or proposed actions, permitted, funded, or undertaken by the agency, that may adversely affect EFH.

Potential impacts to EFH under the No Action Alternative has been described in the previous sections in reference to water quality and benthic invertebrate prey species for both the intertidal zone and the proposed channel dredging areas. In regard to impacts due to implementation of the TSP (*i.e.* beach nourishment), dredging within the Main Channel has the potential to impact EFH several ways: direct entrainment of eggs and larvae, the creation of higher suspended sediment levels in the water column, reduced feeding success for site-feeding fish and reduced water oxygen levels. All of these impacts are temporary in nature, occurring during and briefly after the actual dredging period. Substrate conditions can often return to similar preconstruction conditions and the benthic community recovers through recolonization.

A review of EFH designations and the corresponding 10' x 10' squares, which encompass the project area was completed and coordinated with the NMFS (M. Magliocca, pers. comm.). The following is an evaluation of the potential effects associated with this project on EFH species:

> **American plaice:** No adverse effect is anticipated on adults as they are concentrated in oceanic deep water and not likely to be in the project area. Limited adverse effect is anticipated on juveniles as they would be expected to move away from the dredging disturbance area. Impacts within the placement area will be minimized due to pumping of material onto the beach above the mean high water line and reducing turbidity. Impacts to prey species in the intertidal zone will be temporarily impacted through burial but will recover through recolonization.

Atlantic butterfish: No adverse impacts are anticipated. All life history stages are pelagic and oceanic. Construction activities will take place on the bottom. Elevated turbidity effects are temporary.

Atlantic sea herring: No adverse effect is anticipated as adults and juveniles occur in pelagic waters and can move away from the dredging project area during the temporary construction period. Eggs occur on bottom habitats of gravel, sand, cobble or shell fragments in depths ranging from 20 to 80 meters and a salinity range of 32-33 (oceanic waters) and are therefore not expected to be in the project area.

Black sea bass: No adverse effect is anticipated on juveniles and adults as this species occurs primarily in offshore areas with structure and they can avoid temporary impacts to the water column and prey species during the dredging period. Larvae are generally found on structural inshore habitat such as sponge beds. Black sea bass eggs are found from May through October on the Continental Shelf from southern New England to North Carolina.

Bluefish: No adverse effect on eggs and larvae as these occur in pelagic waters in deeper water than the project area and generally are not collected in estuarine waters. Juveniles and adults occur in mid-Atlantic estuaries from April through October. Temporary impacts to prey items may occur in the project area. Juveniles and adults are expected to move away from the project area during the temporary construction period. Elevated turbidity will be short-term.

Clearnose skate: Habitat for juveniles and adults is generally shallow soft bottoms or rocky, gravelly bottoms. Adults tend to move from shallow shores to deeper water in winter. Impacts may occur to larvae through entrainment. Juveniles and adults are highly mobile. Temporary disruption of benthic food prey organisms may occur within the placement and dredging areas.

Cobia: No adverse effect is anticipated for all life stages as they are all pelagic and construction activities will take place on the bottom. Cobia are not expected to occur in the project impact area.

Dusky shark: Neonates and early juveniles inhabit shallow coastal waters during summer months. No adverse impact is anticipated for neonates, juveniles or adults as these stages are expected to move out of the immediate impact area during the temporary construction period, particularly if dredging activities occur predominantly off-season. Dredge material pumping at the placement site occurs above the high water line on the beach and proceeds in sections to minimize turbidity impacts to surrounding areas.

King mackerel: No adverse effect on all life stages is anticipated as all life stages of this species are pelagic and the species is not expected to be in the area.

Little skate: Habitat consists of shallow coastal water over sand or gravel and up to 80 fathoms. Juveniles and adults are highly mobile. Larvae may be impacted through entrainment. A temporary disruption to benthic food prey organism may occur. Juveniles and adults of this species are likely to avoid the immediate impact area.

Red hake: No adverse effect is anticipated on adults as any that may occur in the Delaware Bay during the temporary construction period are anticipated to move away from the project area.

Sandbar shark: Neonates and early juveniles are found in shallow coastal waters and use the Delaware Bay as a nursery area. Adults are highly migratory and mostly congregate offshore. No adverse impact is anticipated for juveniles or adults as these stages are expected to move out of the construction area during the temporary construction period. No dredging is anticipated to occur during the spring and summer pupping season and the dredge pipe will be floated on pontoons to avoid disrupting movements of young sandbar sharks. Sand is pumped onto the beach above the mean high water line to minimize turbidity at the construction site.

Sand tiger shark: Neonates and early juveniles are found in shallow coastal waters and use the Delaware Bay. Adults are highly migratory and mostly congregate offshore. No adverse impact is anticipated for juveniles or adults as these stages are expected to move out of the construction area during the temporary construction period. No dredging is anticipated to occur during the warmer months when sand tigers occur in the Delaware Bay, and the dredge pipe will be floated on pontoons to avoid disrupting movements of young sand tiger sharks. Sand will be pumped onto the beach above the mean high water line to minimize turbidity at the construction site.

Scup: Eggs and larvae are abundant in estuaries from May through September in waters between 55 and 73 degrees F and salinities greater than 15 ppt**.** Juvenile and adults typically occur in estuaries and bays and migrate to coastal waters in summer. Older life history stages of the species would be expected to avoid the immediate dredging area during temporary construction. No impacts at the placement site are anticipated as any increase in turbidity at the placement site is minimal with pumping above the mean high water line. Prey species composition may be temporarily impacted due to dredging and placement activities.

Spanish mackerel: The species makes seasonal migrations along the Atlantic coast. No adverse effect is anticipated for all life stages as they are all pelagic and not associated with bottom habitats and construction activities will take place on the bottom. The species is not anticipated to occur in the shallow waters of Delaware Bay.

Summer flounder: No adverse effect is anticipated on eggs and larvae because they are pelagic and generally collected at depths of 30 to 360 feet. No adverse effect is anticipated on juveniles and adults because they would be expected to move out of the dredging area due to disturbance at the bay bottom in the channel by the dredge cutterhead. Impacts within the placement area are minimized due to pumping of material onto the beach above the mean high water line and reducing turbidity. Impacts to prey species in the intertidal zone will be temporary. The predominant benthic community composition consists of dominant small taxa, such as polychates and small bivalves, species with fast recruitment rates.

Windowpane flounder: No adverse effect is anticipated on eggs and larvae as they are pelagic and work will be conducted on the bottom during the temporary construction period offshore. Prey species composition may be temporarily impacted due to dredging. No adverse effect on juveniles and adults is anticipated in bottom habitats of the berm placement site as these life stages are anticipated to move away from the placement disturbance area during the temporary construction period. Pumping of material onto the beach will occur above the mean high water line and thereby minimize turbidity and disruption of prey species composition.

Winter skate: habitat consists of shallow coastal water over sand or gravel and up to 80 fathoms. Juveniles and adults are highly mobile. Larvae may be impacted through entrainment. A temporary disruption to benthic food prey organism may occur.

In conclusion, of the species identified with Fishery Management Plans, and juvenile life history stages of highly migratory pelagics that may occur in the vicinity, the potential for adverse impacts to EFH is considered temporary and minimal. The egg and larval stages of winter flounder, which occur predominantly in inlets, are less likely to be impacted in the channel dredging area and placement vicinities. The neonate stages of several shark species are predominately located in shallower coastal waters during summer months, and should be sufficiently mobile to leave the construction area. Potential impacts are further minimized by conducting dredging operations during the cooler, nonbreeding months of the year (*i.e*. fall and winter). To protect juvenile shark species, the dredge pipe will be floated to avoid disruption of movements, following procedures described by the NMFS. Based on the findings of the Field Evaluation of Hopper Dredge Overflow for the Delaware River (USACE, 2013) and sediment quality information provided in (USEPA, 2002) and (Hartwell and Hameedi, 2006), there is no evidence that economic loading in portions of the Reach E navigation channel with sediments greater than 90 percent coarse grained material would adversely affect water quality or aquatic life. Therefore, neither economic loading nor dredging in general is expected to have significant adverse effects on the EFH and HAPC shark species for the affected life stages.

At the beach placement site (nearshore zone), the slurry of dredged material and water pumped onto the beach typically results in an increase in localized turbidity. The Atlantic States Marine Fisheries Commission (Greene, 2002) review of the biological and physical impacts of beach nourishment cites several studies on turbidity plumes and elevated suspended solids that drop off rapidly seaward of the sand placement operation. Other studies support this finding that turbidity plumes and elevated TSS levels are typically limited to a narrow area of the swash zone downcurrent of the discharge pipe (Burlas *et al*., 2001). Fish eggs and larvae are the most vulnerable to increased sediment in the water column and are subject to burial and suffocation. Juvenile fish and adults are capable of avoiding sediment plumes. Increased turbidity due to placement operations will temporarily affect fish foraging behavior and concentrations of food sources are expected to return to the nearshore zone once placement operations cease due to the dynamic nature of nearshore benthic communities (Burlas *et al*., 2001). Turbidity impacts are anticipated to be minimized by the placement of the dredge pipe above the mean high water line during pump-out and development of the raised beach berm moving along the shoreline. Most shallow water coastal species will leave the area of disturbance at the immediate placement site.

The adverse impact on benthic organisms (including fish food prey items) in the dredging and placement areas is considered to be localized, temporary and reversible as benthic studies have demonstrated recolonization following dredging operations within 13 months to 2 years. Authorized maintenance dredging within Reach E in the bay Main Channel will remove approximately 800,000 cubic yards of sandy material every 2 years. The Delaware Estuary is considered sediment starved due to a long history of extensive shoreline development in the upper riverine reaches and decades of dredging and placement into upland CDFs. It is beneficial to the estuarine fish and wildlife coastal habitats to keep the dredged material in the system by placing it on lower bay beaches rather than in CDFs.

5.3.4 Wildlife

Under the No Action Alternative, wildlife species would continue to incur further losses in habitat quality and quantity due to ongoing flooding. Several mammals, reptiles, amphibians, and birds utilize the beach and dune habitat of the proposed project areas. All of these species are mobile and expected to leave the immediate impact area temporarily during construction.

The beach berm and dune restoration plan will provide added protection to interior shrub and forested habitats. Widespread population declines of many migratory songbird species are among the most critical issues in avian conservation today. Numerous studies have shown the critical role that maritime shrub, maritime red cedar woodland, and maritime forested habitats play for migrating passerines, especially on the refuge and along the mid-Atlantic and Delmarva Peninsula coastal areas (Mizarhi, 2006; Clancy and McAvoy, 1997; McCann *et al.,* 1993). Conservation of these habitats and the natural resources associated with them is essential to perpetuate the migratory songbird resources of North America.

Birds. Beach nourishment operations should have minimal effect on birds in the area. Most birds are seasonally transient, as well as highly mobile and can avoid the construction area due to the noise. Birds that use the beach for nesting and breeding are more likely to be affected by beach nourishment activities than those species that use the area for feeding and resting during migration. Birds may be temporarily displaced by dredges, pipelines, and other equipment along the beach, or may avoid foraging along the shore if they are aurally affected (Peterson *et al*., 2001). Seasonal restrictions are critical such that sand placed on the beach doesn't have the potential to crush eggs or hatchlings. Dredged sand that is coarse or high in shell content can inhibit the birds' ability to extract food particles in the sand. Very fine sediment that temporarily reduces water clarity can also decrease feeding efficiency of birds in the immediate area of construction for a short period of time (Peterson *et al*., 2001).

The species listed in Table 1 of the CBFO PAR are protected under the Migratory Bird Treaty Act of 1918 (40 Stat. 755;16 U.S.C. 703-712), as amended and occur in the project area. All species listed are considered Birds of Conservation Concern which are defined as species, subspecies, and populations of all migratory nongame birds that, without additional conservation actions, are likely to become candidates for listing under the Endangered Species Act (ESA) of 1973 (87 Stat. 884, as amended; 16 U.S.C. 1531 *et seq*.). Under the No Action alternative, erosion will continue and may result in beaches with grain size less favorable to migratory shorebirds for feeding and resting (USFWS, 2016). Additionally, the No Action alternative doesn't restore a protective barrier beach berm and dune system that provides storm protection to neighboring salt marshes, scrub shrub, and interior forest habitats during severe coastal storm events.

The preferred plan of beach nourishment is not likely to have an impact on these species. Beach replenishment may offer short term nesting opportunities for some shorebirds and colonial nesting waterbirds, particularly American oystercatcher (*Haematopus palliates*, state endangered) and black skimmer (*Rynchops niger*, State endangered). It is possible that beach nourishment could enhance or inhibit horseshoe crab (*Limulus polyphemus*) spawning by changing grain size. If the grain size becomes more favorable than existing conditions, red knots (*Calidris canutus rufa)*, Federally threatened and State endangered) will likely use these beaches in greater number for forage (USFWS, 2016).

Diamondback Terrapin. Across their range, diamondback terrapin (*Malaclemys terrapin*) populations are in decline. The state of Delaware lists the diamondback terrapin as a species of greatest conservation need within their State Wildlife Action Plan. The USFWS lists the species as an Appendix II species under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). The diamondback terrapin is the only North American turtle that lives exclusively in brackish waters associated with estuaries, coastal bays, and salt marshes. Terrapins are heavily dependent on shoreline conditions to satisfy their habitat requirements.

The terrapin spends most of its life in the water, but it must come ashore for nesting. Nesting normally occurs at bare or sparsely vegetated, unshaded, sandy areas above the level of the normal high tides (Palmer and Cordes, 1988; Roosenburg, 1990; Burger and Montevecchi, 1975).

In the study area, terrapin habitat is mostly associated with shoreline beaches although road shoulders, dikes, and tilled areas may occasionally be used. Nesting season extends from the beginning of June until the end of July, and terrapins often aggregate in the waters adjacent to the nesting beaches during the nesting season (Roosenburg, 1993). Based on a study of a New Jersey population, the incubation period for the eggs is typically on the order of 70 to 80 days with a range between 61 and 104 days for individual terrapins (Burger, 1976; 1977). After hatching the terrapins remain in the nest for several days before they emerge. In Maryland, which is similar to Delaware, it is known that hatchlings of eggs laid later in the season may overwinter in the nest and emerge the following spring (Burger 1976, 1977).

Unlike structural alternatives, such as breakwaters, which impede wildlife movements and block access between the intertidal zone and the upper beach, the TSP of beach nourishment will likely create more nesting habitat for terrapins, but nesting success may be inhibited in developed areas where predators such as dogs are more likely to occur (USFWS, 2016).

Ultimately some fish and wildlife resources at all projects sites may benefit while other species may incur adverse effects from the TSP. The objective of the TSP is to meet the objective of minimizing storm impacts, while maximizing benefits to fish and wildlife resources, and minimizing any adverse effects associated with the plan.

5.3.5 Threatened and Endangered Species

This section presents the potential impacts to threatened and endangered species and discusses the listed species life history requirements and measures taken by the USACE to minimize or avoid adversely impacting these species or their habitats. The No Action alternative will result in continued erosion of beaches from storm events and great flood risk to Bayfront communities. Eroded beaches, particularly those with exposed underlying peat and scarped dunes offer degraded habitat for wildlife.

A habitat suitability mapping study (Lathrop *et al*., 2013) showed that Superstorm Sandy had a greater negative impact on horseshoe crab spawning habitat along the Delaware Bay shoreline than the prior 8 years of typical shoreline dynamics. Spawning horseshoe crabs will avoid beaches with exposed peat, which in turn, may reduce attraction by migratory shorebirds, including the red knot, which relies heavily on horseshoe crab eggs (Botton *et al*., 1988). Horseshoe crabs spawn on beaches fronting residential communities. In turn, residents and state environmental agencies promote seasonal beach use practices that avoid disturbance to migratory shorebirds, such as keeping dogs leashed and not disturbing concentrations of feeding shorebirds during the spring migration. Wide flat sandy, sparsely vegetated barrier beaches are the preferred nesting habitat for the piping plover. Beach nourishment activities can provide positive benefits to listed species by restoring preferred beach habitat.

<u>Piping plover</u>. Prime Hook Beach and Lewes Beach are the only bay shorelines that have the potential to impact endangered piping plovers (*Charadrius melodus*); however, the risk of the TSP impacting the plovers is low (USFWS, 2016). There have not been any recent records of piping plovers present on these beaches, most likely as a result of their development. Prime Hook and Lewes are the largest of the Delaware bayshore developed communities and piping plovers are adverse to human disturbance throughout the nesting season. Due to the proximity of the proposed project sites of Prime Hook and

Lewes to known nesting locations south, there remains the potential that piping plovers could be positively affected by the proposed activities at these locations in the future, particularly after initial placement operations create a more optimal nesting habitat. With a wider beach berm potentially attracting piping plovers in the spring, future maintenance dredging and placement operations should be scheduled outside of the spring/summer nesting season. During migration, piping plover may be present on the beach. Migration times for piping plover in Delaware is from March 1 through June 15 and from August 1 through September 15 USFWS, 2016).

Red knot. Proposed beach nourishment sites from Pickering Beach south to Lewes Beach could impact threatened *rufa* subspecies of the red knot (*Calidris canutus*) if construction occurs during the migration season or alters the beach and renders it unsuitable for horseshoe crab spawning. The USFWS (2016) recommends a seasonal restriction from 15 April through 15 June at sites Pickering Beach, Kitts Hummock Beach, Bowers Beach, South Bowers Beach, Big Stone Beach, Slaughter Beach, Prime Hook Beach, and Lewes Beach. To avoid altering the preferred spawning beach profile, dredged sand will be similar to existing grain size dominated by coarse sandy sediments. The design template for the beach berm slope will be similar to that which occurs on beaches known for large horseshoe crab spawning congregations. The crabs spawn on bay beaches fronting residential development but will avoid spawning on beaches that have insufficient sand depth over peat (USFWS, 2016). The TSP to provide beach nourishment will provide both protection to human infrastructure while also decreasing the need for increased shoreline armoring or other structural stabilization that eliminates horseshoe crab habitat (USFWS, 2016).

Sea turtles. In the marine environment, several species of sea turtles are Federally listed as threatened or endangered under NMFS' jurisdiction and are known to migrate along the Atlantic Ocean coast, while some enter the Delaware Bay. These include the Loggerhead sea turtle (*Caretta caretta*), Kemp's ridley sea turtle (*Lepidochelys kempi*), Green sea turtle (*Chelonia mydas*), and the Leatherback turtle (*Dermochelys coriacea*). All are listed as endangered with the exception of the loggerhead turtle, which is listed as threatened. The TSP is not anticipated to adversely affect sea turtle species on land as these species do not nest in the area. The furthest north leatherbacks nest is southeastern Florida; Kemp's ridleys only nest in Mexico; and loggerheads nest as far north as Virginia. Nesting in the mid-Atlantic is generally rare.

Potential impacts in the marine environment include impingement or entrainment in the dredge, interaction with the dredge or transport vessels, elevated levels of suspended sediments that may impact foraging, migration or prey species, removal of prey species and noise due to project construction operations.

The loggerhead is the most abundant species of sea turtle in U.S. waters. They migrate north along the east coast as water temperatures warm in the spring and move back south in fall. They typically feed on benthic invertebrates in hard bottom habitats (NMFS and USFWS, 2008). Mansfield (2006) saw a decline from the 1980s to the 2000s in loggerhead spring residency in Chesapeake Bay and attributed it to significant declines in prey items such as horseshoe crabs and blue crabs. The Kemp's ridley is the least abundant of the world's sea turtle species. Suitable habitat occurs where there are available food resources (*e.g*. crabs, invertebrates), seagrass beds, oyster reefs, sandy and mud bottoms, and rock outcroppings (NMFS and USFWS, 2007). The Kemp's ridley utilizes Delaware Bay for foraging (Stetzar, 2002) but leave the area to migrate down the coast to the south Atlantic and Gulf of Mexico in fall. Green sea turtles are herbivorous and found in areas containing benthic algae and seagrasses. No sea grass beds occur in the areas to be dredged; therefore, green sea turtles will not use the areas for foraging. Seasonally, they are found in the Mid-Atlantic but are not common (Musick and Limpus, 1997; Morreale and Standora, 1998). Leatherback turtles have the widest distribution of all extant sea turtles species (from as far south as the Cape of Good Hope in Africa to as far north as Alaska and Norway. Leatherbacks feed in colder waters and primarily occur in open oceanic waters and considered rare in Delaware Bay.

In coordination with NMFS, the USACE Philadelphia District is required to have turtle deflector devices on the draghead of hopper dredges in lower Delaware Bay to reduce the risk of sea turtle entrainment. Although a NMFS-approved turtle monitor is not required on hydraulic cutterhead dredges, onboard observers are required on hopper dredges between 1 May and 15 November to monitor dredging activities. An observer trained in identifying biological material is also required to inspect the discharge basket on the beach. Sea turtles do not occur in the action area from December through April and are not expected to be entrained during these months.

<u>Sturgeon</u>. Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) is a long-lived (approximately 60 years), late maturing, estuarine-dependent anadromous species (Bigelow and Schroeder, 1953; Vladykov and Greeley, 1963; Dadswell, 2006; ASSRT, 2007). They can grow to over 14 feet in length and weigh up to 800 pounds (Pikitch *et al*., 2005). Spawning areas within the Delaware Estuary are not yet well defined, but believed to occur in flowing water above the salt line and below the fall line of the river (Shirey *et al*., 1999), well north of the proposed project dredging and placement areas. Larvae and young juveniles are believed to remain in the upper river portion of the estuary. Subadults and adults are more salt-tolerant and travel out of the Delaware Bay at the mouth to the Atlantic Ocean (Brundage and O'Heron, 2009), typically in late summer and early fall.

Reine *et al.* (2014) assessed impacts of dredging on Atlantic sturgeon in the James River, Virginia. To assess potential entrainment by a cutterhead suction dredge, five Atlantic sturgeon were tracked using both active and passive transmitters. Lateral and vertical movements of the sturgeon were examined in relation to river bathymetry, river discharge rate, dredge production rate, and vessel traffic. None of the tagged fish showed evidence of avoidance behavior, and remained in close proximity to the dredge for as long as 21.5 hours before moving away. No strong evidence of attraction was observed either, as sturgeon moved past the operating dredge on several occasions. Movements appeared to be more influenced by tidal flows.

Direct physical impacts to Atlantic sturgeon by the dredge are less likely to occur in the wider bay region than upriver, given the various precautionary measures required to be in place during construction operations. Burial of benthic invertebrate species will occur at the beach placement sites within the intertidal zone. Atlantic sturgeon are not expected to be in the shallow intertidal zone of the selected placement areas within the bay. Currently, numerous research activities are underway, involving NMFS and other Federal, State and academic partners, to obtain more information on the distribution, abundance and behavior of Atlantic sturgeon within the Delaware Estuary and other rivers of the Mid-Atlantic Bight.

As with sea turtles, dredging can indirectly impact Atlantic sturgeon within the Delaware Estuary by removing benthic forage items such as clams, mussels and sea urchins that may be present within the channel. The water surface area of the Delaware Estuary is approximately 700 square miles. The Philadelphia to the Sea navigation channel occupies approximately 15.3 square miles (about 2.2% of the total estuary area) from the upstream project limit in Philadelphia to the downstream limit in lower Delaware Bay. Lower Reach E, which includes the lower portion of Miah Maull Range and all of Brandywine Range, is 80,000 feet long (Stations 432+000 to 512+000) and 1,000 feet wide. The navigation channel in Lower Reach E thus encompasses approximately 2.9 square miles. It is anticipated that about 80% of Lower Reach E (2.3 square miles) will require periodic maintenance dredging once the 45-foot channel construction is complete. Future O&M dredging in Lower Reach E will thus affect about three-tenths of one percent of the estuary surface area.

While there is likely to be a temporary reduction in prey items in the channel within Lower Reach E, the action will result in the loss of forage in a proportionally small area of the estuary. Recolonization of benthic organisms is fairly rapid, as presented in Section 5.3.2. Studies have shown recolonization by benthic organisms within a month (Guerra-Garcia and Garcia-Gomez, 2006) and full recolonization within 12 months (USACE, 2011).

Shortnose sturgeon. Juvenile and adult shortnose sturgeon (*Acipenser brevirostrum*), an endangered species, generally remain in the freshwater portions of the Delaware River above the saltwater/freshwater interface, moving upstream in spring and summer and downstream during fall and winter. Telemetry data has shown, however, that shortnose sturgeon make localized coastal migrations, although not the significant marine migrations seen in Atlantic sturgeon. The NMFS concluded in their B.O. (NMFS, 2015) that the presence of shortnose sturgeon is expected to be rare in the high salinity levels of Reach E, although an occasional shortnose sturgeon may occur in this reach between late April and mid-November.

The effects of dredging on listed sea turtle species and sturgeon varies depending on the type of dredge used. Most sea turtles and sturgeon are able to escape a dredge due to its slow speed of the advancing draghead. Interactions with hopper dredges can cause sea turtle or sturgeon mortality through crushing as the draghead is placed on the bottom or if the sea turtle is impinged on the draghead through suction or entrainment. Procedures to minimize impacts are also employed to ensure that the draghead is properly seated on the bay bottom before starting suction (and turned off before lifting), thereby reducing the risk of injury to sea turtles and sturgeon. Sturgeon are benthic feeders and are often found at or near the bottom while foraging and moving into rivers. However, information suggests that Atlantic sturgeon are up off the bottom while in offshore areas. Likewise, the species is not expected to travel in the shallower waters of the project's dredged material placement sites.

Hydraulic dredges convey sand to the placement site through a pipeline and require less transiting. Material is directly mixed with water. Sea turtles are not known to be vulnerable to entrainment by hydraulic cutterhead dredges. Because the flow field is produced by suction of the operating draghead buried in the sediment, and the proposed borrow area is located in a large open (lower bay) area, it is likely that sturgeon can also avoid an oncoming cutterhead dredge and leave the area. Studies by Clarke (2011) performed swim tunnel tests on juvenile and subadult Atlantic sturgeon and concluded that there is a risk of entrainment only within 1 meter of the cutterhead for a 36 inch pipe diameter and suction of 4.6 m/second. The overall risk of entrainment in a wide area such as lower Delaware Bay is low. Risk is related to swimming stamina, which is positively correlated with total fish length. Entrainment of larger (*i.e.* subadult and adult) fish, which are those that can potentially be present within the project vicinity, is less likely due to their increased swimming performance and the relatively small size of the draghead opening (Hoover *et al*., 2005; Boysen and Hoover, 2009). The risk of entrainment is thought to be much higher in areas where sturgeon movements are restricted (*e.g.* in narrow rivers). Tracking studies of Atlantic sturgeon in the Delaware Estuary supports this assessment of risk, as none of the tagged sturgeon were attracted to or entrained by operating dredges (Brundage and O'Heron, 2011).

Due to the possibility of encountering munitions and explosives of concern (MEC) or unexploded ordnance (UXO) within the lower Delaware Bay, screening is required on all dredges for beach nourishment projects by the USACE Philadelphia District. Beginning in 2007, dredges are outfitted with 1) a screening device placed on the dredge intake or in a pipeline section prior to reaching the dredge pump, and 2) a screen at the discharge end of the pipeline on the beach. The purpose of the screening is to prevent ordnance from being deposited on the beach by dredging. The screening device on the dredge intake prevents the passage of any material greater than 1.25 inches in diameter. The maximum allowable opening size is 1.25 inches by 6 inches. The screening device on the discharge end (on the beach) is designed to retain all items 0.75 inches in diameter and larger. Visual inspection of the screens and sand placement are performed at a minimum of once every 8 hours. The use of munitions screens further reduces the likelihood of entrainment (NMFS, 2014). No entrainment of Atlantic sturgeon, shortnose sturgeon or sea turtles has been observed in Reach E during the past dredging events in the May-November period. The reduced risk of entrainment in this reach is likely due to the width of the bay and the relatively small area, by comparison, of the dredging area to the known use of areas outside of the channel.

NMFS concluded in their most recent B.O. (NMFS, 2015) for the DRMCD project that no Atlantic or shortnose sturgeon are likely to be injured or killed during hopper dredging operations in Reach E.

Provided that maintenance dredging occurs during the May – November window when sea turtles are likely to be present and that it occurs with a hopper dredge, no more than one sea turtle is likely to be entrained for each 600,000 cy of material removed.

As presented in Section 4.4.2, water quality impacts are anticipated to be minor and temporary at both the dredging and placement locations. No information is available on the effects of TSS on sea turtles, but studies on the effects of turbid waters on fish suggest that concentrations of TSS can reach thousands of milligrams per liter before an acute toxic reaction is expected (Burton, 1993). Temporary turbidity plumes from dredging may affect turtle behavior or turtle prey behavior but turtles are highly mobile and are likely to avoid areas of increased suspended solids.

Some marine mammals may be classified as threatened or endangered species, but all fall under the jurisdiction of the Marine Mammal Protection Act. The marine mammal species that are commonly encountered in the Delaware Estuary or traveling past the mouth of the Delaware Bay within the Atlantic Ocean are bottlenose dolphin (*Tursiops truncatus*), harbor porpoise (*Phocoena phocoena*), humpback whale (*Megatera novaeangliae*), harbor seal (*Phoca vitulina concolor*) and gray seal (*Halichooerus grypus*). Species not commonly sighted but could possibly utilize the lower estuary are pygmy sperm whale (*Kogia breviceps*), long-finned pilot whale (*Globicephala melaena*), fin whale (*Balaenoptera physalus*), northern right whale (*Eubalaena glacialis*), harp seal (*Cystophora cristata*) and ringed seal (*Poca hispida*).

Marine mammals would be expected to avoid dredging operations within the Delaware Bay. Section 7 of the Endangered Species Act of 1973 (ESA), as amended, requires Federal agencies to consult with the NMFS to ensure that the action carried out is not likely to jeopardize the continued existence of any endangered species or threatened species or adversely modify or destroy designated critical habitat. In the 2015 BO for the DRMCD, NMFS noted that although several whale species listed under their jurisdiction occur seasonally off the Atlantic coast of Delaware, and occasional transient right and humpback whales have been observed near the mouth of the Delaware Bay, no listed whales are known to occur up in the proposed action dredging and placement area and no further discussion was provided. The USACE Philadelphia District coastal dredging projects, as a rule, require the dredge and tender vessels to reduce transit speeds to 4 knots or less if any marine mammals, sea turtles or sturgeon are observed at the surface within 400 meters.

The USACE Philadelphia District has conducted formal Section 7 consultation with the NMFS several times for the DRMCD project and subsequent maintenance of the 45-foot channel. The DRMCD consultation encompassed the entire 100 river mile length of the deepening project, including Reach E where the present beneficial use of dredged material project dredging and placement operations are proposed.

In the most recent B.O. for the DRMCD project (November 2015), NMFS concluded that the proposed deepening is likely to adversely effect, but not likely to jeopardize the continued existence of endangered shortnose sturgeon, the threatened Gulf of Maine Distinct Population Segment (DPS) of Atlantic sturgeon, the threatened Northwest Atlantic DPS of loggerhead sea turtle or endangered Kemp's ridley sea turtle. The NMFS also concluded that the proposed action may affect, but is not likely to adversely affect endangered Carolina DPS of Atlantic sturgeon, endangered green sea turtles or endangered leatherback sea turtles. The B.O. specifies reasonable and prudent measures (RPMs) to be taken, necessary to minimize and monitor take of shortnose and Atlantic sturgeon and sea turtles. Since the proposed action to beneficially use dredged material from Reach E of the main channel within Delaware Bay is a modification to the original dredged material disposal plan, the USACE has re-initiated Section 7 consultation with NMFS. The USACE will abide by NMFS' RPMs and terms and conditions as specified through re-initiation of consultation.

5.4 HAZARDOUS, TOXIC AND RADIOACTIVE WASTE

Dredging within the Reach E of the Main Channel (*i.e*. bay region) and beach placement activities are not expected to result in the identification and/or disturbance of HTRW, as it has been found that coarse-grained material like sand in a high-energy area is unlikely to be contaminated with HTRW (USACE, 1994). Although the potential is low, small caliber UXO may be encountered during dredging operations, although unlikely considering that this Reach of the channel has most recently been dredged previously in 2015/2016, during the DRMCD project. As a safety precaution, the Corps requires that a screen be placed over the drag head to effectively prevent any of the UXO from entering the hopper and also on the discharge pipe "basket" on the beach, before the sand is subsequently placed on the beach. In the event that UXO is encountered during dredging, the screening will all but eliminate the possibility of any UXO remaining on the new beach after construction.

The contractor would be responsible for proper storage and disposal of any hazardous material such as oils and fuels used during the dredging and beach nourishment operations. The U.S. EPA and U.S. Coast Guard regulations require the treatment of waste (*e.g*., sewage, gray water) from dredge plants and tender/service vessels and prohibit the disposal of debris into the marine environment. The dredge contractor will be required to implement a marine pollution control plan to minimize any direct impacts to water quality from construction activity.

As stated in Section 4.7, no reported HTRW-related impacts were found to have the potential to adversely affect the proposed beachfill projects at the 8 dredged material placement locations.

5.5 AIR QUALITY

Air quality is generally good in the Delaware Bay region. Emissions of criteria pollutants, greenhouse gases, and other hazardous air pollutants would result from operation of the dredge pumps and coupled pump-out equipment, dredge propulsion engines, tugs, barges, and support vessels used in the placement and relocation of mooring buoys. In addition, air emissions would result from bulldozers, trucks, and other heavy equipment used in the construction of the berm and dune. Carbon monoxide and particulate emissions at the project site, during construction, may be considered offensive; but are generally not considered far-reaching. Exhaust from the construction equipment will have an effect on the immediate air quality around the construction operation but should not impact areas away from the construction area. These emissions will subside upon cessation of operation of heavy equipment.

The 1990 Clean Air Act Amendments include the provision of Federal Conformity, which is a regulation that ensures that Federal Actions conform to a nonattainment area's State Implementation Plan (SIP) thus not adversely impacting the area's progress toward attaining the National Ambient Air Quality Standards (NAAQS). The study area of the Delaware Bay encompasses three counties: New Castle, Kent, and Sussex Counties, which are part of the Philadelphia-Wilmington-Atlantic City, PA-NJ-MD-DE marginal areas that did not attain EPA's 2008 standards by 20 July 2015 (oxides of nitrogen NOx and volatile organic carbons VOCs).

There are two types of Federal Conformity: Transportation Conformity and General Conformity. Transportation Conformity does not apply to the proposed construction projects because they are not funded with Federal Highway Administration money and they do not impact the on-road transportation system. General Conformity typically applies to USACE beach projects, however, maintenance dredging activities are exempt from General Conformity review under 40 CFR Ch 1 Sec 93.153(c)(2)(ix): "*(c) The requirements of this subpart shall not apply to the following Federal actions: (2)(ix) Maintenance dredging and debris disposal where no new depths are required, applicable permits are secured, and disposal will be at an approved disposal site.*"

5.6 NOISE

Project-related noise at the placement site during construction will consist of the sound of dredged material passing through the pipe and discharging in a plume of water. Earth-moving equipment, such as bulldozers, will shape the newly deposited dredged material and produce engine noise in the nearby vicinity. Utilizing heavy earth-moving machinery fitted with approved muffling apparatus reduces noise and vibration impacts.

At the dredging location, hydraulic suction dredging involves raising loosened material to the sea surface by way of a pipe and centrifugal pump along with large quantities of water. Suction dredgers produce a combination of sounds from relatively continuous sources including engine and propeller noise from the operating vessel and pumps and the sound of the drag head moving across the substrate. Based upon data collected by Reine *et al*. (2014), sediment removal and the transition from transit to pump-out would be expected to produce the highest sound levels from larger suction dredges at an estimated source level (SL) of 172 decibels (dB) at 3 feet. The two quietest activities would be seawater pump-out (flushing pipes) and transiting (unloaded) to the borrow site, with expected SLs of approximately 159 and 163 dB at 3 feet, respectively. Based upon attenuation rates observed by Reine *et al*. (in prep.), it would be expected that at distances approximately 1.6-1.9 miles from the source, underwater sounds generated by the dredges would attenuate to background levels. However, similar to in-air sounds, wind (and corresponding sea-state) would play a role in dictating the distance to which project-related underwater sounds would be above ambient levels and potentially audible to nearby receptors. Underwater noise levels exceeding 160 dB could harass marine mammals.

Robinson *et al.* (2011) carried out an extensive study of the noise generated by a number of trailing suction hopper dredgers during marine aggregate extraction. Source levels at frequencies below 500 hertz (Hz) were generally in line with those expected for a cargo ship travelling at modest speed. The dredging process is interspersed with quieter periods when the dragheads are raised to allow the dredge to change positions. Clarke *et al*. (2002) evaluated sound levels produced by a hopper dredge during its "fill" cycle working in a sandy substrate. They found that most of the sound energy produced fell within the 70 to 1,000 Hz range, with peak pressure levels in the 120 to 140 dB range at 40 meters from the dredge. These data correlate well with a study conducted in the United Kingdom which found trailing suction hopper dredge sounds to be predominately in the low frequency range (below 500 Hz), with peak spectral levels at approximately 122 dB at a range of 56 meters (DEFRA, 2003).

Underwater sounds generated by hydraulic pipeline dredging operations are generally considered to be of low frequencies (< 1000 Hz) (Clarke *et al*., 2002), and limited to less than 100 meters from the source. In a review by Southall *et.al.* (2007) several studies showed altered behavior or avoidance by dolphins to increased sound related to increased boat traffic in the immediate vicinity. Thomsen *et al.* (2009) conducted a field study to better understand if and how dredge-related noise is likely to disturb marine fauna. This study found that the low-frequency dredge noise would potentially affect low- and mid-frequency cetaceans, such as bottlenose dolphins. Noise in the marine environment has also been responsible for displacement from critical feeding and breeding grounds in several other marine mammal species (Weilgart, 2007). Noise has also been documented to influence fish behavior (Thomsen *et al*., 2009). Fish detect and respond to sound utilizing cues to hunt for prey, avoid predators and for social interaction (LFR, 2004). It is likely that at close distances to the dredge vessel, the noise may produce a behavioral response in mobile marine species, with individuals moving away from the disturbance, thereby reducing the risk of physical or physiological damage. Accordingly, any resulting effects would be negligible. It is unlikely that underwater sound from conventional dredging operations can cause physical injury to fish species (Reine *et al*., 2012).

5.7 CULTURAL RESOURCES

Those areas, specifically Woodland Beach (historic hotel site), Big Stone Beach (Lighthouse), and Lewes Beach (shipwreck) that have potentially eligible historic properties can be successfully avoided during construction with the use of buffer areas. The USACE Cultural Resources Specialist has coordinated the proposed overall project with the Delaware and the New Jersey State Historic Preservation offices (SHPOs) and the Tribes. Since beach specific construction design, staging and access have not yet been developed, it is prudent to negotiate a Programmatic Agreement with both SHPOs and the Tribes in order to have their continued coordination as beach specific construction designs progress. Both SHPOs and the Tribes have reviewed the draft Programmatic Agreement and have submitted comments.

5.8 SOCIOECONOMIC RESOURCES

For the No Action Alternative, future maintenance dredging sand from Lower Reach E will be placed at Buoy 10 open water disposal site for approximately 10 more years, based on the projected capacity remaining at Buoy 10. Beyond this, dredging sand from Lower Reach E will be placed at Artificial Island CDF, per the Federal Standard for the least-cost, environmentally acceptable disposal location.

The No Action Alternative is likely to have an adverse impact on the local economy, social structures and quality of life within the local bayshore communities. Failure to restore and maintain coastal beaches which reduce risk to homes and adjacent wetlands will likely result in increases in damages from storm surges. Flood-related damages to infrastructure and nearby croplands will continue to occur. Crops typically have a low tolerance to salinity so if salinity intrusion of floodwaters continues to occur during significant storm events, interior field productivity and quality would decrease. Mature stands of trees may also die due to saltwater intrusion. Conversion of emergent marsh to large un-vegetated open water and mud flat due to overly frequent inundation would result in a diminished capacity of the surrounding areas to support fish and wildlife populations. Wildlife-dependent recreational resources in state wildlife refuge lands located behind the narrow barrier bayfront beaches, such as hunting, fishing, wildlife observation and general enjoyment of natural spaces would be adversely affected with the continued loss of wetlands and habitat diversity through erosion and inundation.

Under the TSP, more resilient nourished beaches would reduce risk to the residential communities, adjacent salt marshes, interior freshwater wetlands, forests and pond habitats for wildlife. Local long-term beneficial impacts to the socioeconomic environment would be realized from the placement of dredged material to create a robust beach berm and dune system. Ecosystem services to humans provided by the TSP include erosion control, water quality enhancement, storm protection, habitat provision for wildlife and recreation.

Environmental Justice. Appropriate measures will be taken to ensure consistency with local, regional, state, and Federal regulations. Implementation of the TSP is not anticipated to result in any significant or negative human health or safety impacts. The proposed project will not have a disproportionately high adverse effect on minority or low income populations and is in compliance with EO 12898. The project would generally have beneficial social and economic effects and would generally affect all persons equally.

5.9 CUMULATIVE IMPACTS

Cumulative impacts are defined in 40 CFR 1508.7 as those effects that result from:

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

Table 11 summarizes the impact of cumulative actions by identifying the past, present and reasonably foreseeable future condition of the various resources which are directly or indirectly impacted by the proposed action and its alternatives. The table also illustrates the with-project and without-project condition (the difference being the incremental impact of the project). Also illustrated is the future condition with any reasonable alternatives (or range of alternatives).

Unavoidable Adverse Environmental Impacts. Unavoidable adverse environmental impacts associated with dredging include temporary loss of benthic organisms in areas to be dredged and temporary water quality impacts that result from the suspension of bottom sediments during the dredging process. Species of relatively non-motile infaunal invertebrates that inhabit the dredge area will unavoidably be lost during dredging. Species of motile epifaunal invertebrates inhabit the channel bottom. Motile organisms such as fish and crabs should be able to escape both the area of dredging and placement operations. Many of those species that are not able to escape the construction area are expected to recolonize after project completion from adjacent similar habitat.

In Delaware Bay, dredged material from Miah Maull and Brandywine Ranges is predominantly coarse to medium grained clean sand and will be used for beneficial purposes for beach nourishment to reduce flood risks and to enhance wildlife habitat and recreational use. While there would be environmental disturbance during construction, the completed projects will be more productive and beneficial.

Table 19 – Impacts of Cumulative Actions

	Past (baseline condition)	**Present** **(existing condition)**	**Future without project**	**Future with Proposed Action**
Sand Resources	Historically, the bay shoreline was larger in the past, extending several hundred feet further seaward in the project area since 1937 and the losses have accelerated.	The beaches have experienced erosion with each significant storm event. The estuary is "sediment-starved" due to heavy shoreline development in the upper estuary and decades of dredged material placement in CDFs.	Material from Lower Reach E navigational channel will continue to be periodically dredged, and the material will be placed overboard at Buoy 10 and once filled, at the Artificial Island CDF. Bulkheads or seawalls may be required to protect bayfront residences in the project area.	High quality sand dredged from the navigation channel in Lower Reach E will be deposited onto Bayfront developed beaches to reduce flood risk and coastal erosion.
Fish and Wildlife Species	More abundant and widespread prior to development.	Some species have continued to suffer with loss of habitat from erosion (*e.g*. horseshoe crabs, migratory shorebirds).	Increased erosion in the future without project condition will cause beach habitat to continue to erode.	Individuals may be temporarily affected by dredging and placement activities; improved coastal habitat is sustained for life of project
Water Quality	Pristine prior to development and farming runoff. Subsequent decline in water quality.	Water quality has improved since the 1970s but still some degradation due to anthropogenic actions.	No change to present condition; no known projects in the vicinity that would cause a decline in water quality.	Temporary increases in local turbidity due to construction; no long-term change.

Short Term Uses of the Environment and Long-Term Productivity. The Delaware River port complex is considered to be the world's busiest freshwater port. The navigation channel requires periodic nourishment dredging in areas that shoal. These periodic dredging events play a significant role in keeping the ports competitive with others in the United States. Future maintenance dredging sand taken from the navigation channel in lower Reach E would be placed at the Buoy 10 open water disposal site, thereby reducing the available capacity of Buoy 10, which is estimated to have 10 years of remaining capacity with expansion. Once Buoy 10 is filled to capacity, future maintenance dredging sand would need to be transported and disposed at the nearest CDF (Artificial Island) located approximately 41 miles to the north. Placement at either Buoy 10 or Artificial Island provides no economic or environmental benefits to the proposed beach placement sites. However, beneficial use of the high quality clean sand dredged from Lower Reach E placed on eroding beaches provides substantial economic and environmental benefits.

Short-term use of the natural environment would be to achieve long-term productivity of the Delaware River ports and increased coastal storm risk management to Bayfront communities. Dredging does place some stress on the aquatic environment (*i.e.* elevated turbidity and loss of benthic resources). This stress is primarily felt during the actual dredging process, with limited long-term effects.

Irreversible and Irretrievable Commitments of Resources.
An irreversible commitment of resources is one in which the ability to use and/or enjoy the resource is lost permanently. An irretrievable commitment of resources is one in which, due to decisions to mandate the resource for another purpose, opportunities to use or enjoy the resources as they presently exist are lost for a period of time. Dredging and beach placement operations would involve utilization of time and fossil fuels, which are irreversible and irretrievable. Adverse environmental impacts associated with dredging are short-term in nature and will subside after dredging is completed. Placement of dredged material at the beneficial use sites is not irreversible. The project would provide added flood risk management to Bayfront communities from severe storm events but is not irreversible as storms will continue to occur, and in combination with sea level rise, continue to erode the shoreline.

6 PUBLIC INVOLVEMENT, REVIEW AND CONSULTATION

6.1 PUBLIC INVOLVEMENT PROGRAM

To announce the scoping phase of the feasibility study, a NEPA scoping letter was issued on 24 November 2014. The recipients were informed of the purpose and scope of the feasibility study and were invited to provide input to the feasibility, including the scoping of the environmental issues that should be addressed throughout the study. Following the 31 March 2015 Alternatives Milestone Meeting an additional NEPA scoping letter was issued on 27 April 2015.

6.2 INSTITUTIONAL INVOLVEMENT

6.2.1 Agency Coordination

This feasibility study has been coordinated with the following agencies: the U.S. Fish and Wildlife Service (USFWS), the National Marine Fisheries Service (NMFS), the U.S. Environmental Protection Agency (EPA), the Delaware Department of Natural Resources and Environmental Control (DNREC) and the Delaware State Historic Preservation Officer (SHPO).

6.2.2 Compliance with Environmental Requirements

This section provides detailed discussed of agency coordination and associated environmental requirements.

6.2.2.1 National Environmental Policy Act of 1969 (NEPA)

This feasibility report documents the effects of the TSP and served as the Draft Environmental Assessment. It will be subject to public review and comment for a 45-day period. This public coordination and environmental impact assessment complies with the intent of NEPA. The TSP is in compliance with the National Environmental Policy Act of 1969, as amended, 42 U.S.C. 4321, *et seq*. P.L. 91-190.

6.2.2.2 Endangered Species Act of 1973

The TSP falls under the scope of the 20 November 2015 Biological Opinion Re-initiation – Deepening of the Delaware River Federal Navigation Channel (NMFS, 2015). Consultation was reinitiated on 16 August 2016 with NMFS for the modification to beneficially use the dredged material from Lower Reach E to place on the Bayfront beaches identified in the TSP for this study.

Coordination with USFWS was initiated on 24 November 2014 with USFWS Chesapeake Bay Field Office (CBFO). Streamlined (Tier 2) formal consultation was re-initiated on 16 September 2016 after the TSP was selected. An IPAC search was completed and confirmed with CBFO on 14 October 2016. Coordination with USFWS will be finalized prior to completing the NEPA process. This feasibility study is in compliance with the Endangered Species Act of 1973, as amended, 16 U.S.C. 1531, *et seq.* P.L. 93-205.

6.2.2.3 Fish & Wildlife Coordination Act of 1958

Coordination with the USFWS for FWCA reports was initiated on 15 July 2015. The scope of work was finalized on 11 September 2015. A Planning Aid Report was received from USFWS on 08 July 2016. A final 2(b) report will be completed by the USFWS and submitted to USACE prior to finalization of the feasibility report and integrated environmental assessment. The feasibility study is in compliance with the Fish & Wildlife Coordination Act of 1958.

6.2.2.4 National Historic Preservation Act of 1966 (INTER ALIA)

The TSP is in compliance with Section 106 of the National Historic Preservation Act, as amended (P.L. 89-665). As part of the requirements and consultation process contained within the National Historic Preservation Act implementing regulations of 36 CFR 800, this TSP is also in compliance.

6.2.2.5 Clean Water Act of 1972

A Section 401 water quality certification application will be submitted to the Delaware Department of Natural Resources and Environmental Control (DNREC) and USACE will obtain this certification prior to construction. All state water quality requirements would be met. A Section 404(b) evaluation is included in this report. The feasibility study is in compliance with the Clean Water Act of 1972.

6.2.2.6 Clean Air Act of 1972

The short-term impacts from the construction equipment associated with the TSP will not significantly impact air quality. The requirements of this rule are not applicable to this TSP because the project is exempt from the General Conformity requirement under 40 CFR Ch. 1 Sec. 93.153(c)(2)(ix) for maintenance dredging activities.

6.2.2.7 Coastal Zone Management Act of 1972

Coordination with the Delaware Coastal Management Program (DCMP) requires Federal agencies to follow the state's coastal management policies to obtain Federal consistency under the Coastal Zone Management Act (CZMA). USACE has determined that the TSP is consistent with the DCMP concerning acquisition of a Section 401 Water Quality Certificate and other state authorizations. The draft feasibility report and integrated EA and Section 404(b)(1) Evaluation have been submitted to the state in lieu of a summary of environmental impacts to show consistency with the CZMA. A Federal consistency determination in coordination with 15 CFR 930 Subpart C will be obtained from the DCMP prior to construction. Based on the information contained in the scoping notice and comments provided by their reviewing agencies, the state had no objections to the proposed activities.

6.2.2.8 Farmland Protection Policy Act of 1981

No prime or unique farmland would be impacted by implementation of this TSP. This Act is not applicable to this project.

6.2.2.9 Wild and Scenic River Act of 1968

No designated Wild and Scenic river reaches would be affected by project-related activities. This project is in compliance with this Act.

6.2.2.10 Marine Mammal Protection Act of 1972

USACE does not anticipate the take of any marine mammals during any activities associated with the TSP. Should a hopper dredge be utilized, a trained government-certified sea turtle and marine mammal observer will be stationed on the dredge during all water-related construction activities. Appropriate actions will be taken to avoid adverse effects to listed and protected marine mammal species during project construction, including all terms and conditions and reasonable and prudent measures provided by DNREC and NMFS. Therefore, this project is in compliance with this Act.

6.2.2.11 Estuary Protection Act of 1968

In the Estuary Protection Act of 1968, Congress declared that "many estuaries in the United States are rich in a variety of natural, commercial and other resources, including environmental natural beauty, and are of immediate and potential value to the present and future generations of Americans." This Act is intended to protect, conserve and restore estuaries in balance with developing them to further the growth and development of the Nation. The TSP proposes to beneficially use sand material dredged from the Delaware River Main Channel to restore eroded Bayfront barrier beaches. No development will occur. The project will provide a positive benefit to the Delaware Estuary by keeping the dredged sand within the lower estuarine system and will provide a sand source to neighboring undeveloped beaches through natural longshore transport processes. Therefore, this TSP is consistent with the purposes of this Act.

6.2.2.12 Federal Water Project Recreation Act

The principles of the Federal Water Project Recreation Act, as amended, 16 U.S.C. 460-1 (12), *et seq*. P.L. 89-72, do not apply to this TSP.

6.2.2.13 Magnuson-Stevens Fishery Conservation and Management Act of 1976

Coordination with NMFS to initiate consultation under the Magnuson-Stevens Fishery Conservation and Management Act began on 22 December 2014. An Essential Fish Habitat Assessment was prepared for the Delaware River Main Channel Deepening Project (the dredged material source). NMFS identified fish species with Essential Fish Habitat Management Plans; identified ESA species and recommended avoiding sturgeon spawning habitat in the upper Delaware River. NMFS advised that general time of year restrictions could be revised upon review of the draft feasibility report and environmental assessment description of the TSP and its potential impacts. The TSP is being coordinated with NMFS and is in compliance with the Act.

6.2.2.14 Submerged Lands Act of 1953

The project would occur on submerged lands of the State of Delaware. The project is being coordinated with the State and is in compliance with the Act.

6.2.2.15 Coastal Barrier Resources Act and Coastal Barrier Improvement Act of 1990

The Coastal Barrier Resources Act (CBRA) and the Coastal Barrier Improvement Act of 1990 (CBIA) limit Federally subsidized development within CBRA Units to limit the loss of human life by discouraging development in high risk areas, to reduce wasteful expenditures of Federal resources and to protect the natural resources associated with coastal barriers. USACE recognizes that some portions of the dredged material placement locations identified in the TSP (as currently described) are located within CBRA units. USACE will continue to work with USFWS to ensure consistency with CBRA as the TSP is further optimized and refined during the formulation of the recommended plan.

CBIA provides development goals for undeveloped coastal property held in public ownership, including wildlife refuges, parks and other lands set aside for conservation ("otherwise protected areas," or OPAs). These public lands are excluded from most of the CBRA restrictions, although they are prohibited from receiving Federal Flood Insurance for new structures.

Federal dollars can be spent within CBRA Units for certain activities, including (1) projects for the study, management, protection and enhancement of fish and wildlife resources and habitats; (2) establishment of navigation aids; (3) projects funded under the Land and Water Conservation Fund Act of 1965; (4) scientific research; (5) assistance for emergency actions essential to saving lives and the protection of property and the public health and safety, if preferred pursuant to the Disaster Relief Emergency

Assistance Act and the National Flood Insurance Act and are necessary to alleviate the emergency; (6) maintenance, repair or reconstruction, but not expansion, of publicly owned or publicly operated roads, structures or facilities; (7) nonstructural projects for shoreline stabilization that are designed to mimic, enhance or restore a natural stabilization system; (8) any use or facility necessary for the exploration, extraction or transportation energy resources; (9) maintenance or construction of improvements of existing federal navigation channels, including the disposal of dredge materials related to such projects; and (10) military activities essential to national security.

6.2.2.16 Rivers and Harbors Act of 1899

The Rivers and Harbors Act addresses river and harbor projects and activities within navigable waters. The proposed action will beneficially use dredged material from the bay portion of the authorized Philadelphia to the Sea Delaware River Navigation Channel to place on Bayfront beaches rather than dispose at Buoy 10 or and upland CDF. The TSP is in compliance with this Act.

6.2.2.17 Anadromous Fish Conservation Act

This Act authorizes the Secretaries of the Interior and Commerce to enter into cooperative agreements with the states and other non-Federal interests for conservation, development and enhancement of anadromous fish and to contribute up to 50 percent as the Federal share of the cost of carrying out such agreements. As this project is not receiving funding for these purposes, this Act does not apply.

6.2.2.18 Migratory Bird Treaty Act and Migratory Bird Conservation Act

Migratory birds would be minimally affected by dredging at the proposed sand source locations. USACE will include the standard migratory bird protection requirements in the project plans and specifications and will require the contractor to abide by those requirements. USACE will comply with all reasonable and prudent measures as advised by the USFWS. Nourishment activities at the beach placement sites will be monitored during the nesting season to protect nesting migratory birds. If nesting activities occur within the construction area, appropriate buffers will be placed around nests to ensure their protection. The TSP is in compliance with these Acts.

6.2.2.19 Marine Protection, Research and Sanctuaries Act (Ocean Dumping Act)

The term “dumping” as defined in the Act (3[33 U.S.C. 1402](f)) does not apply to the disposal of material for beach nourishment or to the placement of material for a purpose other than disposal. The disposal activities addressed in this EA have been evaluated under Section 404 of the Clean Water Act.

6.2.2.20 Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970

The purpose of this Act (PL 91-646) is to ensure that owners of real property to be acquired for Federal and Federally assisted projects are treated fairly and consistently and that persons displaced as a direct result of such acquisition will not suffer disproportionate injuries as a result of projects designed for the benefit of the public as a whole. No acquisition of real property was considered. Therefore, this project does not involve any real property acquisition or displacement of property owners or tenants. Therefore, this Act is not relevant to this project.

6.2.2.21 Executive Order 11990, Protection of Wetlands
No wetlands would be affected by the TSP. This plan is in compliance with the goals of this Executive Order.

6.2.2.22 Executive Order 11988, Floodplain Management
To comply with Executive Order 11988, the policy of USACE is to formulate alternatives that, to the extent possible, avoid or minimize adverse effects associated with the use of the floodplain and avoid inducing development in the floodplain unless there is no practicable alternative. No activities associated with this project are located within a floodplain, which is defined by Executive Order 11988 as an "area which has a one percent or greater chance of flooding in any given year." The project is located within the Coastal High Hazard Area (CHHA), defined by Executive Order 11988 as an "area subject to inundation by one-percent-annual chance of flood, extending from offshore to the inland limit of a primary frontal dune along an open coast and any other area subject to high velocity wave action from storms." The project shoreline is developed and further development is anticipated to be minimal.

Coastal Storm Risk Management projects are inherently located in coastal areas, and are often located in CHHAs based on the problems the project is seeking to alleviate. The primary objective of this TSP is to reduce infrastructure damage. There is no practicable alternative that could be located outside of the CHHA that would achieve this objective. For the reasons stated above, the project is in compliance with Executive Order 11988, Floodplains Management.

6.2.2.23 Executive Order 12898, Environmental Justice
On February 11, 1994, the President of the United States issued Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*. The Executive Order mandates that each Federal agency make environmental justice part of the agency mission and to address, as appropriate, disproportionately high and adverse human health or environmental effects of the programs and policies on minority and low-income populations.

The TSP is expected to result in coastal storm risk management benefits to residents of all socioeconomic status. The beneficial effect of a wider, more sustainable beach and dune would benefit all members of the public who are able to obtain transportation to access the beach. The storm damage reduction benefits are primarily benefiting the landowners in this area. There are no disproportionate adverse impacts to minority or low income populations resulting from the implementation of the TSP.

6.2.2.24 Executive Order 13045, Disparate Risks Involving Children
On April 21, 1997, the President of the United States issued Executive Order 13045, *Protection of Children from Environmental Health Risks and Safety Risks*. The Executive Order mandates that each Federal agency make it a high priority to identify and assess environmental health risks and safety risks that may disproportionately affect children and ensure that its policies, programs, activities and standards address disproportionate risks to children that result from environmental health risks or safety risks. As the TSP does not affect children disproportionately from other members of the population, the proposed action would not increase any environmental health or safety risks to children.

7 LIST OF PREPARERS

The project delivery team (PDT) prepared the report and consisted of the following people:

Table 20 - Project Delivery Team

Name	Discipline
Tony Pratt – Non-Federal Sponsor	DNREC
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9 RECOMMENDATIONS

A tentatively selected plan (TSP) was developed to reduce damages related to storm surge and elevated water levels from coastal storm events, shoreline erosion and SLC along the Delaware Bay shoreline. The TSP consists of the construction of beach berm and dune via dredged material from the main channel of the Delaware Bay. Specific project details are presented in Section 3.6 of this report.

In making the above-reference recommendation, USACE has given consideration to all significant aspects in the overall public interest, including environmental quality, social effects, economic effects, engineering feasibility, and compatibility of the TSP with policies, desires, and capabilities of the State of Delaware and other non-Federal interests. USACE has evaluated several alternative plans for the purpose of coastal storm risk management. A TSP has been identified that is technically sound, economically cost-effective over the 50-year period of analysis, socially and environmentally acceptable, and has support from the non-Federal sponsor.

The selected plan has primary benefits based on coastal storm risk management and provides average annual total net benefits in accordance with the table below:

Table 21 – Summary of Costs & Benefits

Site	Damages Reduced	Total Estimated Project Cost	Total Net Benefits	Average Annual Net Benefits	BCR
Pickering	$32,653,678	$17,080,359	$15,573,319	$590,978	1.91
Kitts Hummock	$37,612,661	$18,575,604	$19,037,057	$722,420	2.02
Bowers	$9,009,131	$4,176,748	$4,832,383	$183,380	2.16
South Bowers	$15,357,442	$5,498,240	$9,859,202	$374,138	2.79
Big Stone	$11,408,499	$17,375,109	-$5,966,610	-$226,421	0.66
Slaughter	$107,266,146	$14,188,758	$93,077,388	$3,532,109	7.56
Prime Hook	$47,605,197	$10,746,416	$36,858,781	$1,398,720	4.43
Lewes Beach	$60,161,076	$13,348,255	$46,812,821	$1,776,457	4.51
Total	**$321,073,830**	**$100,989,490**	**$220,084,340**	**$8,351,779**	**3.18**

The TSP reflects information available at the time and current USACE policies governing formulation of coastal storm risk management projects. This plan will be subject to optimization and may be modified before finalization of the feasibility report. The project sponsor, interested Federal and non-Federal agencies, and other parties will be advised of any such modifications.