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

Feasibility Report and Integrated Environmental Assessment

Executive Summary

1 Study Information

In October 2005, the Committee on Environment and Public Works of the United States Senate passed a resolution requesting the U.S. Army Corps of Engineers (USACE) to review the report of the Chief of Engineers for two Federal navigation projects (1. Delaware River between Philadelphia, Pennsylvania and Trenton, New Jersey; and 2. Delaware River Philadelphia, Pennsylvania to the Sea) to determine if there were any opportunities for the beneficial use of dredged material resulting from the aforementioned navigation projects. The current standard practice for the above-referenced navigation projects is to dispose of dredged material via the least cost environmentally acceptable disposal location (Federal Standard), not beneficial use. This feasibility study looks at beneficially using dredged material for coastal storm risk management (CSRM) benefits in various Delaware communities. 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.

In 2012, the USACE completed the “Delaware River New Jersey, Delaware and Pennsylvania Dredged Material Utilization and Beneficial Use Opportunities Expedited Reconnaissance Study” (Reconnaissance Study). The authority for the Reconnaissance Study was the October 2005 resolution. The Reconnaissance study looked at the beneficial use of dredged material for a variety of purposes, including ecosystem restoration, flood risk management and navigation. It was recommended that the Reconnaissance Study proceed to the feasibility phase.

Following the completion of the Reconnaissance Study, this feasibility report was prepared in response to the above-referenced 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 damages along the Delaware Estuary shoreline (as well as along Delaware’s Inland Bays) caused by erosion, wave attack and inundation due to coastal storms, along with rising water levels due to sea-level change (SLC). The shoreline is characterized by a flat, low-lying coastal plain with broad marshes and narrow barriers of sand along the bay beaches. The sand beach barrier is widest and most well-developed near the mouth of the bay (south of Prime Hook), becoming less prevalent to the north. 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 opportunity to beneficially use dredged material to reduce vulnerability to coastal storms by minimizing erosion, wave and storm-surge related damages to Delaware communities and increase resiliency along the Delaware Estuary 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 Estuary, which includes the Delaware Bay and the tidal reach of the Delaware River. The “northern reach” is north of the river/bay boundary (Liston Point, DE), while the “southern reach” extends south from the Liston Point, DE area (river/bay boundary) to the mouth of the Delaware Bay.

3 Plans Considered

The primary planning objectives of this study are:

1. Improve CSRM for 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 Estuary and Delaware Inland Bay shoreline, via the beneficial use of dredged material.

The original 26 problem areas were subjected to two rounds of 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.

Each of the identified problem areas was screened to better understand the nature and extent of the CSRM problems. Initially, the USACE 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 North Atlantic Coast Comprehensive Study (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 hazards. 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 USACE chose to use the NACCS CEI as a 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 USACE 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 best professional judgment, it was evaluated further to determine if dredged material would be a feasible CSRM measure in the problem area.

During the initial round of screening, a primary driver behind assessing the feasibility of using dredged material was determining the transport distance from the dredged material source area to the problem area(s). 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 (as defined by the NACCS). 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 USACE 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 Estuary 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.

If the first round of 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 "Project Under 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. After the first round of screening, 14 sites were screened out from the initial 26 and recommended for further analysis under another authority.

The USACE formulated non-structural and structural measures, as well as natural and nature-based features (NNBF), for each problem area. In the second round of screening, the measures were compared against the planning objectives to see if they were in line with the study purpose. In order for measures to be carried forward for further analysis, they must have met one of the two study objectives.

The NACCS criteria for assessing each measure's CSRM Function was applied to determine if a measure met Objective 1. The CSRM 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 USACE 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 USACE 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 the northern planning reach, the No Action Plan and 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 berm and dune restoration (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, the No Action Plan and 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 Environmental Considerations

The study area is located within the Delaware Estuary 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.

The Delaware Estuary is within the historic range of 22 Federally-listed threatened or endangered species: 17 animals and 5 plants (Table ES-1).

Table ES- 1: 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	Squirrel, Delmarva Peninsula fox Entire, except Sussex Co (*Sciurus niger cinereus*)
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*)

The Federally listed species (threatened) under USFWS purview that may occur in the study area include the red knot (Calidris canutus rufa) and northern long-eared bat (Myotis septrentrionalis). The proposed project locations area not considered northern long-eared bat habitat; therefore, no impacts to the northern long-eared bat are anticipated. Small numbers of red knots may occur in Delaware year-round, while large numbers rely on Delaware Bay and Atlantic coast stopover habitats during the spring (May 1 through June 15) and fall (late-July through October) migration periods, respectively (USFWS, 2016).

USACE further recognizes that the proposed project footprints are adjacent to The Coastal Barrier Resources Act (CBRA) and the Coastal Barrier Improvement Act of 1990 (CBIA) system units. Per the USFWS letter dated 03 January 2017, the southern end of Pickering Beach and a small portion of the northern section of Kitts Hummock Beach are within Little Creek CBRA System Unit DE-01. The southern section of South Bowers Beach, the southern section of Slaughter Beach and the northern and southern sections of Prime Hook Beach are located within CBRA System Unit Broadkill Beach H00. While Federal funds for beach restoration may not be expended for projects located in CBRA System Units, coordination between USFWS and USACE have identified exceptions for the proposed project. With the exception of the northern end of Kitts Hummock and the northern end of Prime Hook Beach, the proposed dune and berm will not enter the CBRA system units. At the northern end of Kitts Hummock the dune/berm project may enter the system unit because the two properties in this area were built prior to the establishment of this CBRA system unit. At the northern end of Prime Hook Beach, USFWS will also permit the CSRM dune and berm to tie into the existing Prime Hook National Wildlife Refuge project located within a CBRA system unit. For all other beach projects adjacent to a system unit, USFWS determined that the berm tapers at each of the aforementioned locations are not restricted from entering the CBRA system units, as they do not represent an added line of CSRM but rather serve to stabilize the adjacent CSRM project footprint.

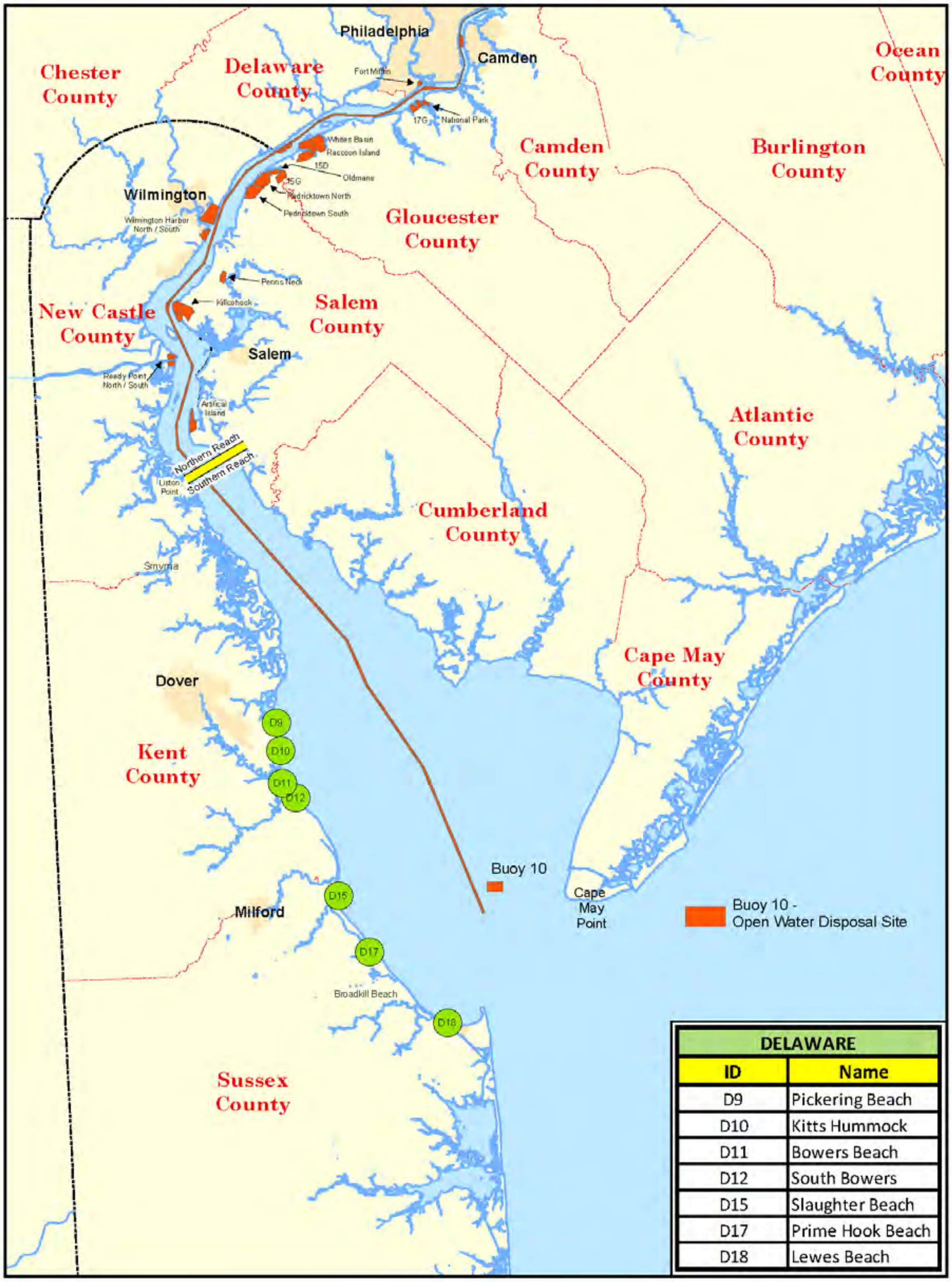
USACE received an email from USFWS on May 11, 2018 stating that "the proposed beach nourishment plans/berm and dune structures at Pickering Beach, Kitts Hummock Beach, Bowers Beach, South Bowers Beach, Slaughter Beach, Prime Hook Beach, and Lewes Beach, are all in compliance with the Coastal Barrier Resource Act (CBRA). However, the U.S. Fish and Wildlife Service reserves the right to revisit CBRA compliance for this project prior to construction based on the potential for changes in land use and regulations."

5 Recommended Plan

The recommended plan consists of beach restoration at 7 dredged material placement locations in the southern reach of the study area. The 7 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, Slaughter Beach, Prime Hook Beach and Lewes. Dune elevations and berm widths from the Beach-fx optimization are presented in Table 2. All of the design profiles consisting of both dune and berm have a dune slope of 1V:5H, foreshore slope of 1V:10H, and a berm elevation of +7 ft NAVD88. The berm elevation is selected to match the natural berm elevations in the study area. The results of the Beach-fx optimization show that Pickering and Kitts Hummock do not need a dune to maximize net benefits. However, a wider design berm is required since there is no dune. Slaughter optimized to a relatively low dune at +8.5 ft NAVD88 that matches the existing dune conditions and the remaining sites optimized to a design dune elevation of +12 ft NAVD88.

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. In a letter date 3 January 2017, USFWS noted that the project as proposed would have no effect on red knot with adherence to a time-of-year restriction for project activities conducted on the beaches between 15 April and 7 June when red knots forage. The USACE will adhere to this environmental window.

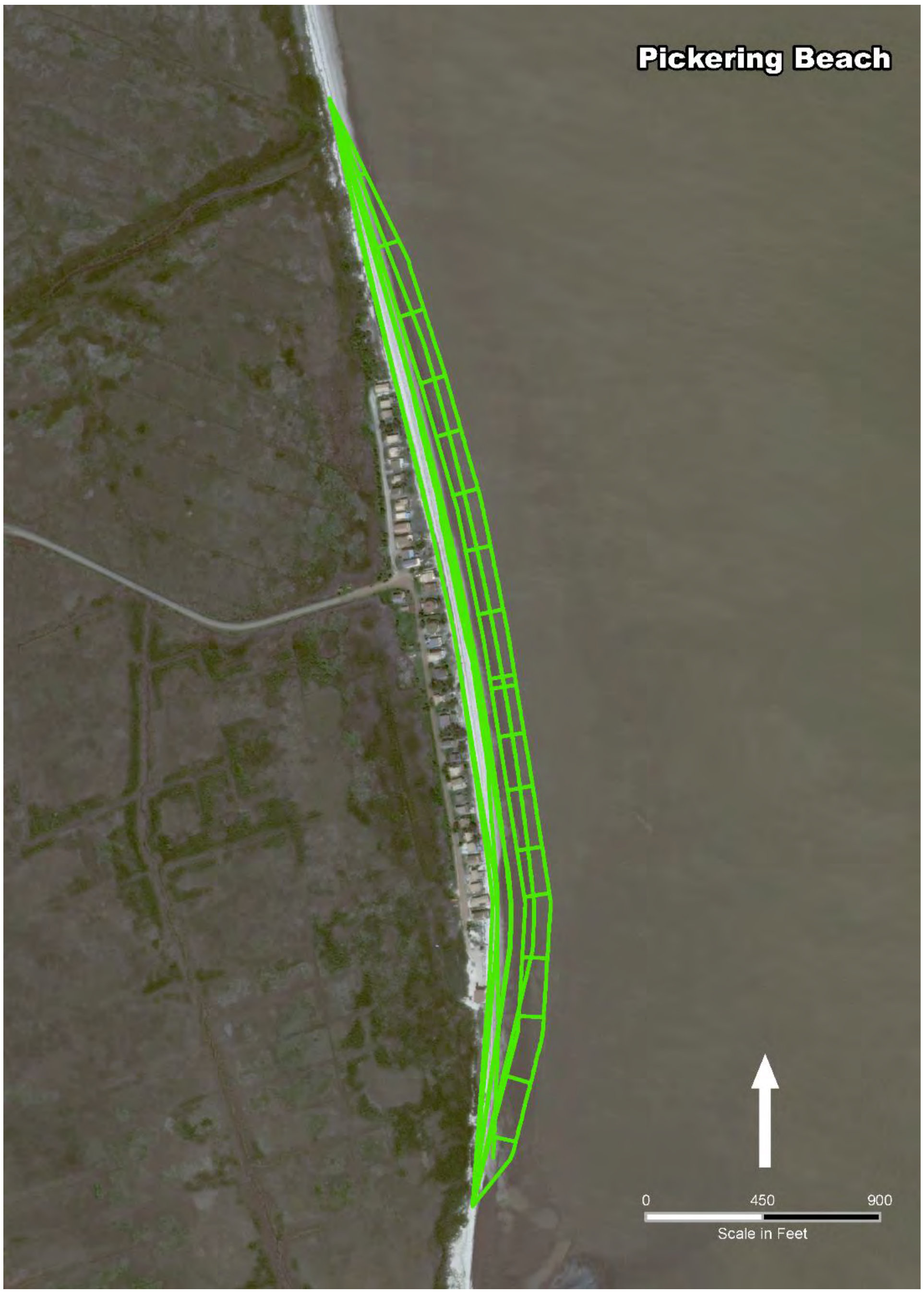
Figure ES- 1: Recommended Plan Dredged Material Placement Sites



DELAWARE	
ID	Name
D9	Pickering Beach
D10	Kitts Hummock
D11	Bowers Beach
D12	South Bowers
D15	Slaughter Beach
D17	Prime Hook Beach
D18	Lewes Beach

Pickering Beach

At Pickering Beach, the recommended plan calls for a berm only beachfill with the parameters shown on Table ES-2. The full width of the design extends in front of all currently developed property in Pickering Beach, with the exception of one home at the southern end of the project. This home is located in Little Creek CBRA System Unit DE-01 and CSRM-related beachfill is not permitted in this area; however, beachfill as part of the southern berm taper will be placed in this area.



Kitts Hummock

The recommended plan calls for a berm only beachfill at Kitts Hummock, as indicated on Table ES-2. The full width of the design berm extends in front of all currently developed property at Kitts Hummock, with the exception of one lot at the northern end of this project, where a home was recently demolished and a new one is planned to be built. This home is located in Little Creek CBRA System Unit DE-01 and no beachfill is permitted in this area, however, some beachfill as part of the northern berm taper will be placed in this area. An existing home immediately south of this lot will be provided CSRM by the full design berm width despite being in the CBRA System Unit due to the date of construction. In addition, the existing outfall is to be extended as necessary.

Bowers Beach

The recommended plan calls for a dune and berm beachfill at Bowers Beach with the parameters shown in Table ES-2. The design does not impact any CBRA System Units. The design will tie into the existing jetty at the southern end, with a tapered beachfill at the north end wrapping around the beachfront at the mouth of the St. Jones River.

South Bowers Beach

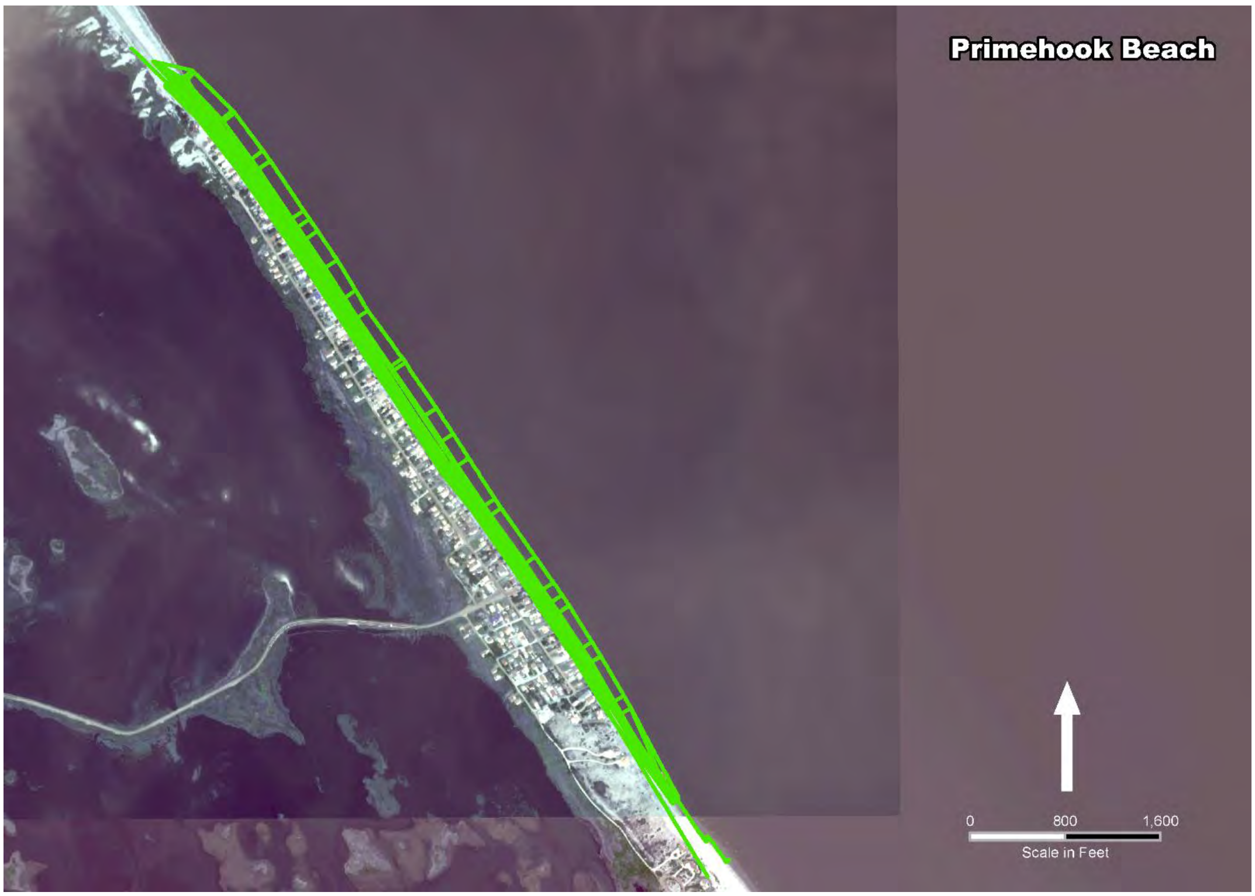
At South Bowers Beach, the recommended plan calls for a dune and berm beachfill with the parameters shown in Table ES-2. The design does not impact any CBRA System Units. The design will tie into the jetty alignment upon reconstruction by the local sponsor at the northern end, with a tapered beachfill at the southern end.

Slaughter Beach

For Slaughter Beach, the recommended plan calls for a dune and berm beachfill with the parameters shown in Table ES-2. The dune and berm design does not impact any CBRA System Units; however, there are several homes built in the CBRA System Unit Broadkill Beach H00 adjacent to the southern end of the project that will not be provided CSRM by this project. The design will utilize berm tapers at each end to tie the beachfill into existing conditions.

Prime Hook Beach

The recommended plan calls for a dune and berm beachfill at Prime Hook Beach with the parameters shown in Table ES-2. The design does impact the CBRA System Unit Broadkill Beach H00 to the north of project. An exception was granted to allow for the proposed project to tie in to the newly constructed PHNWR beach restoration. There are several homes built in the CBRA System Unit Broadkill Beach H00 adjacent to the southern end of the project that will not be provided CSRM by this project. The design will utilize tapers at each ends to tie the beachfill into existing conditions.



Lewes Beach

The recommended plan calls for a dune and berm beachfill at Lewes Beach with the parameters shown in Table ES-2. There currently exists a constructed Federal project (highlighted in yellow on the figure below) consisting of a 1,400 ft. long beachfill (15 ft. wide berm at an elevation of +8 ft. NAVD88, extending bayward at a slope of 1V:10H above MHW, and a dune with a 25 ft. crest width with an elevation of +14 ft. NAVD88 for the purpose of CSRM). Initial construction of the existing Federal project included the reconstruction of the adjacent terminal groin for Roosevelt Inlet for the purpose of navigation and the aforementioned beachfill. The 1,400 ft. length consists of a 900 ft. berm and dune beachfill with a 500 ft. taper. The recommended plan will tie into the existing Federal beachfill project at the western end, while the beachfill will taper to existing conditions at the eastern end.

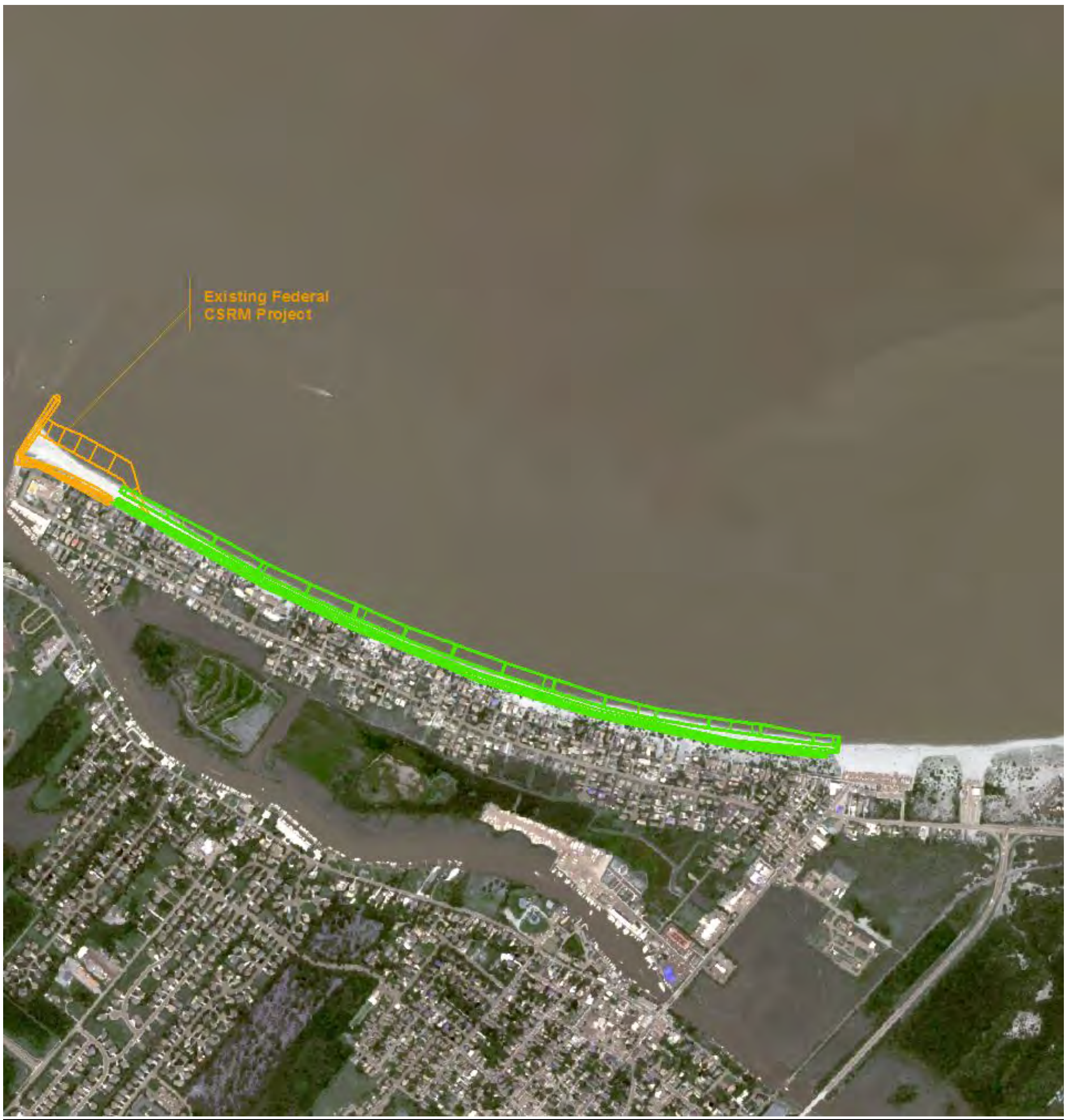


Table ES- 2: Summary of Recommended Plan Beachfill Dimensions

Location	Length of Design Dune/Berm (feet)	Length of Nourishment Dune (feet)	Southern Taper (feet)	Northern Taper (feet)	Length of Shoreline (feet)	Dune Height (feet NAVD88)	Dune Width (feet)	Berm Height (feet NAVD88)	Design Berm Width (feet)	Advance Berm Width (feet)
Pickering Beach	2,295	N/A	1,010	1,016	4,321	N/A	N/A	7	55	45
Kitts Hummock	4,685	N/A	965	1,000	6,650	N/A	N/A	7	55	45
Bowers Beach	2,326	2,326	34	846	3,206	12	25	7	25	50
South Bowers Beach	1,367	1,367	1,005	129	2,501	12	25	7	25	75
Slaughter Beach	14,468	9,482	1,000	942	16,410	8.5	25	7	25	25
Prime Hook Beach	6,408	4,252	941	258	7,607	12	25	7	25	25
Lewes Beach	7,223	2,515	30	0	9,768	12	25	7	25	25

The proposed dredged material source area is the O&M dredged material to be taken from Miah Maull and Brandywine Ranges of Lower Reach E (Lower Reach E) of the Delaware River Main Channel. 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 USACE 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 nourishment (2020), Buoy 10 may serve as a back-up source for nourishment 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 USACE 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).

Nourishment quantities (1.3 million cy) exceed the projected quantity assumed to be available from each dredging cycle. Therefore, the projected implementation of this recommended plan assumes nourishment to be split over two operations in 2020 and 2026. The southernmost 3 sites (Lewes, Prime Hook, and Slaughter) will be constructed in year 2020, and the remaining 4 northern sites (Pickering, Kitts Hummock, Bowers, and South Bowers) will be constructed in year 2026 during the 1st periodic renourishment cycle for the 3 southernmost sites. In year 2032 all 7 sites will be on the same 6-year periodic renourishment cycle.

In order to maintain the integrity of design beachfill alternatives, periodic renourishment must be included in the project design. If periodic renourishment was not performed throughout the life of the project, longshore and cross shore sediment transport mechanisms would act to erode the design beach. A 6-year periodic renourishment cycle is anticipated to maintain optimal coastal storm risk management. This nourishment cycle coincides with the proposed operation and maintenance (O&M) dredging to be performed in Lower Reach E.

6 Real Estate Requirements

Based on the information available, the recommended plan requires 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, are assumed to be located within the project area Limit of Construction for the entire project. At this time, four (4) total road easements are needed in four (4) of the project areas, requiring the use of Standard Estate No. 11, Road/Access Road Easement. One project area includes 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 and/or 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/or 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. 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.

The third estate/instrument required is for lands in the project area currently owned by the United States Fish and Wildlife Service. One parcel located in the Prime Hook project area is owned by the United States of America and managed by the US Fish and Wildlife Service (USFWS) as part of the Prime Hook National Wildlife Refuge. Although the parcel is owned by the United States, it is managed by an Agency other than the USACE. Therefore, one or more of the following documents will be required: a permit or cooperative agreement, a special use permit or an easement (if permissible at the time of request). The particular documentation required will be determined upon completion of plans and specifications. Coordination of project activities with USFWS has completed for the current project phase. Coordination with the U.S. Fish and Wildlife Service has been completed with respect to the Coastal Barrier Resources Act system units as it relates to the recommended plan footprints.

Table ES- 3: Summary of Real Estate Requirements

	Easements Required		**Easements In-Hand**		**Outstanding Easements**	
Project Area	**HSDR**	**Road**	**HSDR**	**Road**	**HSDR**	**Road**
Pickering	32	1	18	1	14	0
Kitts-Hummock	77	0	77	0	0	0
Bowers	50	0	40	0	10	0
South Bowers	10	1	1	1	9	0
Slaughter Beach	106	1	0	0	106	1
Prime Hook	67	1	0	0	67	1
Lewes	1	0	0	0	1	0
TOTALS:	**343**	**4**	**136**	**2**	**207**	**2**

Per the March 19, 2014 CECC-R Memo entitled “Availability of Navigation Servitude for Coastal Storm Damage Reduction Projects,” the determination of the applicability of Federal Navigation Servitude for the construction of coastal storm damage reduction measures by the United States under a Federal cost-shared project is done on a case-by-case basis and requires a two-step review process: a legal opinion of applicability completed by the District and a review for concurrence through the Real Estate Law Section of the Office of the Chief Counsel, staffed through Division Counsel.

In order to align real estate timelines with current project-planning best practices, the request for concurrence through Division Counsel will occur concurrently with this REP. Attached as Exhibit C is a memorandum provided by NAB Office of Counsel, dated 2 February 2018 entitled “Legal Opinion on the Use of Federal Navigation Servitude for Coastal Storm Damage Reduction Projects at Seven Locations Along the Delaware Bay Pursuant to the Delaware Beneficial Use of Dredged Material for the Delaware Feasibility Study.” Per the attached:

It is the District opinion that navigation servitude may be invoked for construction of the proposed coastal storm damage reduction project, in utilization of the federal channel to be dredged, and in the CSRM footprint below mean high water (MHW).

Therefore, although the State of Delaware owns/controls all lands below the MLLW and has navigational servitude and jurisdiction over lands between the MWHL and MLLW, no authorization for entry will be required from the NFS and no credit or reimbursement will be afforded the NFS for these areas.

PERTINENT DATA

Item	Pickering Beach	Kitts Hummock	Bowers Beach	South Bowers Beach	Slaughter Beach	Prime Hook Beach	Lewes Beach	Total
Volume of Initial Fill	181,600 cubic yards	198,500 cubic yards	178,600 cubic yards	119,600 cubic yards	260,800 cubic yards	278,700 cubic yards	191,800 cubic yards	1,300,000 cubic yards
Volume of Renourishment Fill	36,700 cubic yards	81,300 cubic yards	41,500 cubic yards	38,200 cubic yards	79,700 cubic yards	53,300 cubic yards	82,900 cubic yards	413,600 cubic yards
Renourishment Interval	6 years	6 years	6 years	6 years	6 years	6 years	6 years	6 years
Length of Fill	2,295 feet	4,685 feet	2,326 feet	1,367 feet	14,468 feet	6,408 feet	7,223 feet	N/A
Width of Berm	100 feet	100 feet	75 feet	100 feet	50 feet	50 feet	50 feet	N/A
Berm Slope	1V:10H	1V:10H	1V:10H	1V:10H	1V:10H	1V:10H	1V:10H	N/A
Dune Crest	N/A	N/A	12 feet NAVD88	12 feet NAVD88	8.5 feet NAVD88	12 feet NAVD88	12 feet NAVD88	N/A
Dune Slope	N/A	N/A	1V:5H	1V:5H	1V:5H	1V:5H	1V:5H	N/A
Nourishment Costs – 2020	-	-	-	-	$16,729,000	$9,698,000	$5,934,000	$32,360,000
Nourishment Costs - 2026	$15,350,000	$11,722,000	$10,343,000	$6,288,000	-	-	-	$43,703,000
Periodic Renourishment Costs – 2026	-	-	-	-	$4,723,000	$2,096,000	$3,626,000	$10,445,000
Periodic Renourishment Costs – 2032 through 2070	$6,800,000	$4,804,000	$2,300,000	$1,970,000	$4,730,000	$2,000,000	$3,600,000	$26,200,000 (per cycle)
Lands and Damages								$17,300,000
Preconstruction Engineering & Design								$25,500,000
Construction Management								$16,200,000
Average Annual Costs	$986,000	$837,000	$959,000	$862,000	$1,472,000	$1,344,000	$1,226,000	$7,687,000
Average Annual Benefits	$1,775,000	$1,406,000	$1,295,000	$963,000	$2,740,000	$2,430,000	$1,624,000	$12,231,000
Average Annual Net Benefits	$789,000	$568,000	$335,000	$101,000	$1,267,000	$1,086,000	$398,000	$4,544,000
Benefit Cost Ratio	1.8	1.7	1.4	1.1	1.9	1.8	1.3	1.6
Estimated Project First Cost (October 2017 Price Level)								**$328,500,000**

1. Nourishment for Slaughter Beach, Prime Hook Beach and Lewes Beach will occur in 2020.
2. Nourishment for Pickering Beach, Kitts Hummock, Bowers Beach and South Bowers Beach will occur in 2026, along with the first periodic renourishment of Slaughter Beach, Prime Hook Beach and Lewes Beach.
3. The quantities listed represent projected pay quantities required to construct and maintain the beach profile.
4. The berm elevation is +7 feet NAVD88.

FINDING OF NO SIGNIFICANT IMPACT

DELAWARE BENEFICIAL USE OF DREDGED MATERIAL

FOR THE DELAWARE RIVER

In October 2005, the Committee on Environment and Public Works of the United States Senate passed a resolution authorizing the U.S. Army Corps of Engineers (USACE) to review the report of the Chief of Engineers for two Federal navigation projects (1. Delaware River between Philadelphia, Pennsylvania and Trenton, New Jersey; and 2. Delaware River Philadelphia, Pennsylvania to the Sea) to determine if there were any opportunities for the beneficial use of dredged material resulting from the aforementioned navigation projects. The current standard practice for the above-referenced navigation projects is to dispose of dredged material via the least cost environmentally acceptable disposal location (Federal Standard), not beneficial use. This feasibility study looked at beneficially using dredged material for coastal storm risk management (CSRM) benefits in various Delaware communities.

This Feasibility Report and Integrated Environmental Assessment (EA) were 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).

The purpose of the current Feasibility Report and Integrated EA is to present the findings of a study to determine a CSRM plan for bayshore and flood-prone residential areas along the Delaware Estuary shoreline (including Delaware's Inland Bays). In compliance with NEPA, and the White House's Council on Environmental Quality (CEQ) regulations, the Philadelphia District has prepared the Feasibility Report and Integrated EA. The report evaluates the environmental effects of beneficially using maintenance dredged material obtained from the Federally-authorized Delaware River Main Navigation Channel as a sand source for CSRM efforts within the state of Delaware. The evaluation of dredging impacts are incorporated by reference in the EA.

The Feasibility Report and Integrated EA for the project was forwarded to the U.S. Environmental Protection Agency Region 3 (USEPA), the U.S. Fish and Wildlife Service, Chesapeake Bay Field Office (USFWS), the National Marine Fisheries Service, Northeast Region (NMFS), and Delaware's Department of Natural Resources and Environmental Control (DNREC), Division of Water Resources, Coastal Program, Division of Fish and Wildlife, the State Historic Preservation Office, and all other known interested parties for review and comment.

The preferred action consists of beach restoration at 7 dredged material placement locations: Pickering Beach, Kitts Hummock Beach, Bowers Beach, South Bowers Beach, Slaughter Beach, Prime Hook Beach, and Lewes Beach. The design will provide storm risk management benefits and will include a 6-year periodic renourishment cycle. Varying volumes of dredged material are required at each of the 7 placement locations, depending on the length of shoreline to be nourished and the existing beach profile (Table 1). The material will be dredged from the channel within Lower Reach E via a hopper

*Designates a section that is traditionally found in an Environmental Assessment

dredge and transported to a mooring barge (unloader) and the material transferred via a pipeline to the placement areas. Due to the large mean grain size and small fines content, the dredged sand is expected to be relatively stable and produce minimal turbidity in the nearshore environment. The nourishment cycle is in line with the proposed operation and maintenance dredging to be performed in Lower Reach E. The dune will be vegetated with native American beach grass.

Table 1

Dredged Material Placement Location	Proposed Project Length (feet)	Volume of Dredged Material (Nourishment)
Pickering Beach	2,295	182,000 cubic yards
Kitts Hummock	4,685	199,000 cubic yards
Bowers Beach	2,326	179,000 cubic yards
South Bowers Beach	1,367	120,000 cubic yards
Slaughter Beach	14,468	261,000 cubic yards
Prime Hook Beach	6,408	279,000 cubic yards
Lewes Beach	7,223	192,000 cubic yards

I have reviewed the EA of the proposed action. This Finding incorporates by reference all discussions and conclusions continued in the EA enclosed hereto. Based on the information analyzed in the EA as well as all NEPA documentation prepared for the authorized Delaware River Main Navigation Channel, and pertinent information obtained from other agencies and special interest groups having jurisdiction by law and/or special expertise, I conclude that the proposed action will have no significant impact on the quality of the human environment. Reasons for this conclusion are, in summary:

1. The project has been coordinated with the NMFS regarding Essential Fish Habitat pursuant to Section 305(b)(2) of the Magnuson-Stevens Fishery Conservation and Management Act. The USACE has agreed to reinitiate consultation with NMFS once revised highly migratory species EFH designations are finalized. NMFS has requested that dredging and dredged material placement be avoided from May 1 to September 15 to protect sandbar shark and sand tiger shark and from March 1 through June 30 for diadromous fish. NMFS also requested that dredging and dredged material placement be avoided from April 15 to September 15 to minimize adverse effects to horseshoe crabs.

2. The proposed plan has been coordinated with the USFWS and the NMFS regarding issues related to Section 7 of the Endangered Species Act of 1977 (16 U.S.C. 1531 et seq.). Work will be conducted in accordance with Biological Opinions issued by the USFWS for protection to piping plover, red knot and seabeach amaranth; and the NMFS for sea turtles, Atlantic sturgeon, shortnose sturgeon, and marine mammals. The proposed action does not jeopardize the continued existence of any threatened or endangered species or adversely impact any designated critical habitat. The project will abide by the reasonable and prudent measures

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provided in the Biological Assessment for the protection of listed species. Further coordination with USFWS and NMFS will occur as needed.

3. In accordance with Section 106 of the National Historic Preservation Act of 1966, as amended, and pursuant to USACE Tribal Consultation Policy, the USACE, in continued consultation with the Delaware State Historic Preservation Office and the Tribes, will avoid and/or minimize impacts to historic properties to ensure the proposed project will have No Adverse Effect on historic properties eligible for or listed on the National Register of Historic Places.

4. Delaware's Coastal Management Program (DCMP) has reviewed the USACE's consistency certification, and pursuant to 15 CFR, part 930 of the National Oceanographic and Atmospheric Administration (NOAA) regulations, the DCMP concurred with USACE's consistency determination in a letter dated 31 January 2017. As project details are finalized, USACE will continue coordination with the DCMP in adherence with NOAA regulations (15CFR, part 930.46).

5. DNREC's Wetlands and Subaqueous Lands Section (WSLS) has reviewed the draft Feasibility Report and Integrated EA and indicated support in a letter dated 26 February 2018 for the beneficial use of dredged material in a way that improves public safety, habitat and ecology while minimizing impacts to water quality. As project details are finalized, USACE will continue coordination with the WSLS to process Section 401 Water Quality Certification.

6. Measures to eliminate, reduce, or avoid potential impacts to fish and wildlife resources will be implemented through further coordination with DNREC's Division of Fish and Wildlife, the USFWS, and NMFS prior to project construction.

7. Benefits to the public will be the beneficial use of dredged material for the purpose of coastal storm risk management to bayshore residential communities and adjacent undeveloped beach and wetland habitats, including improved nesting habitat for beach nesting birds and resting and feeding habitat for migratory shorebirds and nesting diamondback terrapins.

In consideration of the information summarized, I find that the proposed action will not significantly affect the human environment and does not require an Environmental Impact Statement.

________________________________ ________________________________

Date

Kristen N. Dahle
Lieutenant Colonel, Corps of Engineers
District Commander

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

Feasibility Report and Integrated Environmental Assessment

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1 STUDY INFORMATION
The purpose of this report is to reduce the risk of damages from coastal storms through the beneficial use of dredged material from Federal navigation channels within the Delaware Estuary. The USACE and the Non-Federal Sponsor (DNREC) entered into a feasibility cost share agreement (FCSA) on 27 February 2014.

1.1 PROBLEM DESCRIPTION
The primary problems identified in this study are damages along the Delaware Estuary shoreline and Delaware's Inland Bays[1] caused by erosion, wave attack and inundation due to coastal storms, along with rising water levels due to SLC.

The overall objective of the planning study is to improve CSRM for Delaware communities located along the Delaware Estuary and Inland Bay area.

1.2 STUDY AUTHORITY*
The study authorities for the Delaware Beneficial Use of Dredged Material for the Delaware River Study (DMU) are the October 26, 2005 resolution of the Committee on Environment and Public Works of the United States Senate ("Resolution") and the Disaster Relief Appropriations Act, 2013 (PL 113-2).

The October 2005 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 accordance with the Resolution, the USACE undertook a Reconnaissance Study to review the above-referenced report of the Chief of Engineers to determine if any modifications to the recommendations were warranted with regard to the beneficial use of dredged material. In 2012, the USACE completed the "Delaware River New Jersey, Delaware and Pennsylvania Dredged Material Utilization and Beneficial Use Opportunities Expedited Reconnaissance Study" (Reconnaissance Study). The Reconnaissance

[1] Delaware's Inland Bays consist of Indian River Bay, Little Assawoman Bay, and Rehoboth Bay, which are all interconnected.

Study looked at the beneficial use of dredged material for a variety of purposes, including ecosystem restoration, flood risk management and navigation. It was recommended that the Reconnaissance Study proceed to the feasibility phase. The feasibility study described herein was conducted in accordance with that recommendation and to further facilitate the review requested by Congress in the Resolution. Upon initiation of the study, CSRM was identified as an "other allied purpose" to be considered for the beneficial use of dredged material as authorized by the Resolution.

The passage of PL 113-2 further mandated a CSRM feasibility study for the subject study area. Specifically regarding PL 113-2, 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 (*i.e.* dune and berm), 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 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."

As it was recommended that the Reconnaissance Study proceed to the feasibility phase, this ongoing CSRM feasibility study was identified in the Second Interim Report to Congress as a "Project Under Study" for reducing flooding and storm damage risks in the area affected by Hurricane Sandy. The area affected refers to the project locations for reducing flood and storm damage risks within the North Atlantic Division that were impacted by Hurricane Sandy. This CSRM study has been conducted in accordance with the Resolution and PL 113-2 and its associated reports thereby formulating for CSRM via the beneficial use of dredged material.

1.3 PURPOSE AND SCOPE (PURPOSE AND NEED)*

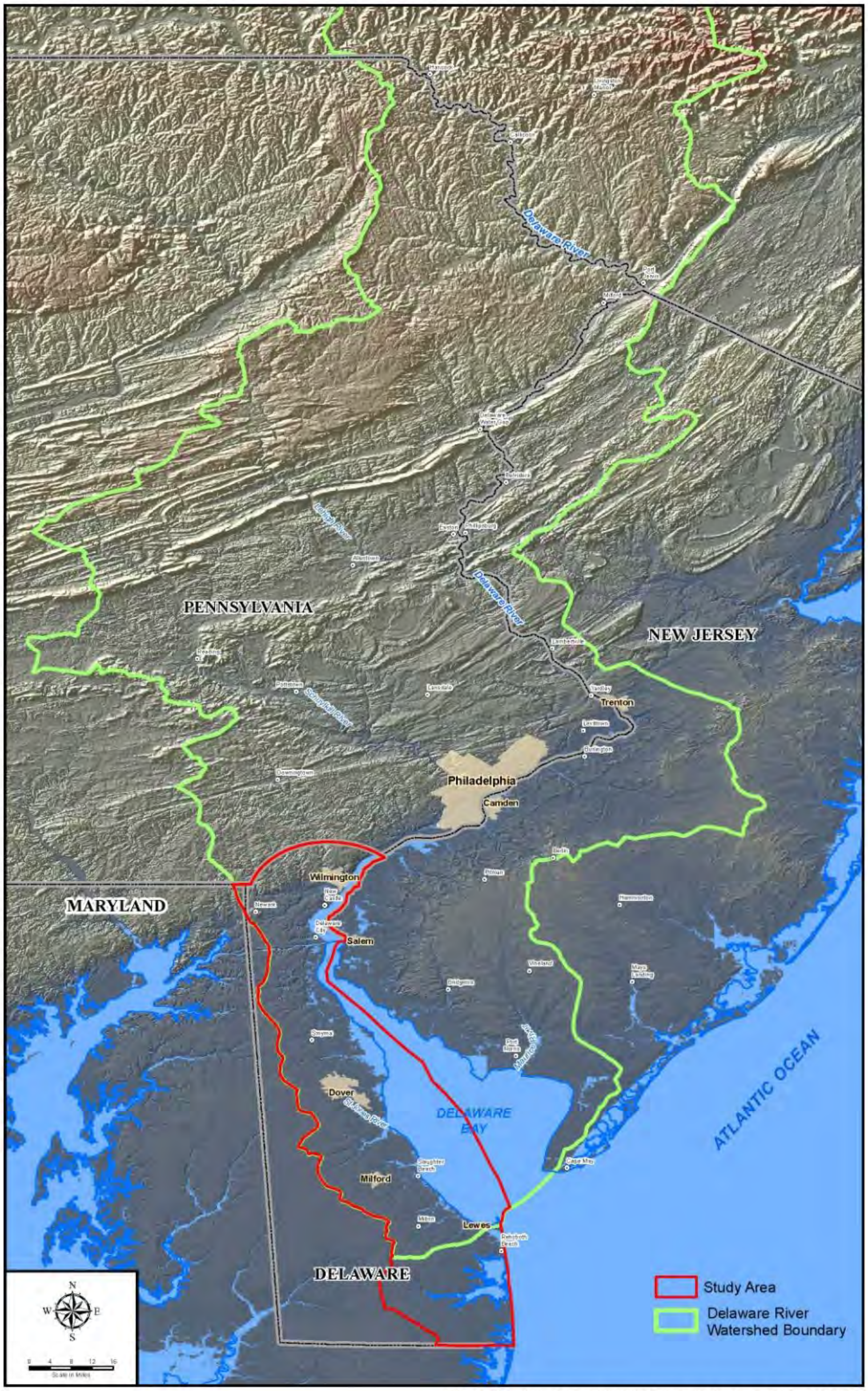
The purpose of this report is to present the findings of a feasibility investigation that was conducted to determine if there is a Federal interest and recommend a solution to identified CSRM problems at various Delaware communities. The study investigated the feasibility of addressing CSRM problem(s) via the beneficial use of dredged material. CSRM alternatives utilizing dredged material were formulated, compared/evaluated against the without project condition and were optimized in order to identify the National Economic Development (NED) plan. If a viable opportunity to implement CSRM alternatives with dredged material was not identified in select problem areas, then other alternatives were 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. 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).

The study area 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



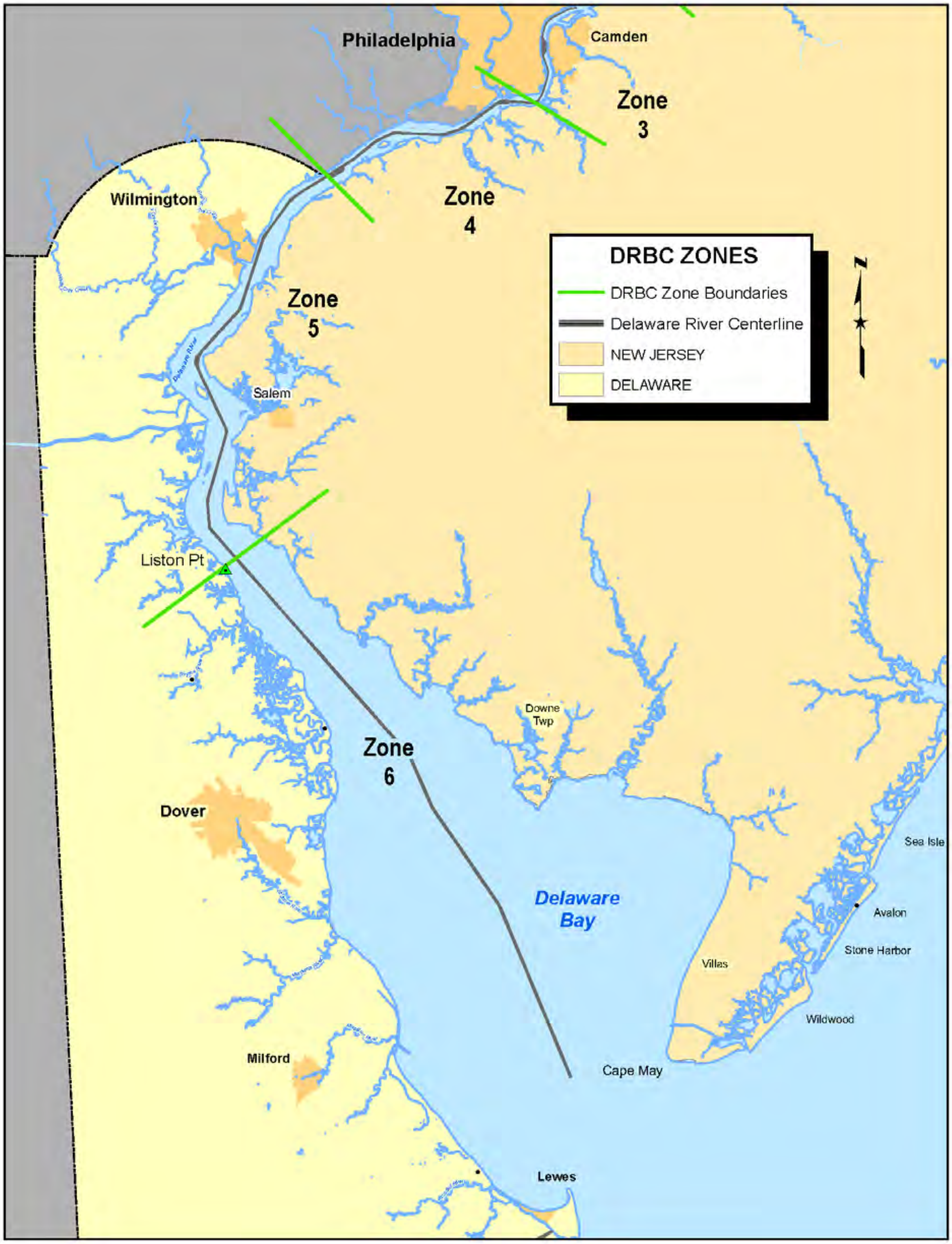
This feasibility study evaluated coastal storm-related damages in Delaware occurring in two defined planning reaches within the Delaware Estuary system. The "northern reach" is north of the river/bay boundary (Liston Point, DE), while the "southern reach" extends south from the river/bay boundary to 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 2). 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 related to coastal storm surge, as occurs during tropical storms, 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.

Sediment composition and grain size also vary 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 for maintenance dredging 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 (MCD) project was beneficially placed as beach fill at Oakwood Beach, Salem County, New Jersey (2014) and Broadkill Beach, Sussex County, Delaware (2015-2016).

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 2018. 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 +14 feet NAVD88.

Delaware Bay Coastline, Broadkill Beach, DE: This project includes 14,600 feet of beach fill with a 100-feet wide berm and a dune +16 feet NAVD88. As part of the initial construction of the Delaware River Main Channel Deepening there was an opportunity to complete nourishment of the Broadkill Beach project as a beneficial use of dredged material project.

Delaware Bay Oyster Revitalization Project: The native oyster population in the Delaware Bay is imperiled by disease. 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.

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 CSRM 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 disease. 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.

North Atlantic Coast Comprehensive Study (USACE, 2015): PL 113-2 also directed USACE to conduct a comprehensive study (the NACCS) to address the flood risks of vulnerable coastal populations in areas that were affected by Hurricane Sandy within the boundaries of the North Atlantic Division of the Corps. The NACCS was completed in January 2015 and provides a step-by-step approach, with advancements in the state of science and tools to conduct three levels of analysis. Tier 1 was a regional scale analysis (completed as part of the NACCS), Tier 2 was conducted at a State or watershed scale (conceptual Tier 2 evaluations were completed in each State and the District of Columbia), and Tier 3 would be a local-scale analysis that incorporates benefit-cost evaluations of CSRM plans. Under the NACCS, more than 31,200 miles of coastal shoreline were delineated into 39 planning reaches based on State boundaries, shoreline types, geomorphic features, and extent of existing or planned risk management projects. Based on coordination with a diverse set of agencies, the NACCS considers population and supporting infrastructure, environmental and cultural resources, and existing and planned CSRM efforts. The study also considers existing and future inundation and SLC. Specifically, the NACCS identified the Delaware Bay shoreline and the Delaware Inland Bays as high risk areas requiring additional analysis.

New Jersey Beneficial Use of Dredged Material for the Delaware River Draft Feasibility Report and Integrated Environmental Assessment (USACE, 2017): The draft feasibility report and integrated EA evaluated CSRM issues in various New Jersey communities, with the intent to beneficially use dredged material from the Federal navigation channels within the Delaware Estuary. Three communities (Gandys Beach, Fortescue and Villas (South)) were identified as dredged material placement sites for CSRM.

1.6 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 fourth step in the planning process (Evaluation of alternative 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 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

As discussed in Section 1.5, PL 113-2 directed USACE to conduct a comprehensive study to address the flood risks of vulnerable coastal populations in areas that were affected by Hurricane Sandy within the boundaries of the North Atlantic Division of the Corps. The NACCS, completed in January 2015, identified the Delaware Bay shoreline and the Delaware Inland Bays as high risk areas requiring additional analysis. The NACCS was used to identify the initial 26 problem areas for inclusion in the feasibility study.

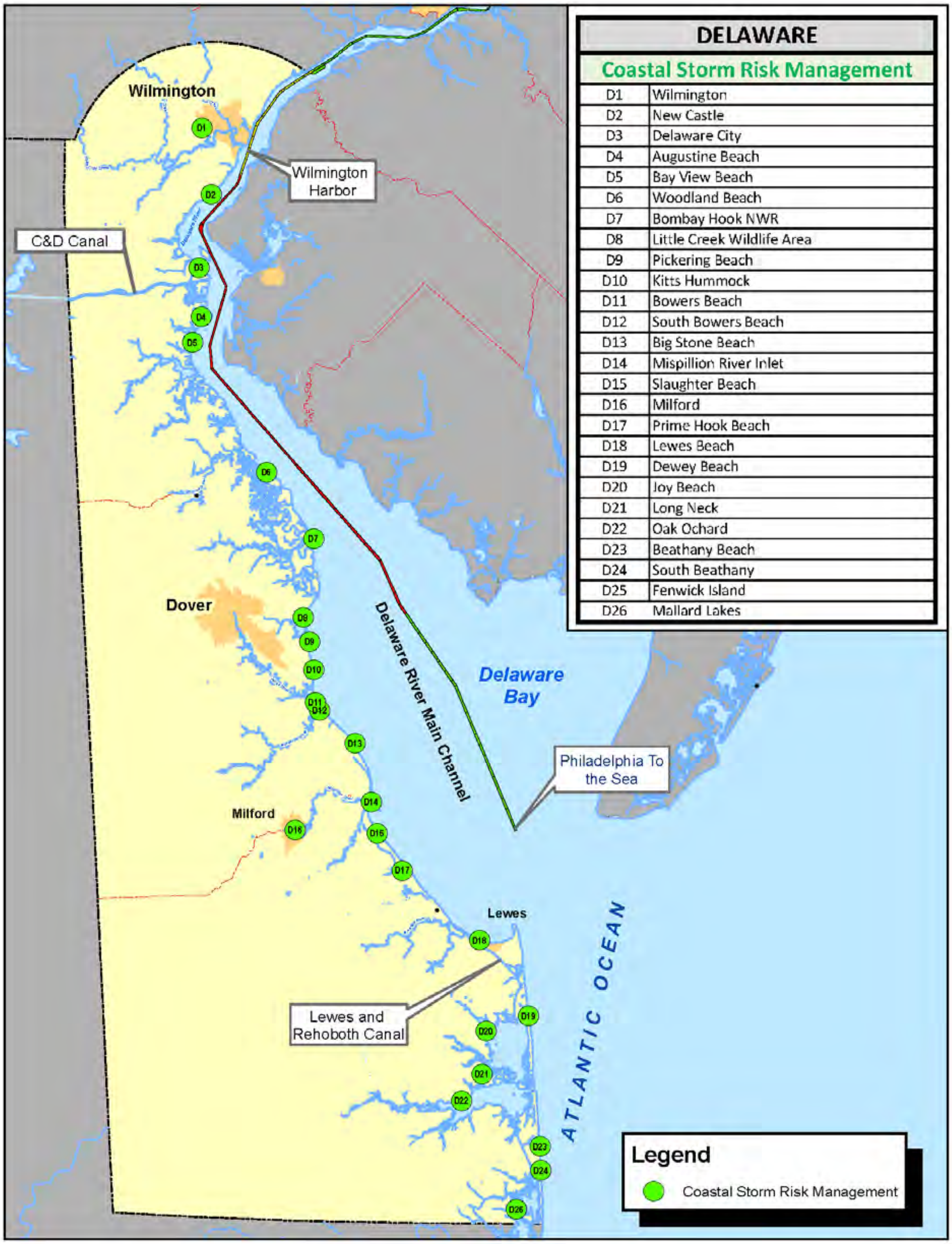
As part of the NACCS’ additional analysis, a visioning meeting (conducted by the USACE Philadelphia District) was held at the St. Jones Reserve in Dover, DE on Tuesday, February 4, 2014. Attendees included representatives from state, county, and local community agencies and representatives and non-profit organizations. Dialogue focused on the Delaware Inland Bays and Delaware Bay Coast, specifically how information was being both coordinated with stakeholders and incorporated into the NACCS. Specific discussion topics included identifying coastal storm risk at the community level, solutions to that risk, and identifying pertinent policy changes and legislative solutions that could improve coastal resilience. Correspondence was also received from the Town of South Bethany associated with the visioning meeting.

In addition, the NACCS effort included several letters to DNREC (non-Federal sponsor) in September through October 2013 requesting feedback with respect to the preliminary problem identification, the post-Sandy most-likely future conditions, vulnerability mapping, and problems, needs and opportunities for future planning initiatives. In response to the April 2014 USACE request letter regarding problems, needs and opportunities, DNREC responded by letter in June 2014 stating that there is significant interest in the development of more specific CSRM and resilience solutions in the State of Delaware.

Specifically, DNREC indicated that Mispillion River/Inlet is the most vulnerable area and should be the focus of such comprehensive and cooperative solutions.

The additional analysis and coordination under the NACCS identified the Delaware Bay shoreline and Delaware Inland Bays as "High Storm Impact" areas from Hurricane Sandy. For the state of Delaware, the NACCS identified 26 CSRM problem areas extending from New Castle to Sussex Counties, as shown in Figure 3.

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 damages along the Delaware Estuary shoreline (as well as along Delaware's Inland Bays) caused by erosion, wave attack and inundation due to coastal storms, along with rising water levels due to SLC. The shoreline is characterized by a flat, low-lying coastal plain with broad marshes and narrow barriers of sand along the bay beaches. The sand beach barrier is widest and most well-developed near the mouth of the bay (south of Prime Hook), becoming less prevalent to the north.

The nature of the CSRM problem and the study area characteristics also present the opportunity to beneficially use dredged material to reduce vulnerability to coastal storms by minimizing erosion, wave and storm-surge related damages to Delaware communities and increase resiliency along the Delaware Estuary shoreline.

2.4 EXISTING AND FUTURE WITHOUT PROJECT CONDITIONS

As referenced above, the CSRM problem areas are located in DRBC Zones 5 and 6. 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, Prime Hook 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 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.

2.4.1 Existing Coastal Storm Risk

The shorelines of the Delaware Estuary and Inland Bays are characterized by flat, low-lying coastal plains that are subject to inundation during storms, wave attack, 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 Estuary 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.

As referenced above, the northern planning reach has 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. 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 PHNWR.

2.4.2 Historical Flooding

According to the National Climatic Data Center (NCDC), 57 flood events were reported in Sussex County, DE between 13 March 1993 and 20 November 2009.

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.

Adjacent to but inland of the Delaware Estuary 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.

Figure 4 and Figure 5 illustrate damages incurred at Kitts Hummock Beach in May 2008 and at Lewes Beach in October 2012, respectively.

Figure 4 - Kitts Hummock, DE – May 2008

Figure 5 - Lewes Beach, DE – Oct 2012

2.4.3 Existing Coastal Storm Risk Management

For approximately 50 years, DNREC has implemented periodic CSRM measures for many of the Delaware 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	26,000	0
Bowers	1962	Beachfill	35,500	0
Bowers	1968	Beachfill	18,000	0
Bowers	1969	Beachfill	6,500	0
Bowers	1972	Beachfill	21,200	0
Bowers	1973	Beachfill	15,800	1,400
Bowers	1974	Beachfill	28,800	1,000
Bowers	1976	Groin	0	900
Bowers	1976	Groin	0	400
Bowers	1985	Beachfill	35,700	
Bowers	1986	Beachfill	13,700	500
Bowers	1986	Groin		213
Bowers	1988	Beachfill	51,700	

Project location	Year	Project Type	Fill Amount (CY)	Length (Ft)
Bowers	1988	Groin		290
Bowers	1988	Groin		320
Bowers	1994	Beachfill	12,000	500
Bowers	1998	Beachfill	46,240	2,200
Bowers	1998	Beachfill	55,165	
Bowers, North Murderkill	1995	Jetty		100
Bowers	2009	Jetty		120+/-
Bowers		Beachfill	1,000	400
Bowers	2009	Beachfill	9,000	2,615+/-
Bowers	2009	Beachfill	7,000	2,000+/-
Bowers	2012	Beachfill	13,000	2,700
Broadkill Beach	1908	Jetty	0	1,263
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	76,800	1,500
Broadkill Beach	1961	Beachfill	120,000	0
Broadkill Beach	1964	Groin		
Broadkill Beach	1964	Groin		
Broadkill Beach	1964	Revetment		
Broadkill Beach	1973	Beachfill	118,100	
Broadkill Beach	1975	Beachfill	295,000	6,100
Broadkill Beach	1976	Beachfill	59,700	2,200
Broadkill Beach	1981	Beachfill	127,700	0
Broadkill Beach	1996	Beachfill	25,000	
Broadkill Beach	1987-88	Beachfill	81,100	
Broadkill Beach	1993-94	Beachfill	67,000	
Broadkill Beach	2005	Beachfill	152,000	5,700
Broadkill Beach	2011	Beachfill	30,000	5,000
Broadkill Beach	2012	Beachfill	10,000	1,500
Broadkill Beach	2013	Beachfill	10,000	1,500
Broadkill Beach	2014	Beachfill	29,000	2,700
Kitts Hummock	1961	Beachfill	80,000	4,250
Kitts Hummock	1962	Beachfill	30,600	0
Kitts Hummock	1969	Beachfill	12,000	0
Kitts Hummock	1973	Beachfill	3,000	0
Kitts Hummock	1974	Beachfill	46,500	1,700
Kitts Hummock	1979	Beachfill	74,000	5,000
Kitts Hummock	1979	Breakwater	0	330
Kitts Hummock	1979	Breakwater	0	330

Project location	Year	Project Type	Fill Amount (CY)	Length (Ft)
Kitts Hummock	1979	Breakwater	0	330
Kitts Hummock	1987	Groin		180
Kitts Hummock	1988	Beachfill	15,780	1,000
Kitts Hummock	1996	Beachfill	32,850	1,000
Kitts Hummock	2006	Beachfill	400+/-	south end
Kitts Hummock	2008	Beachfill	15,000	1,400
Kitts Hummock	2010	Beach	10,000	1,000
Kitts Hummock	2012	Beachfill	7,000	1,500 +/-
Kitts Hummock	2014	Beachfill	7,500	1,500+/-
Lewes	1898	Breakwater	0	5,300
Lewes	1901	Breakwater	0	8,000
Lewes	1937	Jetty	0	1,700
Lewes	1937	Jetty	0	1,700
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	55,100	0
Lewes	1954	Beachfill	44,900	0
Lewes	1956	Groin	0	0
Lewes	1956	Groin	0	0
Lewes	1956	Groin	0	0
Lewes	1957	Beachfill	79,000	0
Lewes	1957	Beachfill	434,400	0
Lewes	1962	Beachfill	20,700	0
Lewes	1963	Beachfill	87,000	0
Lewes	1969	Beachfill	135,600	0
Lewes	1973	Beachfill	69,800	3,700
Lewes	1975	Beachfill	101,700	4,800
Lewes	1977	Beachfill	11,400	1,000
Lewes	1978	Beachfill	31,000	1,000
Lewes	1981	Beachfill	113,900	0
Lewes	1983	Beachfill	50,500	
Lewes	1987	Beachfill	11,000	
Lewes	1989	Beachfill	1,500,000	
Lewes	1990	Beachfill	32,000	
Lewes	1990	Groin		350
Lewes COE	2004	Beachfill	180,745	1,400
Lewes COE	2004	Jetty	18,220 tons	
Lewes COE	2011	Beachfill	111,757	1,500
Lewes	2012	Beachfill	8,315	

Project location	Year	Project Type	Fill Amount (CY)	Length (Ft)
Lewes Beach	2013	Beachfill	25,000	
Mispillion River Breach	1985	Dike	19,500 tons	970
Pickering Beach	1962	Beachfill	39,600	0
Pickering Beach	1969	Beachfill	5,000	0
Pickering Beach	1978	Beachfill	85,200	1,600
Pickering Beach	1978	Beachfill		
Pickering Beach	1979	Breakwater	0	400
Pickering Beach	1984	Breakwater	0	200
Pickering Beach	1990	Beachfill	55,400	2,400
Pickering Beach	2001	Beachfill	27,150	
Prime Hook Beach	1962	Beachfill	20,200	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	49,000	0
Slaughter Beach	1961	Beachfill	165,000	0
Slaughter Beach	1962	Beachfill	56,600	0
Slaughter Beach	1975	Beachfill	179,500	4,700
Slaughter Beach	1976	Beachfill	277,700	9,600
Slaughter Beach	1979	Beachfill	20,000	0
Slaughter Beach	1979	Perched Beach	20,000	0
Slaughter Beach	1985	Beachfill	26,200	1,700
Slaughter Beach	1985	Beachfill	10,300	
Slaughter Beach	2002	Beachfill	8,600	500
Slaughter Beach	2005	Beachfill	115,000	4,400 lf

Project location	Year	Project Type	Fill Amount (CY)	Length (Ft)
South Bowers	1961	Beachfill	20,000	0
South Bowers	1962	Beachfill	10,000	0
South Bowers	1969	Beachfill	4,000	0
South Bowers	1974	Beachfill	4,000	830
South Bowers	1975	Beachfill	15,000	1,000
South Bowers	1976	Beachfill	9,400	0
South Bowers	1976	Groin	0	325
South Bowers	1976	Groin	0	325
South Bowers	1984	Beachfill	17,000	
South Bowers	1988	Groin		600
South Bowers	1989	Beachfill	8,000	
South Bowers	1992	Beachfill	2,000	
South Bowers	1997	Beachfill	7,500	500
South Bowers	2009	Beachfill	2,000	400 +/-
South Bowers	2012	Beachfill	2,000	700

In addition to the state/local CSRM measures listed on Table 1, DNREC recently (2016) completed the rehabilitation of the terminal groin at the southern end of Bowers Beach, adjacent to the Murderkill River. Specifically, quarry-stone was laid over top of the existing concrete-filled bags to widen, raise the height and extend the length of the structure bayward.

Also, previous studies prepared for DNREC (PBS&J 2010, CB&I 2015) recommended rehabilitating the terminal groin at South Bowers, adjacent to the Murderkill River. The existing groin was originally constructed with sand filled bags in 1976 and then reinforced with grout filled bags in 1988 (PBS&J, 2010). The Murderkill River Inlet is a Federal navigation channel that is currently maintained and dredged by DNREC. Over time, the portion of the jetty along the inlet shoreline has been subject to sand transport over the jetty, effectively burying the landward end of the structure and creating a shoal just inside the inlet (PBS&J, 2010). PBS&J (2010) recommended rehabilitating the groin, sand tightening and raising the height, to better maintain sand on the beach and reduce the volume of sand entering the Murderkill River. CB&I (2010) determined that the “effective length of the groin” is only 50 feet and recommended re-establishing the groin to prevent future loss of sand due to overtopping and to promote stabilization of a sand fillet along South Bowers to help address the hot spot area. DNREC has indicated that the South Bowers terminal groin will be re-constructed by the State. Therefore, in the future without project conditions, USACE assumed that South Bowers Beach would have a fully rehabilitated terminal groin in place by 2026.

2.4.4 Future Without Project Conditions

The USACE (1991) and G.T. French (1990) conducted a review of the Delaware Bay and its tributaries to determine the magnitude, location, and effect of the shoreline erosion problems extending from Woodland Beach to Lewes, DE.

Shoreline change rates reported in the USACE 1991 and French 1990 studies are long-term shoreline changes derived from aerial images and NOS "T" sheets dating as far back as the 1800's. Maurmeyer (1977) reports that there has been considerable spatial and temporal variation in the rates of shoreline change in response to changing coastal morphology (opening and closing of inlets; spit growth), changing wave climate, and construction of engineering structures such as groins, jetties, and bulkheads. Shoreline change rates have also been affected by historical beachfill projects with over 3 million cubic yards of fill material placed since the 1950s. USACE 1991 states that "If beachfill projects have been implemented for a community, an attempt was made to use pre-beachfill shoreline changes or use estimates after filtering out beachfills to eliminate the beachfill effect." However, the shoreline change values reported by French represent the raw shoreline changes, without any adjustment for beachfill activities.

Shoreline changes reported by CB&I 2015 are derived from sediment budgets at each individual beach community. The sediment budgets were developed through a comparison of various topographic and hydrographic data. Shoreline location during relevant study years was compared to estimate the average annual sediment loss along each beach community. A sediment budget was derived by taking the observed horizontal shoreline changes over time and converting into an equivalent volume using the active profile height.

Table 2 – Summary of Historical Shoreline Change Rates (ft/yr) from Prior Studies

Sites	USACE 1991[1]	French 1990[1]	CB&I 2015
Pickering Beach	-4.9		-5.2
Kitts Hummock		-4.3	-8
Bowers Beach	-2	-3	-4.7
South Bowers Beach	-7.9		-1.75
Big Stone Beach	-5 to -6	-3.6	
Slaughter Beach	-2	1	-1.9
Prime Hook Beach		1.3	-0.7
Lewes Beach (near Roosevelt)	-3	-3.3	
Lewes Beach (central/eastern)	0.3	1.3	

[1]Values reported in PBS&J 2010, *Management Plan for the Delaware Bay Beaches*.

For the modeling associated with the draft feasibility report, future without project shoreline change rates for the DE DMU project were initially based on USACE 1991 and French 1990. Following the release of the draft feasibility report, future without project shoreline change rates at Slaughter and Prime Hook were adjusted based on the newer information provided by CB&I (2015). Shoreline change rates at the other sites were in relatively good agreement with CB&I (2015) and were not changed. The shoreline change rate at Lewes was updated to distinguish between the erosive shoreline along the western area versus the stable shoreline along the central/eastern area.

Table 3 - Recommended FWOP Shoreline Change Rates (ft/yr)

Location	Shoreline Change (ft/yr)
Pickering	-4.9
Kitts Hummock	-4.3
Bowers	-2.5
South Bowers	-3
Big Stone	-3.6
Slaughter	-1.9
Prime Hook	-0.7
Lewes Beach (western)	-3
Lewes Beach (central/eastern)	0

In the future without project conditions these erosion trends are expected to continue, or even be exacerbated by SLC, resulting in significant shoreline retreat and narrowing of existing beaches and dunes, and reduction in the existing beaches' ability to dissipate storm induced waves, erosion, and flooding. Increased storm-induced wave, erosion, and flooding damages are expected to undermine the physiography supporting the existing structures and infrastructure in the developed areas and adjacent marsh and wetland habitat.

It is important to note that in the absence of a Federal project under this study authority, maintenance dredging is anticipated to continue throughout the Delaware River with the majority of the dredged material disposal occurring in CDFs and/or Buoy 10 open water disposal site. As discussed in Section 3.4, the proposed source of material for the recommended plan is Lower Reach E (Miah Maull and Brandywine Ranges) of the Delaware Estuary main channel. The estimated future O&M dredging of Miah Maull and Brandywine is projected to be 465,000 cy/yr, with a dredging interval of 2 years. For the existing Federal navigation project the dredged material disposal from Lower Reach E will involve bottom dumping in Buoy 10 for approximately 10 more years (based on current plans to expand the Buoy 10 footprint); however, after 10 years, the current plan is to take the material to the Artificial Island CDF for disposal. Section 3.5.1 provides further discussion on the future without project conditions and the potential economic impacts of such conditions.

2.4.5 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 the 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-effective plan, specifically one in which the benefits exceed the costs. It is important to note that benefits can include non-monetary benefits such as reducing life-safety issues and improving the environmental quality.

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 operational, is 2020, and the period of analysis is through the year 2070. The planning objectives are as follows:

1. Improve CSRM for 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 Estuary 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.

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:

- CSRM must be achieved via the beneficial use of dredged material.
- 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.
- The timing of maintenance dredging will control the availability of sand for placement.

In addition to the aforementioned constraints, the following planning considerations were recognized during the formulation process:

- Limit extensive changes to local land use designations and zoning.
- Avoid inducing flood damages.
- Existing topography for tying in dune alignment will impact CSRM benefits realized.
- Avoid and/or minimize effects on cultural resources and historic structures, sites and features.
- Avoid degradation to water quality.

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 USACE 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 USACE to better understand the nature and extent of the CSRM problems. Initially, the USACE 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 and reported 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 hazards. 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 USACE chose to use the NACCS CEI as a 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 USACE 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 best professional judgment, it was evaluated further to determine if dredged material would be a feasible CSRM measure in the problem area.

During the first round of screening, a primary driver behind assessing the feasibility of using dredged material was determining the transport distance from the dredged material source area to the problem area(s). 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, as reported in the NACCS. 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 USACE 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 Estuary 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.

If the first round of 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 "Project Under 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 first round of screening are detailed in Table 4:

Table 4 – Problem Area Screening

First Round of Screening – DE DMU		Question 1: Is CSRM the primary problem?	Question 2: Is DM a feasible measure?	Carry Forward for Further Analysis under "Project Under 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	N	Y	N
D15	**Slaughter Beach**	Y	Y	Y
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 first round of screening, 14 sites were screened out from the initial 26 and recommended for further 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 it is located inland from the bayshore and difficult to access with the dredge and its associated disposal equipment. 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 USACE formulated as many measures as possible, with the understanding that there would be at least one measure for each planning objective:

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.

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. 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. It is important to note that beach restoration has been evaluated as a structural measure as it is a structural element requiring construction or assembly on-site; however, it is also considered a natural or nature-based feature (NNBF), as indicated on Table 5.
3. 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.
4. 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.
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.

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.

1. 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).
2. 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.
3. Reefs - Artificial reefs enhance the resilience of coastal areas by reducing the degradation and shoreline erosion that would occur during a storm event.
4. 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.

As previously referenced, the original 26 problem areas were subjected to 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 USACE formulated structural and non-structural measures for each problem area. In the second round of screening, the measures were compared against the planning objectives to see if they were in line with the study purpose.

USACE used criteria from the NACCS to assess each measure's Coastal Storm Risk Management to determine if a measure met Objective 1. The Coastal Storm Risk Management 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 USACE determined that the measure met Objective 1.

USACE used criteria from the NACCS to assess each measure's resilience 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 USACE determined that the measure increased the shoreline resilience and met Objective 2.

In order for measures to be carried forward for further analysis, they must have met one of the two study objectives, as shown on Table 5.

Table 5 – Objectives/Measures Matrix

Management Measure	Non-Structural	Structural	NNBF	Objective 1: Improve CSRM for people, property and infrastructure along and adjacent to the Delaware coastline from 2020 to 2070, 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. Seawall/Bulkhead 2. Revetments		X		1. Seawall/Bulkhead – N 2. Revetments – N	1. Seawall/Bulkhead - 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	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

Non-Structural Measures
The non-structural measures were screened out because they did not meet at least one of the two study objectives. While acquisition had a high coastal storm risk management 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.

Structural Measures
During the second round of 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 and breakwaters were also carried forward for further analysis because they potentially enhance the functionality of beach restoration measures, thereby creating a more resilient shoreline. In addition, groins and breakwaters could potentially be constructed with dredged material via geotubes for the sand or with the rock that is blasted and removed from the navigation project's channel.

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

Floodwall(s), shoreline stabilization and storm surge barriers were not carried forward for further analysis because they did not involve the beneficial use of dredged material as stipulated in the study objectives.

Natural and Nature-Based Features (NNBF)
Three NNBF measures (living shorelines, reefs, 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 2013). 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.

Reefs can enhance the resilience of coastal areas by reducing the degradation and shoreline erosion that would occur during a storm event. Reef sites may be developed using natural materials such as oyster shells, clam shells, or rock.

3.3 PLAN FORMULATION

During the development of the array of alternatives, the management measures that passed the second round of screening were applied to the remaining 12 CSRM problem areas that passed the initial round of screening, as indicated on Table 6.

Table 6 – Measure Applicability by Problem Area (Second Round of Screening)

Problem Area	Beach Restoration	Groins	Breakwaters	Reefs	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							

As Table 6 shows, beach restoration was considered as a potential measures at 11 problem areas (Augustine Beach, Bay View Beach, Woodland Beach, Pickering Beach, Kitts Hummock, Bowers Beach, Big Stone Beach, South Bowers Beach, Slaughter Beach, Prime Hook Beach and Lewes Beach) based on the existing presence of beaches at each community, that are subject to varying degrees of long-term and storm-induced erosion. In addition, groins and breakwaters were considered as potential measures at these 11 problem areas. After the second round of screening, the USACE carried groins and breakwaters forward for further consideration at these 11 problem areas based on their potential to reduce the effects of long-term and storm-induced erosion. Living shorelines and wetlands were also considered at Augustine Beach based on the existing presence of an expansive marsh/wetland environment along the Augustine Beach shoreline.

In the northern (more riverine) reach, levees/dikes were considered at New Castle because they were considered to be potentially more effective at mitigating flood inundation in a more riverine environment.

Based on the characteristics of the study area and the associated problems, the remaining measures were combined to form alternative plans which were ultimately evaluated and compared in two defined planning reaches within the Delaware Estuary system. The northern reach is from the head of tide at Trenton, NJ down to the approximate river/bay boundary (Liston Point, DE), while the southern reach extends south from the Liston Point area to the mouth of the Delaware Bay. The northern reach experiences damages primarily due to inundation related to storm surge, as occurs during tropical storms, hurricanes or nor'easters. As the width of the bay (fetch) widens moving south, the southern reach experiences damages from the combined effects of long term and storm-related erosion, inundation and waves.

In the northern planning reach, the No Action Plan and five action alternatives were formulated based on the identified problems and shoreline characteristics of each problem area, as summarized on Table 7.

Table 7 - Northern Planning Reach Alternatives

Northern Planning Reach Alternatives						
CSRM Problem Area	No Action Plan	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
New Castle	X	X				
Augustine Beach	X		X	X	X	X
Bay View Beach	X		X	X	X	

As indicated on Table 7, the No Action Plan and the Levee/Dike Plan were formulated in New Castle. At Augustine Beach and Bay View Beach, the No Action Plan, the Beach Restoration Plan, the Beach Restoration with Groin(s) Plan and the Beach Restoration with Breakwater Plan were formulated. The Beach Restoration with Groin(s), Breakwater, Living Shoreline & Wetland Plan was only formulated at Augustine Beach based on the existing presence of an expansive marsh/wetland environment along the Augustine Beach shoreline. While NNBF measures (living shorelines and wetlands) were considered applicable to Augustine Beach, analysis indicated that the limited structural inventory at Augustine Beach versus the added cost of NNBF features, such as wetlands or living shorelines, would provide minimal additional CSRM benefits compared to the added cost.

In the southern planning reach, the No Action Plan, the Beach Restoration Plan, the Beach Restoration with Groin(s) Plan and the Beach Restoration with Breakwater Plan were formulated, as indicated on Table 8.

Table 8 - Southern Planning Reach Alternatives

Southern Planning Reach Alternatives						
CSRM Problem Area	No Action Plan	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
Woodland Beach	X		X			
Pickering Beach	X		X	X	X	
Kitts Hummock	X		X			
Bowers Beach	X		X			
South Bowers Beach	X		X			
Big Stone Beach	X		X	X	X	
Slaughter Beach	X		X			
Prime Hook Beach	X		X			
Lewes Beach	X		X			

In the southern planning reach, the No Action Plan and the Beach Restoration Plan were formulated at all 9 locations. The Beach Restoration with Groin(s) Plan was also formulated at Pickering Beach and Big Stone Beach. The Beach Restoration with Breakwater Plan was also formulated at Pickering Beach and Big Stone Beach.

Regarding the Beach Restoration with Groin(s), Breakwater, Living Shoreline & Wetland Plan, analysis indicated that the additional features, such as wetlands or living shorelines, would provide minimal additional CSRM benefits compared to the added cost. For living shorelines, data from the NACCS indicated that they are generally applicable to relatively low current and wave energy environments. The damage mechanisms resulting from the combined effects of long-term and storm-related erosion, inundation and waves minimize the potential effectiveness of living shorelines. The limited effectiveness coupled with a $1,415 cost per linear foot of living shoreline construction (as estimated in the NACCS) also limits the efficiency of the living shoreline feature. Per the NACCS, wetlands can slow the advance of storm surge somewhat and slightly reduce the surge landward. In addition, wetlands can dissipate wave energy; however, evidence suggests that slow-moving storms and those with long periods of high winds that produce marsh flooding reduce this benefit (Resio and Westerlink, 2008). This limited effectiveness coupled with a $2,593 cost per linear feet of wetland construction (as estimated in the NACCS) also limits the efficiency of the wetland feature.

Based on the aforementioned alternative plans in each planning reach, the final array of alternative plans includes 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 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.

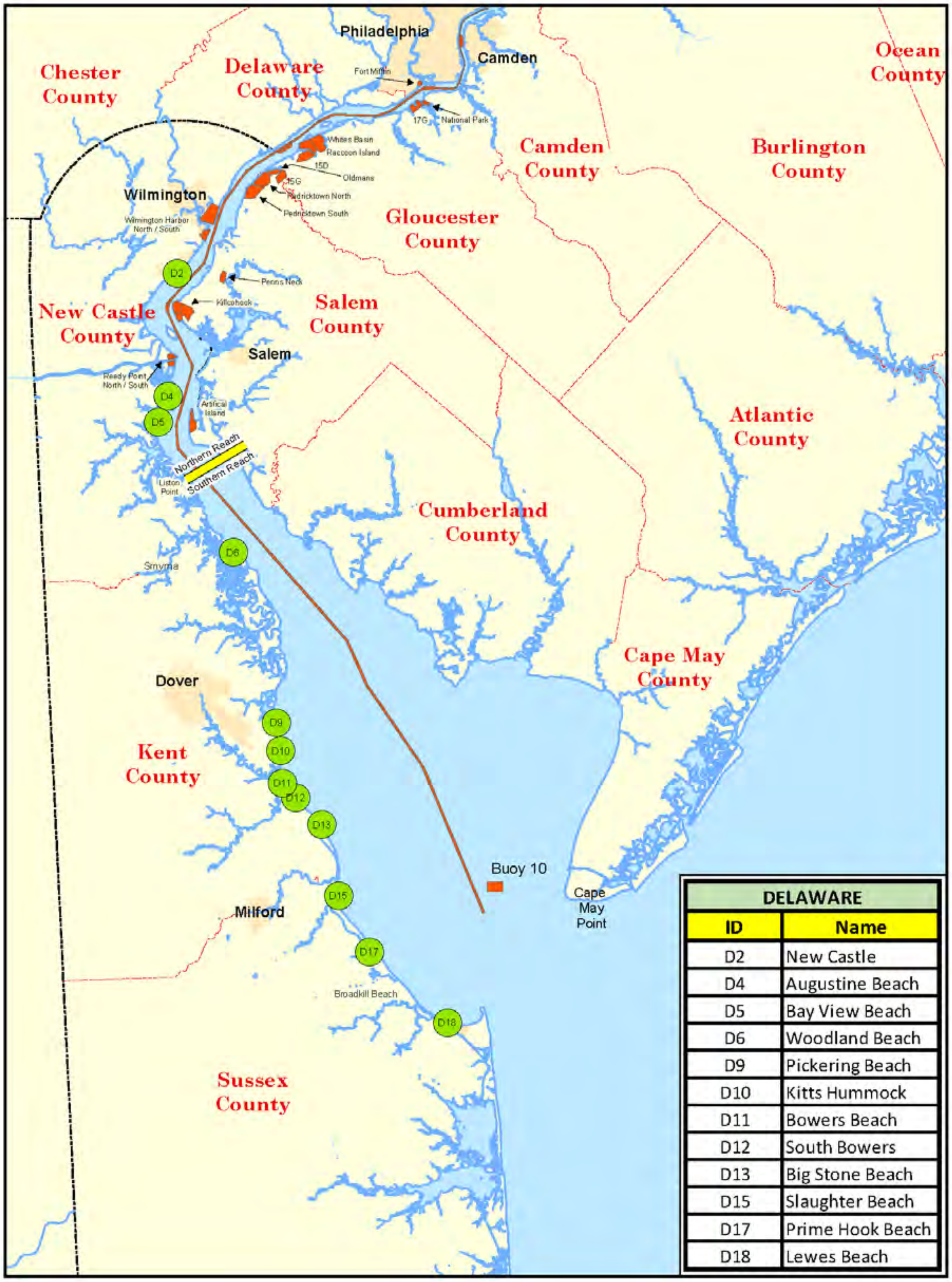
Regional Economic Development (RED) – The RED account registers changes in the distribution of regional economic activity that result from each alternative plan. Two measures of the effects of the plan on regional economies are used in the account: regional income and regional employment.

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.

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.

As previously referenced, the alternatives were evaluated in two defined planning reaches (as shown on Figure 6) within the Delaware Estuary 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.

Figure 6 – Planning Reach Delineation



DELAWARE	
ID	Name
D2	New Castle
D4	Augustine Beach
D5	Bay View Beach
D6	Woodland Beach
D9	Pickering Beach
D10	Kitts Hummock
D11	Bowers Beach
D12	South Bowers
D13	Big Stone Beach
D15	Slaughter Beach
D17	Prime Hook Beach
D18	Lewes Beach

3.4.1 Northern Reach Alternative Evaluation and Comparison

The without project conditions and associated problem(s) at each specified CSRM problem area as well as the availability of a suitable dredged material source area to help address the problem(s) greatly influenced the evaluation and comparison of alternatives, with respect to the NED account.

In the northern reach, the array of alternatives were evaluated and compared across 3 CSRM problem areas (New Castle, Augustine Beach and Bay View Beach) under the NED Account. In addition to the No Action Plan, the Levee/Dike Plan was formulated for the New Castle problem area 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. As indicated on Table 9, 5 potential dredged material source areas were considered for the New Castle Levee/Dike Plan.

Table 9 - New Castle Levee/Dike Plan Dredged Material Source Areas – Northern Reach

Source Area	Distance from Southern End of CSRM Problem Area (Miles)	Distance from Northern End of CSRM Problem Area (Miles)
Buoy 10 Open Water Disposal Site	34	58
Lower Reach E of the Delaware Bay Main Channel	27	52
Artificial Island CDF	11	13
Reedy Point CDF	17	8
Killcohook CDF	20	4

In addition, a Value Engineering (VE) study was conducted to evaluate the viability of applying the Levee/Dike Plan to this area. While some of the VE study recommendations were different than the conclusions of the feasibility report, the purpose of the VE study was to support the plan formulation and offer other potential strategies and solutions. The VE study was conducted at a point in the feasibility process where select Beach-fx modeling results were not yet available to verify planning assumptions.

The VE team consisted of the following technical disciplines: civil engineering, geotechnical engineering, hydrology and hydraulic engineering, cost engineering and planning. The New Castle Levee/Dike Plan was measured against the P&G's evaluation criteria and determined to have low efficiency 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. Specifically, the existing levee(s) were repaired in 2014 at a cost of $8M; thus, replacement of them may not be economically efficient.
- Silt, sand and organic material comprise the bulk of dredged material available for use; however, this material is unsuitable for levee construction without augmentation 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.

A medium rating was assigned for the effectiveness because given the pervious nature of the available dredged material sources, 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.

As referenced in the VE study, available dredged material does not appear to be suitable for USACE levee construction and would require augmentation to improve its suitability. This augmentation would add costs to an already expensive levee construction cost; therefore, given the lack of suitable levee construction material and elevated levee construction costs, New Castle (D2) has been screened out from further consideration under this study.

At the remaining 2 northern reach problem areas (Augustine Beach and Bay View Beach), the No Action Plan and 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 were evaluated and compared. Given the common beach restoration component in each action alternative, the USACE focused on dredged material source areas with predominantly sandy material.

Table 10 – Beach Restoration Dredged Material Source Areas – Northern Reach

Source Area	Distance from Augustine Beach CSRM Problem Area (Miles)	Distance from Bay View Beach CSRM Problem Area (Miles)	Distance from Woodland Beach CSRM Problem Area (Miles)
Buoy 10 Open Water Disposal Site	47	46	34
Lower Reach E of the Delaware Bay Main Channel	41	40	27
Artificial Island CDF	2	3	11

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 three 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 USACE 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 USACE determined that Artificial Island was not a viable source.

Under the NED Account, 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. All northern reach sites were eliminated from further consideration.

While the northern reach sites and their associated alternatives were screened out via the NED Account, the other 3 accounts supported the evaluation and comparison of alternative as highlighted on Table 11:

Table 11 - Northern Planning Reach Alternative Comparison

	National Economic Development (NED)					
	No Action Plan	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
Project Cost vs. Project Benefits	While there is no project cost, the No Action Plan does not provide CSRM benefits and will allow for increasing erosional impacts and coastal storm risk to the identified CSRM problem areas.	Per the NACCS parametric costs, levee construction costs are approximately $1,578 per linear foot. As referenced in the VE study, available dredged material does not appear to be suitable for USACE levee construction and would require augmentation to improve its suitability. The augmentation would add costs to an already expensive levee construction cost.	In the Northern Planning Reach, there were 2 beach communities (Augustine Beach and Bay View Beach) that could potentially benefit from beach restoration via dredged material. The availability of dredged material sources greatly impacted the screening of this alternative at each community. Two of the three potential sources (Miah Maull/Brandywine Ranges of the Delaware Bay Main Channel and Buoy 10 Open Water Disposal Site) were ruled out because their distance from the beach communities led to a high cost to get the material to these communities. Given the high transportation cost and relatively small structural inventories at each community, the 2 aforementioned sources were ruled out. A closer source area (Artificial Island CDF) was also considered; however, given the need for homogeneous beach-quality sand and the heterogeneous nature of the material in the CDF, the USACE determined that Artificial Island was not a viable source.	Relatively high beach erosion rates and losses are typically required to support the addition of groins to beach restoration projects. In the Northern Planning Reach, the added groin cost was not evaluated because the USACE determined that beach restoration was not plausible due to a lack of a viable sediment source.	While breakwaters reduce wave energy and coastal erosion, they have minimal impact on inundation. In the Northern Planning Reach, the added breakwater cost was not evaluated because the USACE determined that beach restoration was not plausible due to a lack of a viable sediment source.	As with the Beach Restoration Plan, this alternative was not cost effective due to the lack of a proximate dredged material source area combined with the relatively small structural inventories.
	Environmental Quality (EQ)					
Physiography & Geology	Storms will continue to erode the shoreline undermining physiography supporting the existing infrastructure in the developed areas and continued erosion of adjacent wetlands.	Available dredged material does not appear to be suitable for USACE levee construction and would require augmentation to improve its suitability.	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 groin would not impact the area geology, but would alter the physiography of the beach by accumulating sand on the updrift side and stabilizing the beach but may cause erosion on the downdrift side. Groins located at inlets (jetties) serve to reduce sand accumulation within the inlet.	The construction of a hardened structure, such as a breakwater may reduce sediment accumulation along the shoreline.	Currently, wetlands exist in a small portion of the northern planning reach (near Augustine Beach). Other portions of the northern planning reach are highly developed with minimal available space for additional wetlands. Living shorelines are infeasible in high energy environments.
Sediment Quality	Future maintenance dredging sand from the proposed project source area will be placed at Buoy 10 for approximately 10 more years. Beyond this, dredging sand from the proposed source area will be place at Artificial Island CDF. This future practice will contribute to an increasing sediment deficit in the	Available dredged material does not appear to be suitable for USACE levee construction and would require augmentation to improve its suitability.	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 groin impedes longshore sediment transport within the beach/intertidal habitat interface. Groins located at inlets (jetties) serve to reduce sediment end losses on the beach and sedimentation in the inlet.	The construction of a hardened structure, such as a breakwater is not advised by the natural resources agencies as it impedes the natural transfer of sediments within the beach/intertidal habitat interface.	Hardened structures disrupt natural longshore transport and reduce nutrient uptake in adjacent marshes. A wetland plan adds additional cost with minimal CSRM benefits. Living shorelines are infeasible in high energy environments.

	Delaware Bay as studies indicate that the bed of the bay has eroded at a rate that exceeds the average annual rate at which new sediment is supplied from the watershed.					
Vegetation & Wetlands	The majority of wetlands within the study area are estuarine intertidal emergent wetlands. The No Action Plan is expected to exacerbate the loss of shoreline vegetation and excessive inundation of neighboring wetlands with erosion of the barrier beachfront.	In developed areas, the plan will have minimal effect. In wetland areas, the plan interrupts the hydrodynamic interface of tidal influx.	Beach restoration maintains the hydrodynamic interface of the tidal shoreline, providing nutrients/sediment source to adjacent wetlands.	The construction of a hardened structure, such as a groin would be located seaward of beach vegetation and wetlands. No adverse impact. Groins accumulate sand on the updrift beach side which may provide additional erosion protection for landward vegetation and wetlands.	The construction of a hardened structure, such as a breakwater is not advised by the natural resources agencies as it impedes the natural transfer of sediments within the beach/intertidal habitat interface.	Hardened structures disrupt natural longshore transport and reduce nutrient uptake in adjacent marshes. A wetland plan adds additional cost with minimal CSRM benefits. Living shorelines are infeasible in high energy environments.
Planktonic & Benthic Organisms	With the No Action Plan, low quality intertidal habitat would continue to exist due to severe erosion and exposed peat. Continued shoreline erosion elevates water turbidity which reduces primary productivity.	No impact.	Beach restoration will involve the pumping of dredged material onto the beach above the mean high water line, thereby reducing 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 groin would permanently reduce available shallow water soft bottom habitat in the structure footprint but adds to the intertidal habitat diversity by providing hard bottom substrate for benthic macroinvertebrates.	The construction of a hardened structure, such as a breakwater would permanently impact intertidal and beach habitat by obstructing the hydrodynamic connection between the two.	Hardened structures disrupt natural longshore transport and reduce nutrient uptake in adjacent marshes. A wetland plan adds additional cost with minimal CSRM benefits. Living shorelines are infeasible in high energy environments.
Fish	Under the No Action Plan, adult fish occurring in the nearshore zone of the bay would not be impacted. However, with continued erosion of the shoreline, larval and juvenile fish stages are likely to be adversely impacted if salt marshes incur lower habitat quantity and quality through loss of wetlands.	No impact.	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 fish that can leave the impact area during construction.	Minor temporary impacts to fish during construction due to elevated turbidity. Groins provide habitat diversity through the creation of hard substrate in a soft bottom habitat for prey species and refugia from currents and for feeding.	Minor temporary impacts to fish during construction due to elevated turbidity. Permanent displacement of shallow water bottom habitat.	Hardened structures disrupt natural longshore transport and reduce nutrient uptake in adjacent marshes. A wetland plan adds additional cost with minimal CSRM benefits. Living shorelines are infeasible in high energy environments.
Wildlife	Under the No Action Plan, wildlife species would continue to incur further losses in habitat quality and quantity due to ongoing flooding and erosion.	Levee/dike footprint reduces available habitat for wildlife.	Beach restoration will provide added risk management to wildlife habitats along the bayshore and within interior wetlands, scrub shrub and forested areas.	The construction of a hardened structure, such as a groin provides a resting area for waterbirds and feeding sites for coastal birds of prey. Groins may impede movement by small mammals, spawning horseshoe crabs and terrapins.	Minimal to no impact.	Hardened structures disrupt natural longshore transport and reduce nutrient uptake in adjacent marsh habitats. A wetland plan adds additional cost with minimal CSRM benefits. Living shorelines are infeasible in high energy environments.
Threatened & Endangered Species	Under the No Action Plan, continued erosion and flooding	Levee/dike footprint reduces available habitat for threatened	Beach restoration can provide positive benefits to listed species by restoring preferred beach habitat and	The construction of a hardened structure, such as a groin would	The construction of a hardened structure, such as a breakwater	Hardened structures disrupt natural longshore transport

	will result in degraded habitat for species, including exposed underlying peat and scarped dunes.	and endangered species.	increased flood risk management to interior wetlands, scrub shrub and maritime forested habitats. Adverse impacts are avoided with environmental windows during placement operations.	permanently reduce soft bottom habitat within the intertidal zone but provides erosion protection of beach habitat on the updrift side for beach foraging and nesting birds but impedes visual sight lines for foraging shorebirds. Groins at inlets accumulate sand on the updrift side, enlarging and elevating the beach, which is preferred by migratory shorebirds for predator avoidance.	would impede wildlife movements and block access between the intertidal zone and the upper beach.	and reduce nutrient uptake in adjacent marsh habitats. A wetland plan adds additional cost with minimal CSRM benefits. Living shorelines are infeasible in high energy environments.
Air Quality	The No Action Plan will have no impact on Air Quality.	Temporary impact to air quality during construction and maintenance operations.	Temporary impact to air quality during construction and maintenance operations.	Temporary impact to air quality during construction and maintenance operations.	Temporary impact to air quality during construction and maintenance operations.	Temporary impact to air quality during construction and maintenance operations.
Noise	Normal noise levels created by traffic, businesses and industrial activities would continue under the No Action Plan.	Temporary elevation of noise levels during construction and maintenance operations.	Temporary elevation of noise levels during construction and maintenance operations.	Temporary elevation of noise levels during construction and maintenance operations.	Temporary elevation of noise levels during construction and maintenance operations.	Temporary elevation of noise levels during construction and maintenance operations.
Cultural Resources & Historic Properties	In the northern planning reach, a historic hotel site exists at Woodland Beach; however, this would not be impacted by the No Action Plan.	No impact because this plan was not proposed at Woodland Beach.	No impact because this plan will not be implemented at Woodland Beach. Also, the historic hotel site could have been successfully avoided during construction with the use of buffer areas.	No impact because this plan will not be implemented at Woodland Beach. Also, the historic hotel site could have been successfully avoided during construction with the use of buffer areas.	No impact because this plan will not be implemented at Woodland Beach. Also, the historic hotel site could have been successfully avoided during construction with the use of buffer areas.	No impact because this plan will not be implemented at Woodland Beach. Also, the historic hotel site could have been successfully avoided during construction with the use of buffer areas.
	Other Social Effects (OSE)					
Environmental Justice	The No Action Plan will have no impact on Environmental Justice.	This plan will have no impact on Environmental Justice.	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 with Groin(s) 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 with Breakwater 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 with Groin(s), Breakwater, Living Shoreline & Wetland 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.
Quality of Life/Recreation	Continued erosion and flooding will have an adverse impact on ecosystem services and related recreation opportunities.	Potential flood risk management combined with a potential recreational use of the levee crest may improve quality of life 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 with Groin(s) will enhance ecosystem services to humans by providing erosion control, water quality enhancement, storm risk management and habitat provision for wildlife and	Beach restoration with Breakwater 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 with Groin(s), Breakwater, Living Shoreline & Wetland will enhance ecosystem services to humans by providing erosion control, water quality enhancement, storm

				recreation.		risk management and habitat provision for wildlife and recreation.
	Regional Economic Development (RED)					
RED Impacts	While there is no project cost, the No Action Plan does not provide RED benefits and will allow for increasing erosional impacts and coastal storm risk to the identified CSRM problem areas.	As referenced in the VE study, available dredged material does not appear to be suitable for USACE levee construction and would require augmentation to improve its suitability.	Same as NED impacts.	Same as NED impacts.	Same as NED impacts.	Same as NED impacts.

Table 12 - Northern Planning Reach Alternative Evaluation

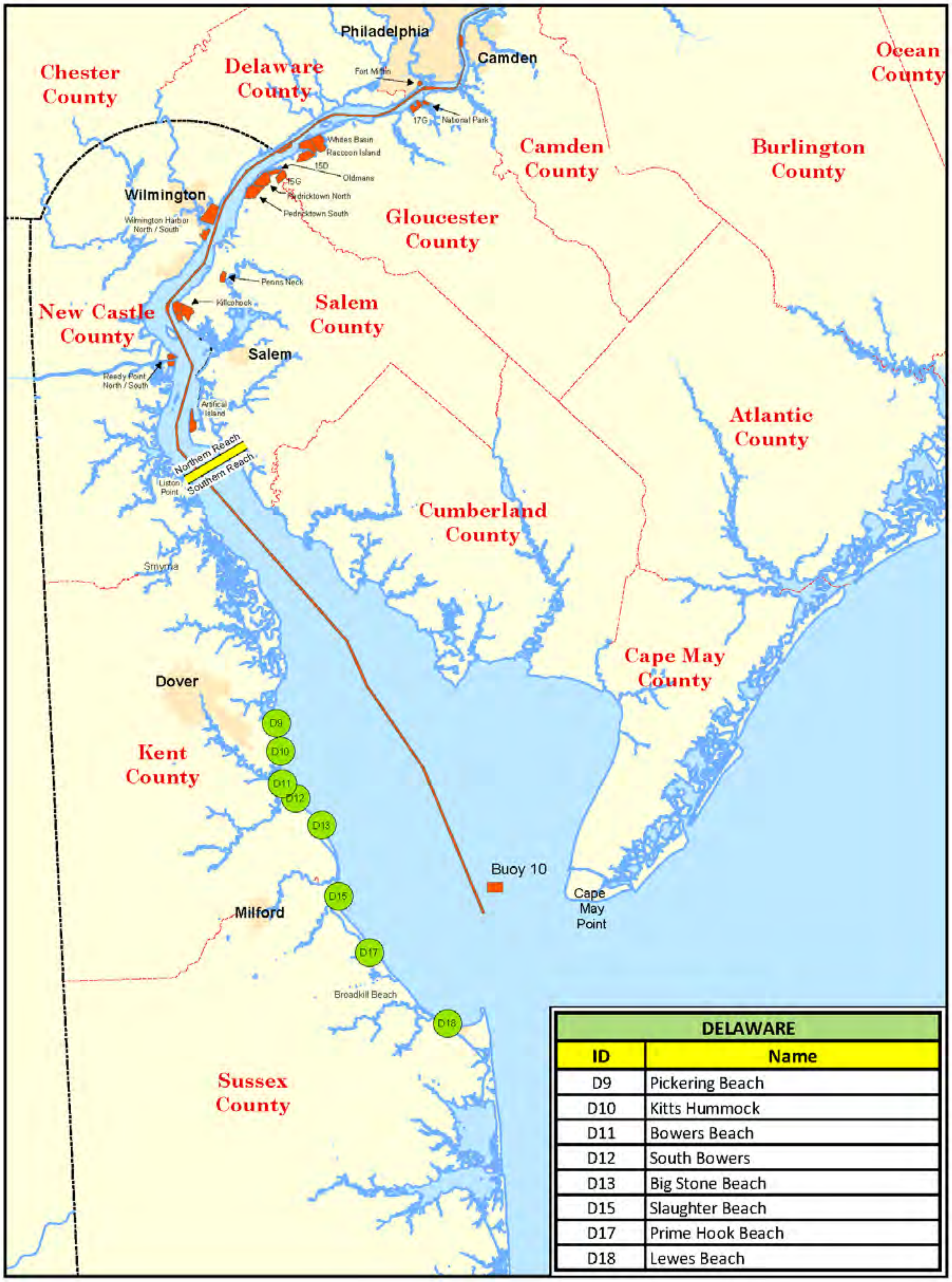
Contribution to Planning Objectives						
	No Action Plan	Levee/Dike Plan	Beach Restoration Plan	Beach Restoration with Groin(s) Plan	Beach Restoration with Breakwater Plan	Beach Restoration with Groin(s), Breakwater, Living Shoreline & Wetland Plan
1. Improve CSRM for people, property and infrastructure along and adjacent to the Delaware shoreline from 2020 to 2070, via the beneficial use of dredged material.	Erosion and storm-related damage will continue; therefore, the No Action Plan does not meet the objective.	While levees and dikes potentially could reduce impacts, this does not meet the objective because a cost-effective levee cannot be constructed with the available dredged material sources.	In the Northern Planning Reach, there were 2 beach communities (Augustine Beach and Bay View Beach) that could potentially benefit from beach restoration via dredged material. Given the high transportation cost and relatively small structural inventories at Augustine Beach and Bay View Beach, this alternative did not meet the objective at these two locations.	In the Northern Planning Reach, there were 2 beach communities (Augustine Beach and Bay View Beach) that could potentially benefit from beach restoration via dredged material. Given the high transportation cost and relatively small structural inventories at Augustine Beach and Bay View Beach, this alternative did not meet the objective at these two locations.	Per the NACCS, an estimated total first construction cost of a breakwater could be as high as $90,000,000 for a 10,000 feet stretch of shoreline. Given the size of the structure inventories of the communities in the northern reach, this added breakwater cost will greatly outweigh any added CSRM benefits; therefore, this alternative did not meet the objective.	As with the Beach Restoration Plan, this alternative was not cost effective due to the lack of a proximate dredged material source area combined with the relatively small structural inventories; therefore, this alternative did not meet the 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.	Erosion and storm-related damage will continue to reduce the resiliency of coastal Delaware; therefore, the No Action Plan does not meet the objective.	While levees and dikes potentially could reduce impacts and increase the resiliency of coastal Delaware, this does not meet the objective because a cost-effective levee cannot be constructed with the available dredged material sources.	In the Northern Planning Reach, there were 2 beach communities (Augustine Beach and Bay View Beach) that could potentially benefit from beach restoration via dredged material. Given the high transportation cost and relatively small structural inventories at Augustine Beach and Bay View Beach, this alternative did not meet the objective at these two locations.	In the Northern Planning Reach, there were 2 beach communities (Augustine Beach and Bay View Beach) that could potentially benefit from beach restoration via dredged material. Given the high transportation cost and relatively small structural inventories at Augustine Beach and Bay View Beach, this alternative did not meet the objective at these two locations.	Per the NACCS, an estimated total first construction cost of a breakwater could be as high as $90,000,000 for a 10,000 feet stretch of shoreline. Given the size of the structure inventories of the communities in the northern reach, this added breakwater cost will greatly outweigh any added CSRM benefits; therefore, this alternative did not meet the objective.	As with the Beach Restoration Plan, this alternative was not cost effective due to the lack of a proximate dredged material source area combined with the relatively small structural inventories; therefore, this alternative did not meet the objective.
Response to Evaluation Criteria						
Completeness	This does not meet the completeness criteria because the No Action Plan does not provide CSRM benefits and will allow for increasing erosional impacts and coastal storm risk to the identified CSRM problem areas.	As referenced in the VE study, available dredged material does not appear to be suitable for USACE levee construction and would require augmentation to improve its suitability. The augmentation would add costs to an already expensive levee construction cost; therefore, the levee/dike plan was screened out and will not	In the northern planning reach, beach restoration would provide a complete solution; however, the lack of proximate dredged material source areas make this alternative cost prohibitive.	In the northern planning reach, beach restoration with groin(s) would provide a complete solution; however, the lack of proximate dredged material source areas and the added cost of groin construction make this alternative cost prohibitive.	In the northern planning reach, beach restoration with breakwater would provide a complete solution; however, the lack of proximate dredged material source areas and the added cost of breakwater construction make this alternative cost prohibitive.	In the northern planning reach, beach restoration with groin(s), breakwater, living shoreline & wetland would provide a complete solution; however, the lack of proximate dredged material source areas and the added cost of living shoreline and wetland construction make this alternative cost prohibitive.

		provide a complete CSRM solution.				
Effectiveness	This does not meet the effectiveness criteria because the No Action Plan does not provide CSRM benefits and will allow for increasing erosional impacts and coastal storm risk to the identified CSRM problem areas.	As referenced in the VE study, available dredged material does not appear to be suitable for USACE levee construction and would require augmentation to improve its suitability. The augmentation would add costs to an already expensive levee construction cost; therefore, the levee/dike plan was screened out and will not provide an effective CSRM solution.	The lack of proximate dredged material source areas make this alternative cost prohibitive.	The lack of proximate dredged material source areas and the added cost of groin construction make this alternative cost prohibitive.	The lack of proximate dredged material source areas and the added cost of breakwater construction make this alternative cost prohibitive.	The lack of proximate dredged material source areas and the added cost of living shoreline and wetland construction make this alternative cost prohibitive.
Efficiency	This does not meet the efficiency criteria. While there is no project cost, the No Action Plan does not provide CSRM benefits and will allow for increasing erosional impacts and coastal storm risk to the identified CSRM problem areas.	As referenced in the VE study, available dredged material does not appear to be suitable for USACE levee construction and would require augmentation to improve its suitability. The augmentation would add costs to an already expensive levee construction cost; therefore, the levee/dike plan was screened out and will not provide an efficient CSRM solution.	The lack of proximate dredged material source areas make this alternative cost prohibitive.	The lack of proximate dredged material source areas and the added cost of groin construction make this alternative cost prohibitive.	The lack of proximate dredged material source areas and the added cost of breakwater construction make this alternative cost prohibitive.	The lack of proximate dredged material source areas and the added cost of living shoreline and wetland construction make this alternative cost prohibitive.
Acceptability	This does not meet the acceptability criteria as State and local entities are generally supportive of beach restoration.	The acceptability of the levee/dike plan is not known at this time as the aforementioned technical limitations of utilizing dredged material for levee construction prevented the levee/dike plan from being carried forward for further analysis.	State and local entities are generally supportive of beach restoration.	The acceptability of beach restoration with groin(s) is not known at this time as the added cost of groin construction make this alternative cost prohibitive.	The acceptability of beach restoration with breakwater is not known at this time as the added cost of breakwater construction make this alternative cost prohibitive.	The acceptability of beach restoration with groin(s), breakwater, living shoreline &wetland(s) is not known at this time as the added cost of living shoreline and wetland construction make this alternative cost prohibitive.

3.4.2 Southern Reach Alternative Evaluation and Comparison

Under the NED Account in the southern reach, the array of alternatives were evaluated and compared across 8 CSRM problem areas (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. Therefore, the problem areas were evaluated with Beach-fx and are highlighted on Figure 7.

Figure 7 - Southern Reach Beach-fx Evaluation



DELAWARE	
ID	Name
D9	Pickering Beach
D10	Kitts Hummock
D11	Bowers Beach
D12	South Bowers
D13	Big Stone Beach
D15	Slaughter Beach
D17	Prime Hook Beach
D18	Lewes Beach

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 with-project design templates, estimated sand quantities for nourishment and periodic renourishment were determined within Beach-fx. Dredged material beach restoration source areas were identified and the costs associated with placing material from these source areas were also provided as inputs into Beach-fx.

Given the presence of sandy beach barriers (with broad marshes on the landward side of the beach and residential structures) at each of the 8 southern reach CSRM problem areas, the USACE focused the alternative evaluation and comparison to the Beach Restoration Plan and the No Action Plan. Also, due to the potentially high with-project end losses at Pickering Beach and Big Stone Beach, the Beach Restoration with Groin(s) Plan and the Beach Restoration with Breakwater Plan were also formulated at these two locations. However, at the remaining 6 southern reach CSRM problem areas, only the stand-alone Beach Restoration Plan (without groins, breakwaters, wetlands or living shorelines) and the No Action Plan were evaluated and compared.

As previously discussed, additional features, such as wetlands or living shorelines, would provide minimal additional CSRM compared to the added cost. Regarding living shorelines, data from the NACCS indicated that they are generally applicable to relatively low current and wave energy environments. 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; thereby, minimizing the potential effectiveness of living shorelines. This limited effectiveness coupled with a $1,415 cost per linear feet of living shoreline construction (as estimated in the NACCS) also limits the efficiency of the living shoreline feature.

Per the NACCS, wetlands can slow the advance of storm surge somewhat and slightly reduce the surge landward. In addition, wetlands can dissipate wave energy; however, evidence suggests that slow-moving storms and those with long periods of high winds that produce marsh flooding reduce this benefit (Resio and Westerlink, 2008). This limited effectiveness coupled with a $2,593 cost per linear feet of wetland construction (as estimated in the NACCS) also limits the efficiency of the wetland feature.

According to the NACCS, the typical breakwater layout consists of breakwater segments of 300 feet (with 400 feet gaps between segments) and breakwaters located 500 feet seaward of the design shoreline. While breakwaters reduce wave energy and coastal erosion, they have minimal impact on inundation. In addition, based on the aforementioned design template and parametric costs in the

NACCS, an estimated total first construction cost of a breakwater could be as high as $90,000,000 for a 10,000 feet stretch of shoreline. Given the size of the structure inventories of the communities in the southern reach, this added breakwater cost will greatly outweigh any added CSRM benefits.

In accordance with ER 1100-2-8162, the direct and indirect effects of future SLC on the recommended plan were also evaluated using the Beach-fx model. Potential effects of relative sea level change (RSLC) on overall water levels were analyzed for each study location, over a 50-yr economic analysis period and a 100-year planning horizon. A RSLC may be composed of both an absolute mean sea level change component and a vertical land movement change component. Historical RSLC and USAC SLC scenarios for this study are based on NOAA tidal records at Lewes, DE. The Intermediate RSLC curve was evaluated for plan formulation and optimization, then a sensitivity test was run with the Low and High RSLC curves to evaluate project performance. Table 13 presents RSLC projections for the three USACE scenarios: Low/Historical, Intermediate, and High. A graphical display of the three RSLC scenarios over the 100-yr planning horizon is presented in Figures 8 and 9.

Table 13 - RSLC Adjustments applied during Screening Level Assessments

Year	USACE - Low (ft, MSL[1])	USACE - Int (ft, MSL[1])	USACE - High (ft, MSL[1])
1992	0.0	0.0	0.0
2020	0.3	0.4	0.6
2045	0.6	0.8	1.6
2070	0.8	1.4	3.1
2095	1.1	2.0	5.0
2120	1.3	2.8	7.4

[1]Mean Sea Level based on National Tidal Datum Epoch (NTDE) of 1983-2001

Figure 8 - Historical Relative Sea Level Change at Lewes, DE

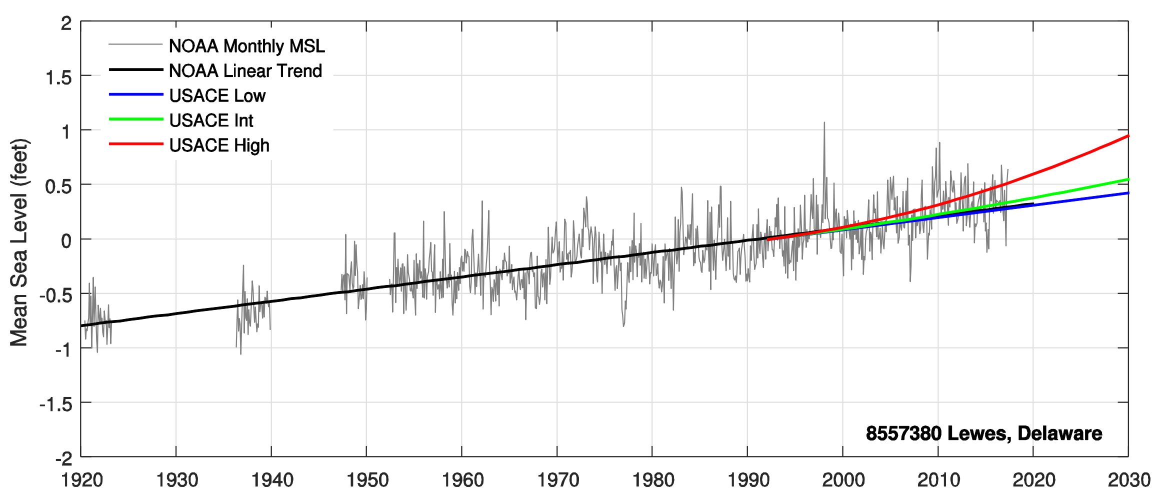
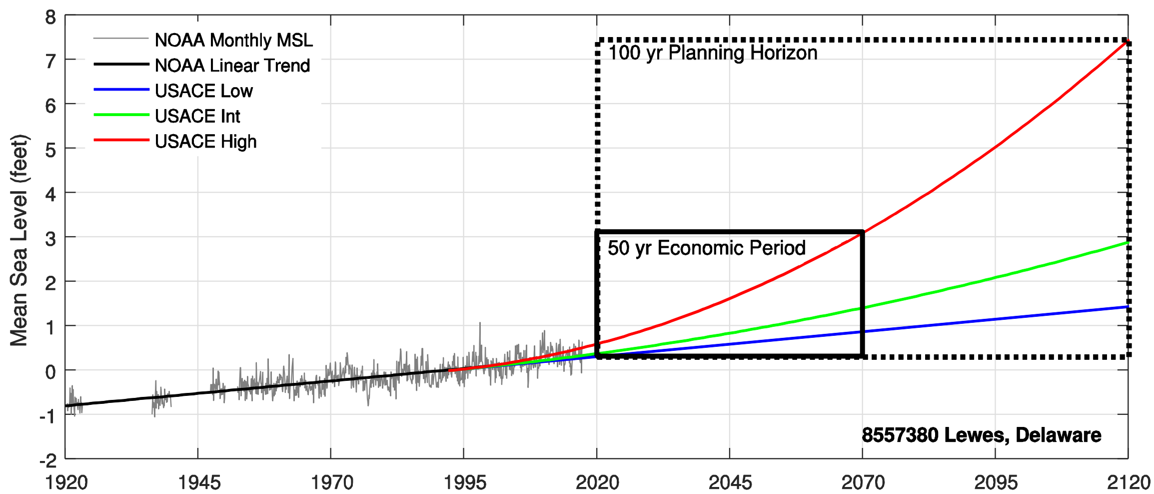


Figure 9 - Relative Sea Level Projections at Lewes, DE



While the economic analysis is limited to the 50-yr life cycle, SLC was also assessed on a 100-yr planning horizon, and used to qualitatively inform project performance (e.g. understanding future level of protection offered in 2100), and identify potential for adaptive management (e.g. increasing dune/berm height). For the 50-yr life cycle, the economic evaluation in Beach-fX supports the conclusion that the project has positive net benefits at all placement locations for the three RSLC curves. It is relatively easy to adapt the dune and beach restoration alternatives to RSLC, additional sediment can be included in each renourishment operation to offset losses from SLC. The natural berm elevation will rise in concert with the rising sea surface. The dune elevation will also need to be raised in response to SLC to maintain the design performance. For the 100-year planning horizon, the proposed project remains sustainable for the intermediate and low RSLC curve; however, the project would not be sustainable for the high RSLC curve as back-bay flooding would compromise the benefits of beach restoration to the communities. Please see Appendix C-1 for further details on RSLC change and its impacts on the project sustainability.

As the feasibility study focused on the No Action Plan, the Beach Restoration Plan and the Beach Restoration with Groin(s) Plan in the southern reach, the USACE focused on dredged material source areas with predominantly sandy material and their associated distance from the placement locations.

Table 14 – Beach Restoration Dredged Material Source Areas – Southern Reach

Source Area	Distance to Pickering Beach (Miles)	Distance to Kitts Hummock (Miles)	Distance to Bowers Beach (Miles)	Distance to South Bowers (Miles)	Distance to Big Stone Beach (Miles)	Distance to Slaughter Beach (Miles)	Distance to Prime Hook Beach (Miles)	Distance to Lewes Beach (Miles)
Buoy 10 Open Water Disposal Site	22	20	19	17	14	11	11	11
Lower Reach E of the Delaware Bay Main Channel	16	14	13	12	10	11	12	16

Geotechnical analysis of available dredged material for beach restoration further supported the selection of potential source areas with available sand: Lower Reach E (Miah Maull and Brandywine Ranges) of the main Delaware Estuary 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 (as indicated on Table 14) 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 nourishment 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.

Based on the projected quantities required for nourishment and periodic renourishment, Lower Reach E (Miah Maull and Brandywine Ranges) of the main Delaware Bay channel is the likely dredged material source for the CSRM project. Specifically, the proposed source area 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.

Table 15 - Grain Size Comparison

	Previously Dredged Sediment - Lower Reach E	Pickering Beach	Kitts Hummock	Bowers Beach	South Bowers Beach	Slaughter Beach	Prime Hook Beach	Lewes Beach
Average Grain Size (mm)	0.60	0.57	0.57	0.29	0.40	0.81	0.56	0.45

1. Average grain size data for Lower Reach E is based on vibracore samples of dredged material from Lower Reach E currently sitting in Buoy 10 open water disposal site.
2. Average grain size data for Pickering Beach, Kitts Hummock, Bowers Beach, South Bowers Beach, Slaughter Beach and Prime Hook Beach is based on CB&I Coastal Planning & Engineering, Inc., State of Delaware Bay Beach Design Verification Report (2015).
3. Average grain size data for Lewes Beach is based on Roosevelt Inlet – Lewes Beach Interim Feasibility Study (1997).

When the draft feasibility report was released in November 2016, the USACE estimated that approximately 900,000 cubic yards of dredged material would be required for nourishment of the 8 sites in the TSP. Considering the proposed source area and the projected quantities for nourishment and periodic renourishment, the USACE determined that the likely project implementation would consist of a systematic and continuous dredging operation with one primary mobilization shared across each site. The USACE applied the systematic analysis to the eight sites referenced above (Pickering Beach, Kitts Hummock, Bowers Beach, South Bowers Beach, Big Stone Beach, Slaughter Beach, Prime Hook Beach and Lewes Beach). While the likely project implementation creates a system with non-separable dredge mobilization costs, the eight sites do not appear to be hydraulically connected. Therefore, each site was incrementally justified with individual net benefits calculated for each site, rather than combining the net benefits for the eight sites.

Prime Hook Beach, Slaughter Beach, Bowers Beach, South Bowers Beach, Kitts Hummock, Pickering Beach and Lewes Beach had positive Average Annual Net Benefits (AANB) and a Benefit-Cost Ratio (BCR) above 1.0 over the 50-year period of analysis. As each site must be incrementally justified for inclusion in the recommended plan, Big Stone Beach was screened from further consideration.

As the final beach restoration designs were further refined, the estimated total quantity required for nourishment increased to approximately 1,300,000 cubic yards of dredged material. Considering the estimated volume of sand anticipated to be available for nourishment was approximately 930,000 cubic yards, the USACE revised the likely project implementation plan as explained below. In addition, because the New Jersey DMU period of analysis potentially overlaps a large portion of the Delaware DMU period of analysis, the USACE assumed that available dredged material would need to be distributed to each project over each overlapping period of analysis, as highlighted on Table 16.

Table 16 - Projected Nourishment & Periodic Renourishment Quantities

Year	Dredged Material Placement Quantity – DE DMU (cubic yards)	Dredged Material Placement Quantity – NJ DMU (cubic yards)	Dredged Material Placement Quantity – Total (cubic yards)	Notes
2020 (DE DMU Base Year)	731,000		731,000	Nourishment – Lewes Beach, Prime Hook Beach and Slaughter Beach
2022 (NJ DMU Base Year)		633,000	633,000	Nourishment – Gandys Beach, Fortescue and Villas (South)
2024				
2026	894,000		894,000	Nourishment – South Bowers Beach, Bowers Beach, Kitts Hummock and Pickering Beach Periodic Renourishment – Lewes Beach, Prime Hook Beach and Slaughter Beach
2028				
2030		273,000	273,000	Periodic Renourishment (NJ DMU)
2032	414,000		414,000	Periodic Renourishment (DE DMU)
2034				
2036				
2038	414,000	273,000	687,000	Periodic Renourishment (DE and NJ DMU)
2040				
2042				
2044	414,000		414,000	Periodic Renourishment (DE DMU)
2046		273,000	273,000	Periodic Renourishment (NJ DMU)
2048				
2050	414,000		414,000	Periodic Renourishment (DE DMU)
2052				
2054		273,000	273,000	Periodic Renourishment (NJ DMU)
2056	414,000		414,000	Periodic Renourishment (DE DMU)
2058				
2060				
2062	414,000	273,000	687,000	Periodic Renourishment (DE and NJ DMU)
2064				
2066				
2068	414,000		414,000	Periodic Renourishment (DE DMU)
2070		273,000	273,000	Periodic Renourishment (NJ DMU)
2072				

1. The quantities listed on Table 16 represent projected pay quantities required to construct and maintain the beach profile

Instead of one continuous mobilization to all 7 remaining Delaware placement sites, the USACE assumed that there would be an initial mobilization and construction of 3 sites (Lewes Beach, Prime Hook Beach and Slaughter Beach) completed by 2020. As indicated on Table 15, the quantity required for the 2020 nourishment (731,000 cubic yards) is less than the projected quantity of dredged material expected to be available at that time (930,000 cubic yards). By the year 2026, the remaining 4 sites (South Bowers Beach, Bowers Beach, Kitts Hummock and Pickering Beach) would be constructed while the sites that were initially constructed received their first periodic renourishment. The estimated quantity required for the 2026 nourishment/renourishment (894,000 cubic yards) is also less than the projected quantity of dredged material expected to be available at that time (930,000 cubic yards).

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 (an open water disposal site located in the southern planning reach adjacent to the mouth of the Delaware Bay). Buoy 10 is approaching full capacity. In 2017, Buoy 10 was estimated to be at or near capacity; however, the USACE requested and received from NJDEP a permit to expand the footprint and gain an approximate 10 years of additional capacity. A new Coastal Zone Management Act Consistency Determination (CZM) and WQC were received on 24 January 2018. 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 nourishment through the first 10 years of the period of analysis, 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 discussed above, nourishment will be completed in two phases with the initial phase completed in 2020 and the final phase completed in 2026 (concurrent with the periodic renourishment of the original 3 sites). Therefore, the mobilization cost for the 2020 nourishment phase is shared by 3 sites (Lewes Beach, Prime Hook Beach and Slaughter Beach), while 2026 nourishment/periodic renourishment mobilization cost will be shared by all 7 sites in the southern reach.

Table 17 - Southern Planning Reach Alternative Comparison

	National Economic Development (NED)					
	No Action Plan	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
Project Cost vs. Project Benefits	While there is no project cost, the No Action Plan does not provide CSRM benefits and will allow for increasing erosional impacts and coastal storm risk to the identified CSRM problem areas.	Per the NACCS parametric costs, levee construction costs are approximately $1,578 per linear foot. As referenced in the VE study, available dredged material does not appear to be suitable for USACE levee construction and would require augmentation to improve its suitability. The augmentation would add costs to an already expensive levee construction cost.	The benefits of beach restoration at Pickering Beach, Kitts Hummock, Bowers Beach, Slaughter Beach, Prime Hook Beach and Lewes Beach are greater than the associated dredged material placement costs.	Relatively high beach erosion rates and losses are typically required to support the addition of groins to beach restoration projects. However, stand-alone beach restoration yielded higher AANB because of the added initial construction cost associated with groins.	According to the NACCS, the typical breakwater layout consists of breakwater segments of 300 feet (with 400 feet gaps between segments) and breakwaters located 500 feet seaward of the design shoreline. While breakwaters reduce wave energy and coastal erosion, they have minimal impact on inundation. In addition, based on the aforementioned design template and parametric costs in the NACCS, an estimated total first construction cost of a breakwater could be as high as $90,000,000 for a 10,000 feet stretch of shoreline. Given the size of the structure inventories of the communities in the southern reach, this added breakwater cost will greatly outweigh any added CSRM benefits.	Analysis indicated that the additional features, such as wetlands or living shorelines, would provide minimal additional CSRM compared to the added cost. Living shorelines are infeasible in high energy environments. Per the NACCS, wetlands can slow the advance of storm surge somewhat and slightly reduce the surge landward. In addition, wetlands can dissipate wave energy; however, evidence suggests that slow-moving storms and those with long periods of high winds that produce marsh flooding reduce this benefit (Resio and Westerlink, 2008).
	Environmental Quality (EQ)					
Physiography & Geology	Storms will continue to erode the shoreline, exposing the underlying peat and reducing available sandy beach habitat for wildlife. A loss of barrier beach could result in flood inundation to interior salt marshes, forests and neighboring farmland.	This plan was not applicable to this planning reach and was not evaluated in this reach.	Beach restoration will help restore the natural bayfront physiography and geology. Also, beach nourishment using compatible grain size materials enhances habitat within the study area.	The construction of a hardened structure, such as a groin would not impact the area geology, but would alter the physiography of the beach by accumulating sand on the updrfit side and stabilizing the beach but may cause erosion on the downdrift side. Groins located at inlets (jetties) serve to reduce sand accumulation within the inlet.	The construction of a hardened structure, such as a breakwater may reduce sediment accumulation along the shoreline.	Hardened structures will affect natural sediment transport processes. A wetland plan adds additional cost with minimal CSRM benefits. Living shorelines are infeasible in high energy environments.
Sediment Quality	Future maintenance dredging sand from the proposed project source area will be placed at Buoy 10 for approximately 10 more years. Beyond this, dredging sand from the	This plan was not applicable to this planning reach and was not evaluated in this reach.	Beach restoration will reduce the sediment deficit in the Delaware Estuary and improve the overall health of the estuary.	The construction of a hardened structure, such as a groin impedes longshore sediment transport within the beach/intertidal habitat interface. Groins located at inlets (jetties) serve to reduce sand	The construction of a hardened structure, such as a breakwater is not advised by the natural resources agencies as it impedes the natural transfer of sediments within the beach/intertidal habitat interface.	Additional features such as a hardened structure will not affect sediment quality; however, it will affect natural sediment transport processes. A wetland plan

	proposed source area will be place at Artificial Island CDF. This future practice will contribute to increasing sediment deficit in the Delaware Bay as studies indicate that the bed of the bay has eroded at a rate that exceeds the average annual rate at which new sediment is supplied from the watershed.			accumulation within the inlet.		adds additional cost with minimal CSRM benefits. Living shorelines are infeasible in high energy environments.
Vegetation & Wetlands	The majority of wetlands within the study area are estuarine intertidal emergent wetlands, with additional estuarine intertidal scrub-shrub and forested wetlands occurring intermittently. The No Action Plan is expected to exacerbate the loss of beach vegetation and excessive inundation of neighboring wetlands with erosion of the barrier beachfront.	This plan was not applicable to this planning reach and was not evaluated in this reach.	Beach restoration will enhance reduction of risk to 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 groin would be located seaward of beach vegetation and wetlands. No adverse impact. Groins accumulate sand on the updrift beach side which may provide additional erosion protection for landward vegetation and wetlands.	The construction of a hardened structure, such as a breakwater is not advised by the natural resources agencies as it impedes the natural transfer of sediments within the beach/intertidal habitat interface.	Hardened structures disrupt natural longshore transport and reduce nutrient uptake in adjacent marshes. A wetland plan adds additional cost with minimal CSRM benefits. Living shorelines are infeasible in high energy environments.
Planktonic & Benthic Organisms	With the No Action Plan, low quality intertidal habitat would continue to exist due to severe erosion and exposed peat. Continued shoreline erosion elevates water turbidity which reduces primary productivity.	This plan was not applicable to this planning reach and was not evaluated in this reach.	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 groin would permanently reduce available shallow water soft bottom habitat in the structure footprint but adds to the intertidal habitat diversity by providing hard bottom substrate for benthic macroinvertebrates. There will be a temporary increase in turbidity during construction.	The construction of a hardened structure, such as a breakwater would permanently impact intertidal and beach habitat by obstructing the hydrodynamic connection between the two.	Hardened structures disrupt natural longshore transport and reduce available shallow water soft bottom habitat in the structure footprint. A wetland plan adds additional cost with minimal CSRM benefits. Living shorelines are infeasible in high energy environments.
Fish	Under the No Action Plan, adult fish occurring in the nearshore zone of the bay would not be impacted. However, with continued erosion of the shoreline, larval and juvenile fish stages are likely to be adversely impacted if area salt marshes incur lower habitat quantity and quality through loss of wetlands.	This plan was not applicable to this planning reach and was not evaluated in this reach.	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 fish that can leave the impact area during construction.	Minor temporary impacts to fish during construction due to elevated turbidity. Groins provide habitat diversity through the creation of hard substrate in a soft bottom habitat for prey species and refugia from currents and for feeding.	Minor temporary impacts to fish during construction due to elevated turbidity. Permanent displacement of shallow water bottom habitat.	Hardened structures create temporary impacts to fish during construction due to elevated turbidity. A wetland plan adds additional cost with minimal CSRM benefits. Living shorelines are infeasible in high energy environments.
Wildlife	Under the No Action Plan,	This plan was not applicable to	Beach restoration will provide added risk management to	The construction of a hardened	The construction of a hardened	Hardened structures would

	wildlife species would continue to incur further losses in habitat quality and quantity due to ongoing flooding and erosion.	this planning reach and was not evaluated in this reach.	wildlife habitats along the bayshore, interior shrub and within interior wetlands, scrub shrub and forested areas.	structure, such as a groin provides a resting area for waterbirds and feeding sites for coastal birds of prey. Groins may impede movement by small mammals, spawning horseshoe crabs and terrapins.	structure, such as a breakwater would impede horseshoe crab movements and potentially block access to spawning areas between the intertidal areas and the upper beach.	impede horseshoe crab movement, block spawning areas, and reduce available forage areas. A wetland plan adds additional cost with minimal CSRM benefits. Living shorelines are infeasible in high energy environments.
Threatened & Endangered Species	Under the No Action Plan, continued erosion and flooding will result in degraded habitat for species, including exposed underlying peat and scarped dunes.	This plan was not applicable to this planning reach and was not evaluated in this reach.	Beach restoration can provide positive benefits to listed species by restoring preferred beach habitat and increased flood protection to interior wetlands, scrub shrub and maritime forested habitats. Adverse impacts are avoided with environmental windows during placement operations.	The construction of a hardened structure, such as a groin would permanently reduce soft bottom habitat within the intertidal zone but provides erosion protection of beach habitat on the updrift side for beach foraging and nesting birds but impedes visual sight lines for foraging shorebirds. Groins at inlets accumulate sand on the updrift side, enlarging and elevating the beach, which is preferred by migratory shorebirds for predator avoidance.	The construction of a hardened structure, such as a breakwater would impede wildlife movements and block access between the intertidal zone and the upper beach.	Hardened structures would impede horseshoe crab movement, block spawning areas, and reduce available forage areas. A wetland plan adds additional cost with minimal CSRM benefits. Living shorelines are infeasible in high energy environments.
Air Quality	Air quality is generally good in the Delaware Bay region.	This plan was not applicable to this planning reach and was not evaluated in this reach.	Temporary impact to air quality during construction and maintenance operations.	Temporary impact to air quality during construction and maintenance operations.	Temporary impact to air quality during construction and maintenance operations.	Temporary impact to air quality during construction and maintenance operations.
Noise	Normal noise levels created by traffic, businesses and industrial activities would continue under the No Action Plan.	This plan was not applicable to this planning reach and was not evaluated in this reach.	Temporary elevation of noise levels during construction and maintenance operations.	Temporary elevation of noise levels during construction and maintenance operations.	Temporary elevation of noise levels during construction and maintenance operations.	Temporary elevation of noise levels during construction and maintenance operations.
Cultural Resources & Historic Properties	With the No Action Plan, no archaeological sites eligible for or listed on the NRHP would be affected. However, if no action is taken there is a potential for adverse effects to historic properties, such as historic structures and historic districts, due to SLC.	This plan was not applicable to this planning reach and was not evaluated in this reach.	This plan will have no adverse effect on archaeological sites eligible for or listed on the NRHP within the current APE. Also, the plan will have no adverse effect on historic structures eligible for or listed on the NRHP within the current APE; however, there may be some viewshed impacts to historic structures or historic districts eligible for or listed on the NRHP depending on the final design of each beachfill location.	No impact because this plan will not be implemented.	No impact because this plan will not be implemented.	No impact because this plan will not be implemented.
	Other Social Effects (OSE)					
Environmental Justice	The No Action Plan will have no impact on Environmental Justice	This plan was not applicable to this planning reach and was not evaluated in this reach.	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 with Groin(s) 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	Beach restoration with Breakwater 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	Beach restoration with Groin(s), Breakwater, Living Shoreline & Wetland is not anticipated to result in any significant or negative human health or safety

				low income populations and is in compliance with EO 12898.	income populations and is in compliance with EO 12898.	impacts. Also, it will not have a disproportionately high adverse effect on minority or low income populations and is in compliance with EO 12898.
Quality of Life/Recreation	Continued erosion and flooding will have an adverse impact on ecosystem services and related recreation opportunities.	This plan was not applicable to this planning reach and was not evaluated in this reach.	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 with Groin(s) 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 with Breakwater will enhance ecosystem services to humans by providing erosion control, storm risk management and habitat provision for wildlife and recreation.	Beach restoration with Groin(s), Breakwater, Living Shoreline & Wetland will enhance ecosystem services to humans by providing erosion control, water quality enhancement, storm risk management and habitat provision for wildlife and recreation.
	Regional Economic Development (RED)					
Jobs	While there is no project cost, the No Action Plan does not provide RED benefits and will allow for increasing erosional impacts and coastal storm risk, thereby providing little or no employment benefits to the areas.	This plan was not applicable to this planning reach and was not evaluated in this reach.	Regionally, the benefits of beach restoration could benefit the local economy by providing consistent CSRM benefits to the areas.	Regionally, the benefits of beach restoration with groin(s) could benefit the local economy by providing consistent CSRM benefits to the areas.	Regionally, the benefits of beach restoration with breakwater could benefit the local economy by providing consistent CSRM benefits to the areas.	Regionally, the benefits of beach restoration with Groin(s), Breakwater, Living Shoreline & Wetland could benefit the local economy by providing consistent CSRM benefits to the areas.
Income	While there is no project cost, the No Action Plan does not provide RED benefits and will allow for increasing erosional impacts and coastal storm risk, thereby providing little or no income-related benefits to the areas.	This plan was not applicable to this planning reach and was not evaluated in this reach.	Regionally, the benefits of beach restoration could benefit the local economy by providing consistent CSRM benefits to the areas.	Regionally, the benefits of beach restoration with groin(s) could benefit the local economy by providing consistent CSRM benefits to the areas.	Regionally, the benefits of beach restoration with breakwater could benefit the local economy by providing consistent CSRM benefits to the areas.	Regionally, the benefits of beach restoration with Groin(s), Breakwater, Living Shoreline & Wetland could benefit the local economy by providing consistent CSRM benefits to the areas.
Tax Base	While there is no project cost, the No Action Plan does not provide RED benefits and will allow for increasing erosional impacts and coastal storm risk, thereby providing little or no benefits to the area tax base.	This plan was not applicable to this planning reach and was not evaluated in this reach.	Regionally, the benefits of beach restoration could benefit the local economy by providing consistent CSRM benefits to the areas.	Regionally, the benefits of beach restoration with groin(s) could benefit the local economy by providing consistent CSRM benefits to the areas.	Regionally, the benefits of beach restoration with breakwater could benefit the local economy by providing consistent CSRM benefits to the areas.	Regionally, the benefits of beach restoration with Groin(s), Breakwater, Living Shoreline & Wetland could benefit the local economy by providing consistent CSRM benefits to the areas.

Table 18 - Southern Planning Reach Alternative Evaluation

Contribution to Planning Objectives						
	No Action Plan	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
1. Improve CSRM for people, property and infrastructure along and adjacent to the Delaware shoreline from 2020 to 2070, via the beneficial use of dredged material.	Erosion and storm-related damage will continue; therefore, the No Action Plan does not meet the objective.	While levees and dikes potentially could reduce impacts, this does not meet the objective because a cost-effective levee cannot be constructed with the available dredged material sources.	By reducing erosion and storm-related damage to coastal Delaware, this alternative meets the objective.	By reducing erosion and storm-related damage to coastal Delaware, this alternative meets the objective.	By reducing erosion and storm-related damage to coastal Delaware, this alternative meets the objective.	By reducing erosion and storm-related damage to coastal Delaware, this alternative meets the 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.	Erosion and storm-related damage will continue to reduce the resiliency of coastal Delaware; therefore, the No Action Plan does not meet the objective.	While levees and dikes potentially could reduce impacts and increase the resiliency of coastal Delaware, this does not meet the objective because a cost-effective levee cannot be constructed with the available dredged material sources.	By reducing erosion and storm-related damage to coastal Delaware, this alternative meets the objective by creating a more resilient coastal Delaware.	By reducing erosion and storm-related damage to coastal Delaware, this alternative meets the objective by creating a more resilient coastal Delaware.	By reducing erosion and storm-related damage to coastal Delaware, this alternative meets the objective by creating a more resilient coastal Delaware.	By reducing erosion and storm-related damage to coastal Delaware, this alternative meets the objective by creating a more resilient coastal Delaware.
Response to Evaluation Criteria						
Completeness	This does not meet the completeness criteria because the No Action Plan does not provide CSRM benefits and will allow for increasing erosional impacts and coastal storm risk to the identified CSRM problem areas.	As referenced in the VE study, available dredged material does not appear to be suitable for USACE levee construction and would require augmentation to improve its suitability. Since the dredged material does not appear suitable for levee construction, this alternative will not ensure the realization of the planned effects; therefore, the levee/dike plan was screened out and will not provide a complete CSRM solution.	This alternative meets the completeness criteria as it provides and accounts for all necessary investments or other actions to ensure the realization of the planned effects.	This alternative meets the completeness criteria as it provides and accounts for all necessary investments or other actions to ensure the realization of the planned effects.	This alternative meets the completeness criteria as it provides and accounts for all necessary investments or other actions to ensure the realization of the planned effects.	This alternative meets the completeness criteria as it provides and accounts for all necessary investments or other actions to ensure the realization of the planned effects.
Effectiveness	This does not meet the effectiveness criteria because the No Action Plan does not provide CSRM benefits and will allow for increasing erosional impacts and coastal storm risk	As referenced in the VE study, available dredged material does not appear to be suitable for USACE levee construction and would require augmentation to improve its suitability. The	This alternative effectively reduces erosion and storm-related damage to coastal Delaware.	This alternative effectively reduces erosion and storm-related damage to coastal Delaware.	This alternative effectively reduces erosion and storm-related damage to coastal Delaware.	This alternative effectively reduces erosion and storm-related damage to coastal Delaware.

	to the identified CSRM problem areas.	augmentation would add costs to an already expensive levee construction cost; therefore, the levee/dike plan was screened out and will not provide an effective CSRM solution.				
Efficiency	This does not meet the efficiency criteria. While there is no project cost, the No Action Plan does not provide CSRM benefits and will allow for increasing erosional impacts and coastal storm risk to the identified CSRM problem areas.	As referenced in the VE study, available dredged material does not appear to be suitable for USACE levee construction and would require augmentation to improve its suitability. The augmentation would add costs to an already expensive levee construction cost; therefore, the levee/dike plan was screened out and will not provide an efficient CSRM solution.	The benefits of beach restoration at Pickering Beach, Kitts Hummock, Bowers Beach, South Bowers Beach, Slaughter Beach, Prime Hook Beach and Lewes Beach are greater than the associated dredged material placement costs.	As discussed in the NED System of Accounts, relatively high beach erosion rates and losses are typically required to support the addition of groins to beach restoration projects. However, stand-alone beach restoration yielded higher AANB because of the added initial construction cost associated with groins.	Per the NACCS, an estimated total first construction cost of a breakwater could be as high as $90,000,000 for a 10,000 feet stretch of shoreline. Given the size of the structure inventories of the communities in the northern reach, this added breakwater cost will greatly outweigh any added CSRM benefits; therefore, this alternative is not efficient.	As discussed in the NED System of Accounts, additional features, such as wetlands or living shorelines, would provide minimal additional CSRM compared to the added cost; therefore, this alternative is not efficient. Per the NACCS, wetlands can slow the advance of storm surge somewhat and slightly reduce the surge landward. In addition, wetlands can dissipate wave energy; however, evidence suggests that slow-moving storms and those with long periods of high winds that produce marsh flooding reduce this benefit (Resio and Westerlink, 2008). This limited effectiveness coupled with a $2,593 cost per linear feet of wetland construction (as estimated in the NACCS) also limits the efficiency of the wetland feature.
Acceptability	This does not meet the acceptability criteria as State and local entities are generally supportive of beach restoration.	The acceptability of the levee/dike plan is not known at this time as the aforementioned technical limitations of utilizing dredged material for levee construction prevented the levee/dike plan from being carried forward for further analysis.	State and local entities are generally supportive of beach restoration.	The acceptability of the beach restoration with groin(s) is not known at this time as the aforementioned efficiency limitations associated with this plan prevented it from being carried forward for further analysis.	The acceptability of the beach restoration with breakwater is not known at this time as the aforementioned efficiency limitations associated with this plan prevented it from being carried forward for further analysis.	The acceptability of the beach restoration with groin(s), breakwater, living shoreline &wetland(s) is not known at this time as the aforementioned efficiency limitations associated with this plan prevented it from being carried forward for further analysis.

3.5 PLAN SELECTION

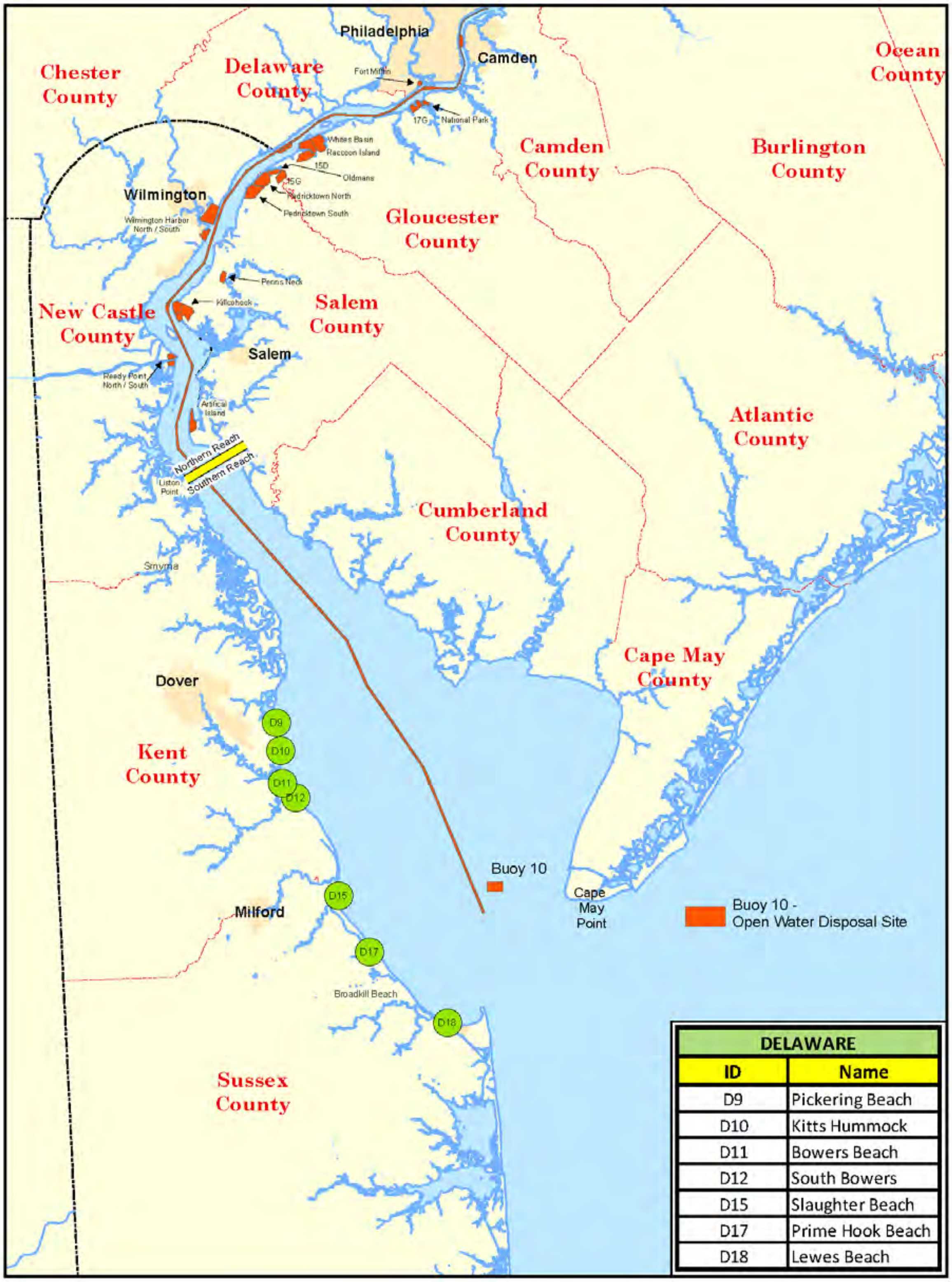
As referenced in Section 3.4, the project cost was compared against the benefits at each individual dredged material placement location to determine the BCR and net benefits at each placement location.

The primary NED benefit categories considered in this study included the following: reduction in damage to structures and content and local costs foregone. The benefits at each proposed placement location are greater than the associated dredged material placement costs for all locations except for Big Stone Beach.

3.5.1 Economic Summary

Current results indicate that the benefits of the recommended plan at the 7 remaining dredged material placement sites have benefits exceeding costs. The location of the 7 sites in the recommended plan are shown on Figure 10.

Figure 10 - Recommended Plan Dredged Material Placement Sites



DELAWARE	
ID	Name
D9	Pickering Beach
D10	Kitts Hummock
D11	Bowers Beach
D12	South Bowers
D15	Slaughter Beach
D17	Prime Hook Beach
D18	Lewes Beach

Table 19 provides a summary of the estimated costs associated with the recommended plan. For cost estimating purposes, USACE completed a cost and schedule risk analysis (CSRA) regarding the risk findings and recommended contingencies to be applied the estimated project cost. In compliance with ER 1110-2-1302 CIVIL WORKS COST ENGINEERING, dated September 15, 2008, a formal risk analysis, *Monte-Carlo* based study was conducted. The purpose of this risk analysis study is to present the cost and schedule risks considered, those determined and respective project contingencies at a recommend 80%confidence level of successful execution to project completion. Table 20 summarizes the individual costs and benefits associated with each dredged material placement site in the recommended plan.

Table 19 - Summary of Estimated Costs for the Recommended Plan

ESTIMATED COSTS FOR THE RECOMMENDED PLAN	
Period of Analysis	2020 to 2070 (50 Years)
Price Level	October 2017
Discount Rate	2.75%
Base Year	2020
Nourishment Costs	
2020 (including Real Estate)	$53,300,000
2026	$45,300,000
Interest During Construction	$1,885,000
Periodic Renourishment Costs	
2026	$14,900,000
2032 through 2070	$215,000,000
AVERAGE ANNUAL COSTS	
Nourishment Costs	
2020 (without Interest During Construction)	$1,975,000
2026 (without Interest During Construction)	$1,288,000
Interest During Construction	$70,000
Periodic Renourishment	$3,819,000
Subtotal Average Annual Costs	**$7,152,000**
Monitoring Costs – 2020	$146,000
Monitoring Costs – 2026	$244,000
Monitoring Costs – 2032 through 2070	$118,000
OMRR&R	$27,000
Total Average Annual Cost	**$7,687,000**

Notes:

1. Major rehabilitation costs are not included due to the required major rehabilitation quantity (165,900 cubic yards) being less than periodic renourishment quantity of 413,600 cubic yards.
2. Mid-point of construction is 2020 Q4 and 2026 Q4 for nourishment.

Table 20 – Summary of Costs & Benefits

Site	AAC	AAB	AANB	BCR
Pickering	$986,000	$1,775,000	$789,000	1.8
Kitts Hummock	$837,000	$1,405,000	$568,000	1.7
Bowers	$959,000	$1,295,000	$336,000	1.4
South Bowers	$862,000	$963,000	$101,000	1.1
Slaughter Beach	$1,472,000	$2,739,000	$1,267,000	1.9
Prime Hook	$1,344,000	$2,430,000	$1,086,000	1.8
Lewes Beach	$1,226,000	$1,624,000	$398,000	1.3
Total Project	**$7,687,000**	**$12,231,000**	**$4,545,000**	**1.6**

Note: The cost and benefit values in Table 20 cover a 50-year period of analysis with a base year of 2020.

3.5.1.1 Residual Risk

CSRM benefits for this study included Structure Damages avoided, Content Damages avoided, and ancillary Navigation cost savings. Benefits were computed using the formula *Without Project Damages – With Project Damages + Navigation Savings = CSRM Benefits.* No other benefit categories (e.g. Recreation) were found to be significant contributors to overall 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*.

Table 21 provides a summary of damages prevented, which increase as residual risk decreases.

Table 21 - Summary of Damages Reduction Benefits by Site

Site	Without Project	With Project	Damages Avoided	AAB	Residual Risk
Pickering	$42,711,000	$4,392,000	$38,319,000	$1,775,000	10%
Kitts Hummock	$41,840,000	$13,490,000	$28,350,000	$1,405,000	32%
Bowers	$33,129,000	$7,775,000	$25,354,000	$1,295,000	24%
South Bowers	$22,074,000	$5,660,000	$16,414,000	$963,000	26%
Slaughter Beach	$117,200,000	$52,836,000	$64,363,000	$2,739,000	45%
Prime Hook	$85,514,000	$29,504,000	$56,010,000	$2,430,000	35%
Lewes Beach	$54,859,000	$20,436,000	$34,248,000	$1,624,000	37%
Total Project	**$397,226,000**	**$134,168,000**	**$263,058,000**	**$12,231,000**	**34%**

Note: The damage and damages prevented values in Table 21 cover a 50-year period of analysis with a base year of 2020.

The recommended plan reduces 66% of damages in the study area. For this particular study area, the proposed plan is expected to significantly reduce erosion and wave attack damages with only minimal reductions to inundation damage due to the presence of back bay flooding. Specifically, Slaughter Beach experiences greater inundation impacts than the other study locations and in turn Slaughter Beach also experiences the highest Residual Risk post construction.

3.5.1.2 Risk & Uncertainty

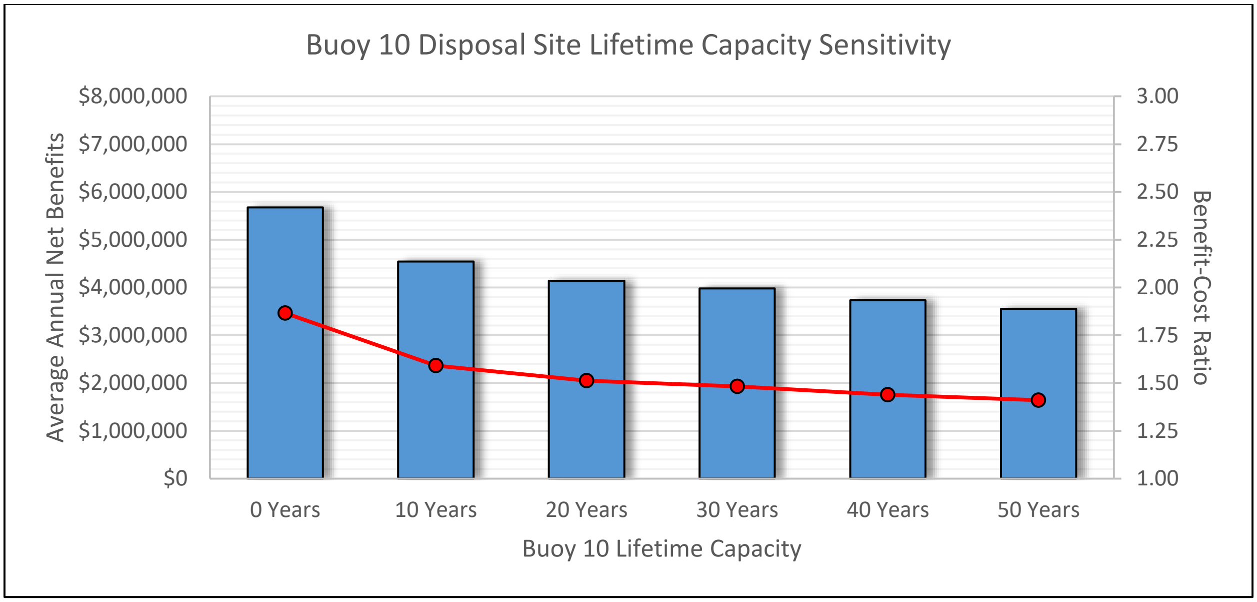
As stated in Appendix A, Beach-fx is an event-based Monte Carlo life cycle simulation that uses historic storms to calculate damages over the course of a project life cycle. The model links the predictive capability of coastal evolution modeling with project area infrastructure information, structure and content damage functions, and economic valuations to estimate the costs and total damages under various CSRM 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 condition and future with project 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.

As previously stated, the current Federal Standard for dredged material disposal from the proposed recommended plan source area is dredging via a hopper dredged and bottom dumping at Buoy 10, which is approaching operational capacity. In 2017, Buoy 10 was estimated to be at or near capacity; however, the USACE requested and received from NJDEP a permit to expand the footprint and gain an approximate 10 years of additional capacity. A new Coastal Zone Management Act Consistency Determination (CZM) and WQC were received on 24 January 2018. While the NJDEP permit provides approximately an additional 10 years of capacity, the USACE recognizes a degree of uncertainty related to the projected Buoy 10 capacity. Because the assumed Federal Standard impacts the DE DMU economics as project costs are based on the difference between placement at the DMU project location (with-project condition) and placement at Buoy 10 and/or Artificial Island, an economic sensitivity analysis was conducted to evaluate the impact of the Federal Standard assumptions on the project economics.

To evaluate the relative risk of this assumption, the total project Average Annual Net Benefits are calculated with a range of scenarios regarding the lifetime capacity of Buoy 10. Ranging from 0 Years capacity (all maintenance dredged material is shipped to Artificial Island in the Without-Project Condition) to 50 Years capacity (dredged material is only shipped to Buoy 10). The results of the sensitivity analysis are summarized on Figure 11:

Figure 11 - Economic Sensitivity Analysis



Results in Figure 9 illustrate that while overall project Average Annual Net Benefits rely on the Federal Standard to remain positive, the assumptions governing Buoy 10 vs Artificial Island placement are much less impactful. Even with Buoy 10 capacity extended to the end of the period of analysis, Average Annual Net Benefits remain positive and the BCR remains above 1.0.

Damage Functions

Damage functions are user-defined curves that are applied within the Beach-fx 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 NACCS Physical Depth Damage Function Summary Report.

Future Without Project Condition 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, as described in greater detail in the Economics Appendix. Values are in Present Worth using the FY2018 (2.75%) Federal Discount Rate.

Table 22 - Future Without Project Condition Damages by Site

Site	Structure	Content	Total	% Total
Pickering Beach	$27,420,000	$15,292,000	$42,711,000	10%
Kitts Hummock	$29,728,000	$12,112,000	$41,840,000	10%
Bowers Beach	$24,075,000	$9,053,000	$33,129,000	8%
South Bowers Beach	$16,084,000	$5,990,000	$22,074,000	6%
Slaughter Beach	$79,663,000	$37,537,000	$117,200,000	30%
Prime Hook Beach	$61,061,000	$24,453,000	$85,514,000	22%
Lewes Beach	$39,597,000	$15,162,000	$54,759,000	14%
TOTAL ESTIMATE	**$277,628,000**	**$119,598,000**	**$397,226,000**	**100%**

Note: The future without project condition damage values in Table 22 cover a 50-year period of analysis with a base year of 2020.

In addition to the economic risk and uncertainty drivers referenced above, risk-informed decision making was applied in other areas of the plan formulation. There are two issues that appear to present the greatest risk and uncertainty for project implementation: quantity of available dredged material and sediment compatibility. Based on the analysis completed for the feasibility report in support of the Delaware River Main Channel Deepening project, 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. USACE recognizes that the aforementioned shoaling rate and associated dredging cycle is based on an estimate and will need to be confirmed with post-deepening surveys.

Regarding sediment compatibility, a beachfill compatibility analysis is typically conducted to statistically compare the existing or "native" beach sand grain size to the intended borrow material that will be placed on that site. A resulting overfill factor is calculated and is greater than 1.0 when the borrow material is considerably smaller than the native materials. Due to several factors, a more general comparison needs has been applied for this project. Determining the true "native" grain size characteristics of the seven placement sites is difficult due to limited older available data and the fact that most of these beaches have been supplemented with numerous fills of varying materials through previous CSRM efforts (dredging events and truck fill operations). The average grain size for Lewes Beach was determined for the Roosevelt Inlet - Lewes Beach Feasibility Study. The average grain size of the remaining sites is based on the DNREC Report "Bay Beach Design Verification Report," prepared by CB&I Coastal Planning and Engineering. Determining the exact grain size characteristics of the proposed borrow material to be utilized is also difficult, as the dredged materials to be utilized are shoaling in to the deepened Delaware River navigation channel as this report is being prepared. It is with a high level of confidence, however, that those shoaling sands will be very similar to the maintenance materials that have been dredged from the channel and placed at the Bouy 10 site over the past several decades. Seven vibracores from the Bouy 10 site were retrieved and detailed sieve analyses show that the average grain size of these materials is anticipated to be very similar to the sands that historically have existed at and near the seven proposed placement sites as demonstrated in Table 14. Logically, an average overfill factor of 1.0 can be applied to all fill quantities for these fill locations.

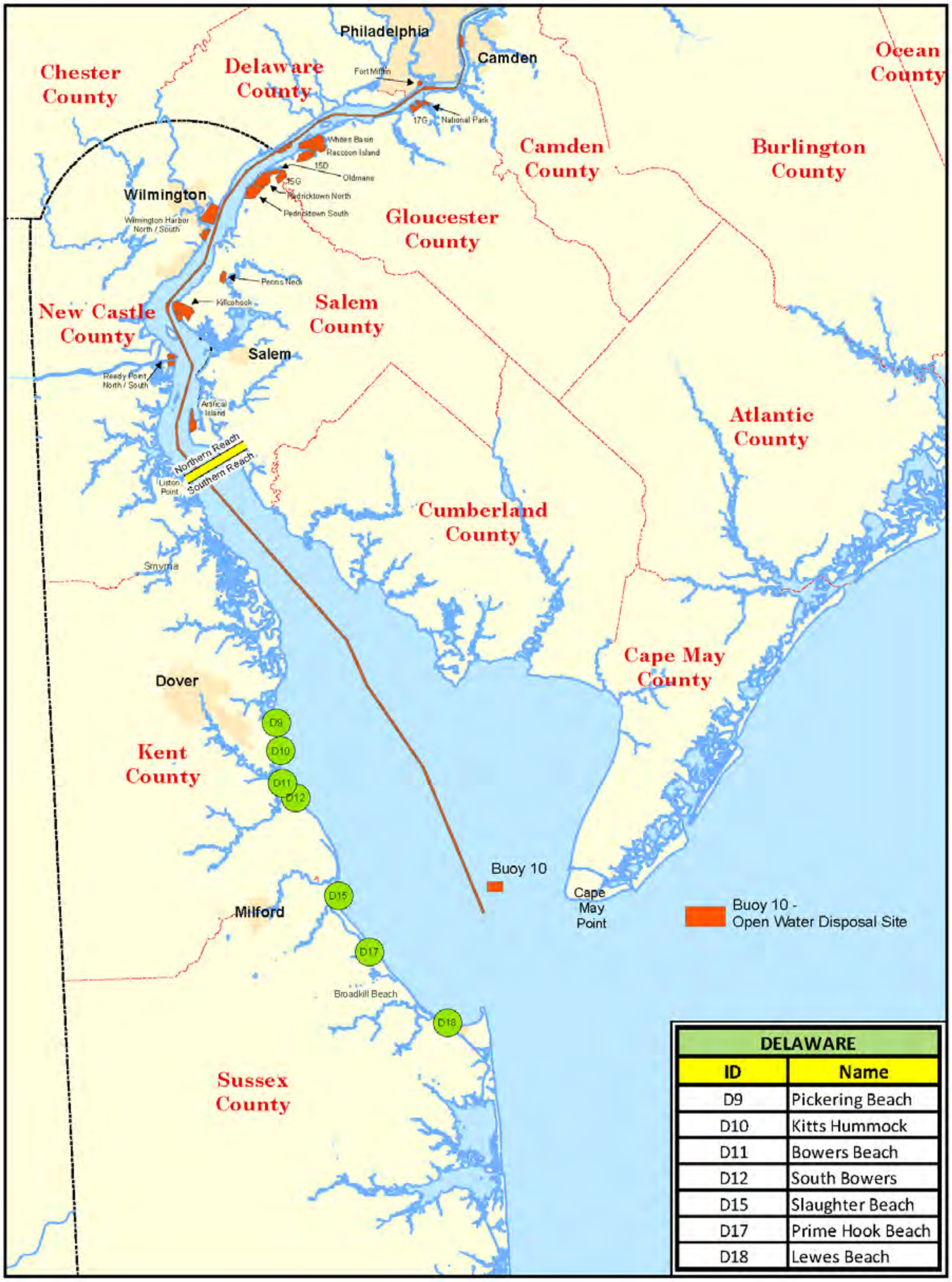
3.6 DESCRIPTION OF THE RECOMMENDED PLAN

3.6.1 Plan Components

The recommended plan consists of beach restoration at 7 dredged material placement locations in the southern reach of the study area. The 7 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, Slaughter Beach, Prime Hook Beach and Lewes. Dune elevations and berm widths from the Beach-fx optimization are presented in Table 23. All of the design profiles consisting of both dune and berm have a dune slope of 1V:5H, foreshore slope of 1V:10H, and a berm elevation of +7 ft NAVD88. The berm elevations is selected to match the natural berm elevations in the study area. The results of the Beach-fx optimization show that Pickering and Kitts Hummock do not need a dune to maximize net benefits. However, a wider design berm is required since there is no dune. Slaughter optimized to a relatively low dune at +8.5 ft NAVD88 that matches the existing dune conditions and the remaining sites optimized to a design dune elevation of +12 ft NAVD88.

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. In a letter date 3 January 2017, USFWS noted that the project as proposed would have no effect on red knot with adherence to a time-of-year restriction for project activities conducted on the beaches between 15 April and 7 June when red knots forage. The USACE will adhere to this environmental window.

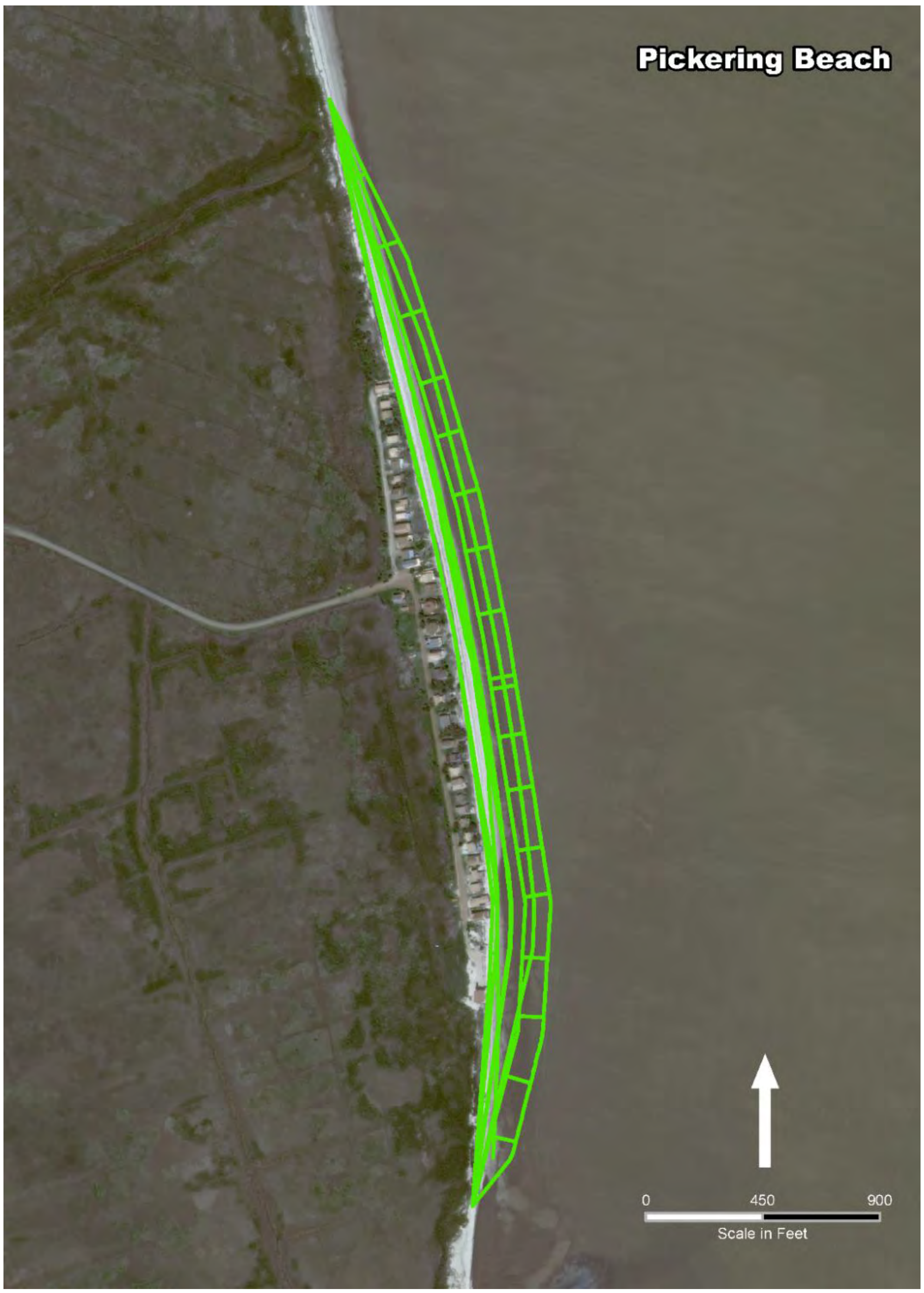
Figure 12 - Recommended Plan Dredged Material Placement Sites



DELAWARE	
ID	Name
D9	Pickering Beach
D10	Kitts Hummock
D11	Bowers Beach
D12	South Bowers
D15	Slaughter Beach
D17	Prime Hook Beach
D18	Lewes Beach

Pickering Beach

At Pickering Beach, the recommended plan calls for a berm only beachfill with the parameters shown on Table 23. The full width of the design extends in front of all currently developed property in Pickering Beach, with the exception of one home at the southern end of the project. This home is located in Little Creek CBRA System Unit DE-01 and CSRM-related beachfill is not permitted in this area; however, beachfill as part of the southern berm taper will be placed in this area, based on USFWS' determination that the berm tapers are not restricted from entering the CBRA system units, as they do not represent an added line of CSRM but rather serve to stabilize the adjacent CSRM project footprint.



Kitts Hummock

The recommended plan calls for a berm only beachfill at Kitts Hummock, as indicated on Table 23. The full width of the design berm extends in front of all currently developed property at Kitts Hummock, with the exception of one lot at the northern end of this project, where a home was recently demolished and a new one is planned to be built. This home is located in Little Creek CBRA System Unit DE-01 and no beachfill is permitted in this area, however, some beachfill as part of the northern berm taper will be placed in this area. An existing home immediately south of this lot will be provided CSRM by the full design berm width despite being in the CBRA System Unit due to the date of construction. In addition, the existing outfall is to be extended as necessary.

Bowers Beach

The recommended plan calls for a dune and berm beachfill at Bowers Beach with the parameters shown in Table 23. The design does not impact any CBRA System Units. The design will tie into the existing jetty at the southern end, with a tapered beachfill at the north end wrapping around the beachfront at the mouth of the St. Jones River.

South Bowers Beach

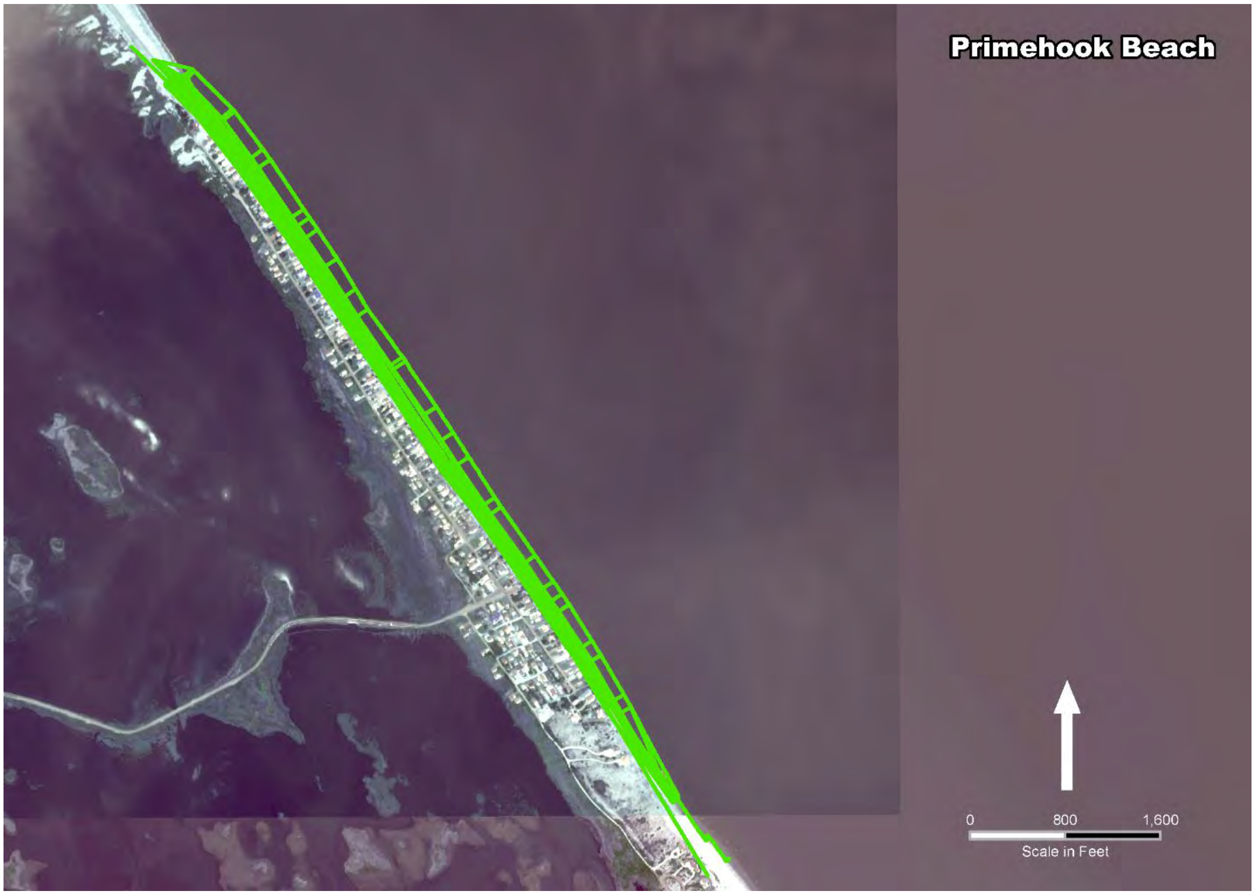
At South Bowers Beach, the recommended plan calls for a dune and berm beachfill with the parameters shown in Table 23. The design does not impact any CBRA System Units. The design will tie into the jetty alignment upon reconstruction by the local sponsor at the northern end, with a tapered beachfill at the southern end, based on USFWS' determination that the berm tapers are not restricted from entering the CBRA system units, as they do not represent an added line of CSRM but rather serve to stabilize the adjacent CSRM project footprint.

Slaughter Beach

For Slaughter Beach, the recommended plan calls for a dune and berm beachfill with the parameters shown in Table 23. The dune and berm design does not impact any CBRA System Units; however, there are several homes built in the CBRA System Unit Broadkill Beach H00 adjacent to the southern end of the project that will not be provided CSRM by this project. The design will utilize berm tapers at each end to tie the beachfill into existing conditions. Specifically, the southern taper will extend into the aforementioned CBRA System Unit, based on USFWS' determination that the berm tapers are not restricted from entering the CBRA system units, as they do not represent an added line of CSRM but rather serve to stabilize the adjacent CSRM project footprint.

Prime Hook Beach

The recommended plan calls for a dune and berm beachfill at Prime Hook Beach with the parameters shown in Table 23. The design does impact the CBRA System Unit Broadkill Beach H00 to the north of project. An exception was granted to allow for the proposed project to tie in to the newly constructed PHNWR beach restoration. There are several homes built in the CBRA System Unit Broadkill Beach H00 adjacent to the southern end of the project that will not be provided CSRM by this project. The design will utilize tapers at each ends to tie the beachfill into existing conditions. Specifically, the southern taper will extend into the aforementioned CBRA System Unit, based on USFWS' determination that the berm tapers are not restricted from entering the CBRA system units, as they do not represent an added line of CSRM but rather serve to stabilize the adjacent CSRM project footprint.



Lewes Beach

The recommended plan calls for a dune and berm beachfill at Lewes Beach with the parameters shown in Table 23. There currently exists a constructed Federal project (highlighted in yellow on the figure below) consisting of a 1,400 ft. long beachfill (15 ft. wide berm at an elevation of +8 ft. NAVD88, extending bayward at a slope of 1V:10H above MHW, and a dune with a 25 ft. crest width with an elevation of +14 ft. NAVD88 for the purpose of CSRM). Initial construction of the existing Federal project included the reconstruction of the adjacent terminal groin for Roosevelt Inlet for the purpose of navigation and the aforementioned beachfill. The 1,400 ft. length consists of a 900 ft. berm and dune beachfill with a 500 ft. taper. The recommended plan will tie into the existing Federal beachfill project at the western end, while the beachfill will taper to existing conditions at the eastern end.

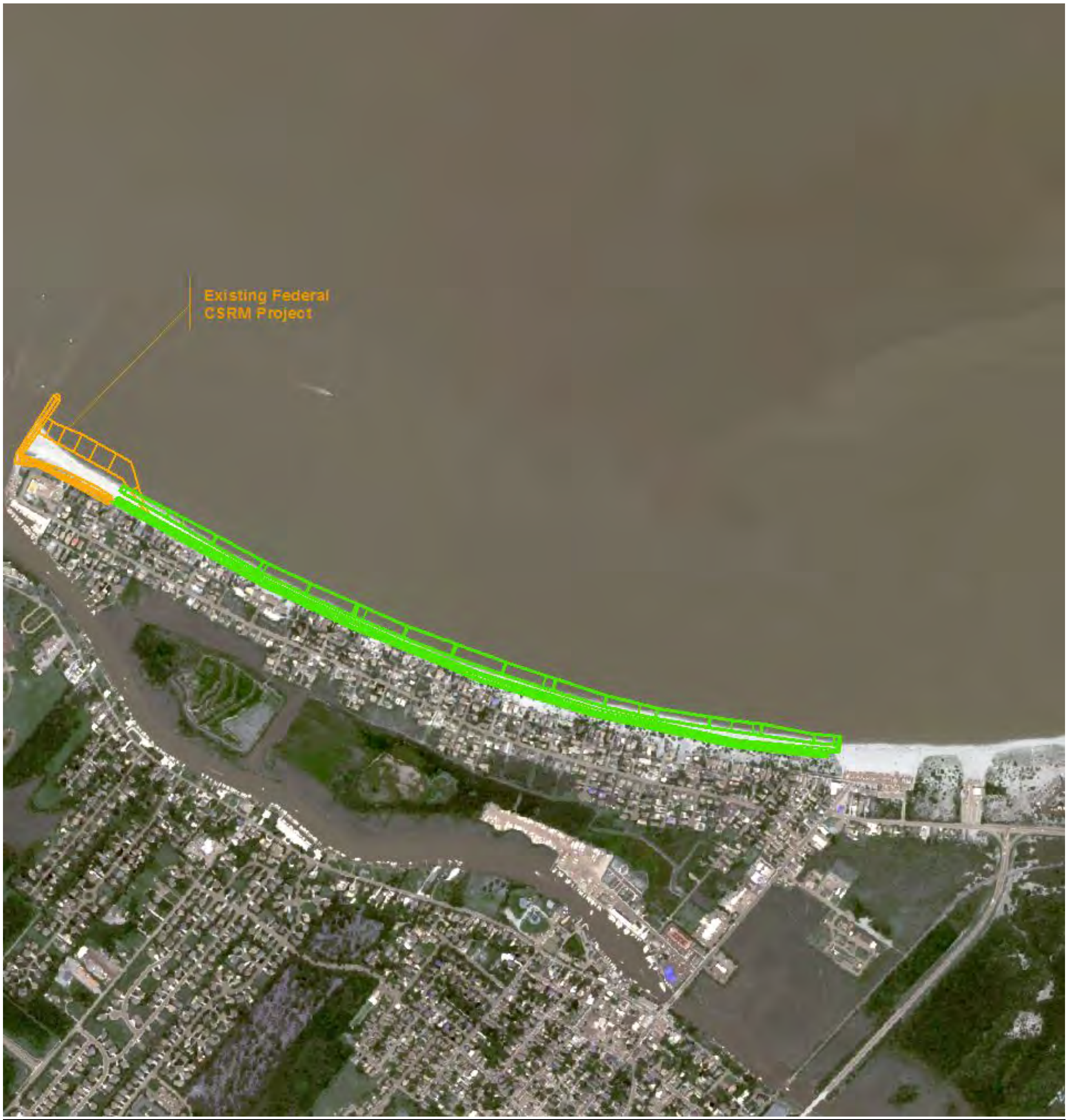

Existing Federal
CSRM Project

Table 23 - Summary of Recommended Plan Beachfill Dimensions

Location	Volume of Initial Fill (cubic yards)	Length of Design Dune/Berm (feet)	Length of Nourishment Dune (feet)	Southern Taper (feet)	Northern Taper (feet)	Length of Shoreline (feet)	Dune Height (feet NAVD88)	Dune Width (feet)	Berm Height (feet NAVD88)	Design Berm Width (feet)	Advance Berm Width (feet)
Pickering Beach	181,600	2,295	N/A	1,010	1,016	4,321	N/A	N/A	7	55	45
Kitts Hummock	198,500	4,685	N/A	965	1,000	6,650	N/A	N/A	7	55	45
Bowers Beach	178,600	2,326	2,326	34	846	3,206	12'	25	7	25	50
South Bowers Beach	119,600	1,367	1,367	1,005	129	2,501	12'	25	7	25	75
Slaughter Beach	260,800	14,468	9,482	1,000	942	16,410	8.5'	25	7	25	25
Prime Hook Beach	278,700	6,408	4,252	941	258	7,607	12	25	7	25	25
Lewes Beach	191,800	7,223	2,515	30	0	9,768	12	25	7	25	25

Table 24 - Pertinent Data

Item	Pickering Beach	Kitts Hummock	Bowers Beach	South Bowers Beach	Slaughter Beach	Prime Hook Beach	Lewes Beach	Total
Volume of Initial Fill	181,600 cubic yards	198,500 cubic yards	178,600 cubic yards	119,600 cubic yards	260,800 cubic yards	278,700 cubic yards	191,800 cubic yards	1,300,000 cubic yards
Volume of Renourishment Fill	36,700 cubic yards	81,300 cubic yards	41,500 cubic yards	38,200 cubic yards	79,700 cubic yards	53,300 cubic yards	82,900 cubic yards	413,600 cubic yards
Renourishment Interval	6 years	6 years	6 years	6 years	6 years	6 years	6 years	6 years
Length of Fill	2,295 feet	4,685 feet	2,326 feet	1,367 feet	14,468 feet	6,408 feet	7,223 feet	N/A
Width of Berm	100 feet	100 feet	75 feet	100 feet	50 feet	50 feet	50 feet	N/A
Berm Slope	1V:10H	1V:10H	1V:10H	1V:10H	1V:10H	1V:10H	1V:10H	N/A
Dune Crest	N/A	N/A	12 feet NAVD88	12 feet NAVD88	8.5 feet NAVD88	12 feet NAVD88	12 feet NAVD88	N/A
Dune Slope	N/A	N/A	1V:5H	1V:5H	1V:5H	1V:5H	1V:5H	N/A
Nourishment Costs – 2020	-	-	-	-	$16,729,000	$9,698,000	$5,934,000	$32,360,000
Nourishment Costs - 2026	$15,350,000	$11,722,000	$10,343,000	$6,288,000	-	-	-	$43,703,000
Periodic Renourishment Costs – 2026	-	-	-	-	$4,723,000	$2,096,000	$3,626,000	$10,445,000
Periodic Renourishment Costs – 2032 through 2070	$6,800,000	$4,804,000	$2,300,000	$1,970,000	$4,730,000	$2,000,000	$3,600,000	$26,200,000 (per cycle)
Lands and Damages								$17,300,000
Preconstruction Engineering & Design								$25,500,000
Construction Management								$16,200,000
Average Annual Costs	$986,000	$837,000	$959,000	$862,000	$1,472,000	$1,344,000	$1,226,000	$7,687,000
Average Annual Benefits	$1,775,000	$1,406,000	$1,295,000	$963,000	$2,740,000	$2,430,000	$1,624,000	$12,231,000
Average Annual Net Benefits	$789,000	$568,000	$335,000	$101,000	$1,267,000	$1,086,000	$398,000	$4,544,000
Benefit Cost Ratio	1.8	1.7	1.4	1.1	1.9	1.8	1.3	1.6
Estimated Project First Cost (October 2017 Price Level)								**$328,500,000**

Note: The quantities listed on Table 23 and Table 24 represent projected pay quantities required to construct and maintain the beach profile

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 USACE 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 nourishment (2020), Buoy 10 may serve as a back-up source for nourishment 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 USACE 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).

Nourishment quantities (1.3 million cy) exceed the projected quantity assumed to be available from each dredging cycle. Therefore, the projected implementation of this recommended plan assumes nourishment to be split over two operation in 2020 and 2026. The southernmost 3 sites (Lewes, Prime Hook, and Slaughter) will be constructed in year 2020, and the remaining 4 northern sites (Pickering, Kitts Hummock, Bowers, and South Bowers) will be constructed in year 2026 during the 1st periodic renourishment cycle for the 3 southernmost sites. In year 2032 all 7 sites will be on the same 6-year periodic renourishment cycle.

In order to maintain the integrity of design beachfill alternatives, periodic renourishment must be included in the project design. If periodic renourishment was not performed throughout the life of the project, longshore and cross shore sediment transport mechanisms would act to erode the design beach. A 6-year periodic renourishment cycle is anticipated to maintain optimal coastal storm risk management. This nourishment cycle coincides with the proposed operation and maintenance (O&M) dredging to be performed in Lower Reach E.

3.6.2 Public Law 113-2 Requirements

This section has been prepared to address how the recommended plan contributes to the resiliency of the Delaware shoreline; how it affects the sustainability of environmental conditions in the affected area; and how it will be consistent with the findings and recommendations of the NACCS.

Resiliency is defined in the February 2013 USACE-NOAA Infrastructure Systems Rebuilding Principles white paper as the ability to adapt to changing conditions and withstand, and rapidly recover from disruption due to emergencies. Sustainability is defined as the ability to continue (in existence or a certain state, or in force or intensity), with interruption or diminution.

3.6.2.1 Resiliency

One of the planning objectives of the DE DMU is to "increase the resiliency of coastal Delaware, specifically along the Delaware Estuary and Delaware Inland Bay shoreline, via the beneficial use of dredged material." The formulated measures and alternatives have all been designed to enhance the resiliency of the coastal system, particularly with regard to erosion and SLC.

In general CSRM projects, such as the DE DMU, are engineered beaches that are designed, constructed and periodically nourished to reduce the risk of economic losses arising from coastal storms. The intent is to replicate the function of beaches in areas that were once part of natural, undeveloped systems that have subsequently experienced significant human development and utilization. Storms reduce the degree of storm risk management provided by the beach fill project; elevated water levels and larger-than-normal waves displace sand from the berm and dune portions of the engineered beach profile and transport it principally in the offshore direction. After the storm, normal tide and wave conditions return, typically resulting in onshore-directed sand transport that rebuilds at least a portion of the berm (i.e., beach). This natural recovery of the beach berm occurs over a period that may range from days to months. Natural rebuilding of the dune is a process that requires years to decades, given its dependence on wind transport and an adequate sand supply on the beach. In the period between the storm and the partial natural recovery, an increased level of storm damage risk exists due to the eroded condition of the project berm and dune relative to the level of risk associated with a constructed, fully maintained project. Consequently, repair of an engineered beach to its design dimensions is usually accomplished as a planned renourishment, which is included in the authorized period of analysis cycle, or as an emergency activity under the USACE Flood Control and Coastal Emergencies authority (PL 84-99), to restore the storm damage risk reduction function for which the project was authorized. This post-storm repair is necessary because the engineered beach may not otherwise fully recover to its authorized dimensions naturally, or at least not in a time frame that would minimize risks due to the deteriorated condition. In this regard, it is apparent that storm risk management projects involving beach replenishment possess intrinsic "resilience", in light of the large volume of sediment that remains within the system after a major disturbance and the associated repair or replenishment that is included to restore the project design dimensions.

3.6.2.2 Sustainability/Adaptability

The DE DMU recommended plan meets the economic, environmental and community sustainability goals for the fifty year length of the project. Economic principals area used in benefit calculations, plan formulation ranking and project justification by their contributions to the NED account. Environmental concerns are evaluated in the integrated EA and through coordination and review with various resource agencies. Community sustainability, as known as social accounts, are intrinsic in beach nourishment projects since they maintain habitat for beach patrons. The nexus of these three pillars indicates that the recommended plan is sustainable.

3.6.2.3 Consistency with the NACCS

The NACCS was released in January 2015 and provides a risk management framework designed to help local communities better understand changing flood risks associated with climate change and to provide tools to help those communities better prepare for future flood risks. In particular it encourages planning for resilient coastal communities that incorporates wherever possible sustainable coastal landscape systems that takes into account, future sea level and climate change scenarios. The process used to identify the recommended plan utilized the NACCS Risk Management framework that included evaluating alternative solutions and also considering future SLC and climate change.

Recognizing the Federal government's commitment to ensure no inducement of development in the floodplain pursuant to Executive Order 11988, this project will identify in the Project Partnership Agreement (PPA) the need for the non-Federal sponsor to develop a floodplain management plan and a requirement for the sponsor to certify that measures are in place to ensure that the project does not induce development within the floodplains.

3.6.3 Real Estate Requirements

Based on the information available, the recommended plan requires 3 types of easements/instruments for the combined projects: Road/Access Easements, Perpetual Beach Storm Damage Reduction Easements, and permits or easements for the use of lands in the project area currently owned by the United States Fish and Wildlife Service. Currently, all mobilization and construction activities, including lay down and storage of contractor materials and equipment, are assumed to be located within the project area Limit of Construction for the entire project. At this time, four (4) total road easements are needed in four (4) of the project areas, requiring the use of Standard Estate No. 11, Road/Access Road Easement.

The standard Perpetual Beach Storm Damage Reduction Easement (Standard Estate No. 26) is required for the construction of the beach berm and/or 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. 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.

The third estate/instrument required is for lands in the project area currently owned by the United States Fish and Wildlife Service. One parcel located in the Prime Hook project area is owned by the United States of America and managed by the US Fish and Wildlife Service (USFWS) as part of the Prime Hook National Wildlife Refuge. Although the parcel is owned by the United States, it is managed by an Agency other than the USACE. Therefore, one or more of the following documents will be required: a permit or cooperative agreement, a special use permit or an easement (if permissible at the time of request). The particular documentation required will be determined once more detailed plans are completed for those particular project areas. Coordination of project activities with USFWS is on-going and has resulted in additional land requirements for the project and taper area currently located upon FWS-managed property.

Table 25 - Summary of Real Estate Requirements

	Easements Required		Easements In-Hand		Outstanding Easements	
Project Area	HSDR	Road	HSDR	Road	HSDR	Road
Pickering	32	1	18	1	14	0
Kitts-Hummock	77	0	77	0	0	0
Bowers	50	0	40	0	10	0
South Bowers	10	1	1	1	9	0
Slaughter Beach	106	1	0	0	106	1
Prime Hook	67	1	0	0	67	1
Lewes	1	0	0	0	1	0
TOTALS:	**343**	**4**	**136**	**2**	**207**	**2**

Per the March 19, 2014 CECC-R Memo entitled "Availability of Navigation Servitude for Coastal Storm Damage Reduction Projects," the determination of the applicability of Federal Navigation Servitude for the construction of coastal storm damage reduction measures by the United States under a Federal cost-shared project is done on a case-by-case basis and requires a two-step review process: a legal opinion of applicability completed by the District and a review for concurrence through the Real Estate Law Section of the Office of the Chief Counsel, staffed through Division Counsel.

In order to align real estate timelines with current project-planning best practices, the request for concurrence through Division Counsel will occur concurrently with this REP. Attached as Exhibit C is a memorandum provided by NAB Office of Counsel, dated 2 February 2018 entitled "Legal Opinion on the Use of Federal Navigation Servitude for Coastal Storm Damage Reduction Projects at Seven Locations Along the Delaware Bay Pursuant to the Delaware Beneficial Use of Dredged Material for the Delaware Feasibility Study." Per the attached:

"It is the District opinion that navigation servitude may be invoked for construction of the proposed coastal storm damage reduction project, in utilization of the federal channel to be dredged, and in the CSRM footprint below MHW."

Therefore, although the State of Delaware owns/controls all lands below the MLLW and has navigational servitude and jurisdiction over lands between the MWHL and MLLW, no authorization for entry will be required from the NFS and no credit or reimbursement will be afforded the NFS for these areas.

Based on the easement costs listed above, acquisition/administrative costs, condemnation costs, real estate payments and a 50% real estate cost contingency, the total estimated baseline cost for real estate is $17,274,000. Additional details on the factors affecting the baseline cost estimate are further discussed in Appendix B.

3.6.4 Environmental Compliance

Table 26 provides a summary of the environmental compliance status to date. Additional details regarding the environmental compliance are provided in Section 6.2.2.

Table 26 - Summary of Environmental Compliance

Item	Compliance
Anadromous Fish Conservation Act	N/A
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.	Full
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)	Full
Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations, February 11, 1994	Full
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
- Pending indicates coordination ongoing and will be completed prior to completion of the NEPA process.

3.6.5 Environmental Operating Principles

The USACE 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 Estuary system by dredging with no reductions in maintained depths or any significant reduction in dredging projects requiring maintenance. The Delaware Bay shoreline has incurred significant erosion and tidal flooding. The lower bay shoreline in the vicinity of Prime Hook Beach has lost approximately 1,100 feet or roughly a loss of 10 feet/year on average (B. Scarborough, Delaware Coastal Programs, personal comment). Most shoreline erosion of the Delaware Bay is caused by waves generated by local winds. The beach berm is the primary feature. A gently sloped beach dissipates wave energy while dunes reduce the erosion impact of wind, buffer the effects of floodwaters, and provide a sediment source to adjacent salt marshes (Knutson, 1988; Rosen, 1980). The dune is the secondary feature that provides additional height to reduce storm surge overtopping. Dune vegetation provides additional protection against erosion forces of wind and waves. American beach grass (*Ammophila breviligulata*) is a natural dune plant species that increases stability of the dune. The Delaware Bay beaches, including the beaches fronting residential communities, provide an important stopover site for migratory birds that travel up and down the Atlantic Flyway, provide breeding habitat for Federally and State-listed threatened and endangered species, as well as for many neo-tropical migrating bird species. Diamondback terrapins and horseshoe crabs utilize these beaches for nesting and spawning, respectively.

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 recommended plan will provide improved CSRM for the Delaware Bay shoreline by utilizing dredged material to alleviate shoreline erosion and flooding. This recommended plan 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. Specifically, implementation of this recommended plan may potentially change the overall sediment management practices for the watershed, as it will achieve the same navigation benefits as the current dredged material management practices, but may provide the added benefit of retaining sediment in a sediment starved estuary.

There is a potential for this recommended plan to enhance resiliency and sustainability of the natural coastal environment by retaining sediment in the system, and thereby providing shoreline stabilization. Specifically, the importation and deposition of new sediments is essential to the long-term sustainability of coastal wetlands. Wetlands promote shoreline stabilization and a defense against more frequent/lower level flooding events. 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.

3.6.6 Contributions to the USACE Campaign Plan

The USACE Campaign Plan is comprised of four separate goals: 1 – Supporting the Warfighter, 2 – Transforming Civil Works, 3 – Reducing Disaster Risks, and 4 – Preparing for Tomorrow.

Transforming Civil Works will enable the Corps to deliver essential water resource solutions using effective transformation strategies through a systems-based watershed approach. The DE DMU recommended plan enhances resiliency and sustainability of the natural coastal environment by retaining sediment in the system and improving CSRM and habitat protection along the Delaware shoreline.

Reducing Disaster Risk will be achieved through the reduction in coastal storm risk offered by the protective dune and berm.

Preparing for Tomorrow contributions are through maintaining a commitment to the project through periodic renourishment and life cycle adaptive management while mitigating for increases in water levels and storm frequency.

4 AFFECTED ENVIRONMENT*

The study area is located within the Delaware Estuary 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 Killcohook 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.

4.2 PHYSICAL ENVIRONMENT

4.2.1 Land Use

The Delaware River, which is fed by 216 tributaries, is the longest un-dammed river east of the Mississippi River. Approximately 15 million people, or about 5% of the U.S. population, rely on the waters of the Delaware River Basin for drinking and industrial use, and the Delaware River is only a one to two hour drive away for about 20% of the people living in the United States (Kaufman, 2011). 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 port for national defense and economic interests. The Delaware Estuary has 64 municipalities bordering it. 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, extensive tidal marshes that sustain vibrant ecosystems and shoreline habitats for horseshoe crabs and migratory shorebirds, and both fresh water and salt water habitats for shellfish (Kreeger *et al.* 2010). The beaches and marshes of the Delaware Bay provide many natural areas for recreational opportunities such as birding, fishing, kayaking, beachcombing and crabbing.

The riverine portion of the study area (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 Estuary 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 formations of the Piedmont Plateau consist primarily of Cambrian to Ordovician age, hard, crystalline rocks. 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 formations 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 concerns raised during the MCD Feasibility study regarding sediment chemical quality and the potential adverse effects on aquatic resources, 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 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 *et al.*, 1994; DNREC, 2005; 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 samples 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 Gahagan & Bryant Associates, Inc. (GBA) dated October 2010. This GBA geotechnical report is included as Appendix C4 of this feasibility report. These investigations between Philadelphia and the sea were conducted between the early 1960s and 2010 for local project feasibility studies and the MCD. 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.

Specifically, the Philadelphia District has placed sand dredged from Lower Reach E (the Brandywine and Miah Maull ranges of the Main Channel in DRBC Zone 6) in Buoy 10 approximately ten times between 1991 and 2012. In 2014, 11 sediment grab samples were collected in and around the Buoy 10 open water disposal site by the Philadelphia District. All samples were analyzed for grain size and ranged from 96.1% to 99.8% sand. The remaining component was shell fragments. Vibracores were collected from Buoy 10 in 2007 (Schnabel Engineering, 2007) for the Philadelphia District and again in 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. Materials with large grain sizes (>90% sand) are typically not contaminated and chemical testing is not required. 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 climate within the study area is considered subtropical which generally produces mild summer and winter seasons with only a few short hot, humid periods in summer, and cold, windy periods in winter.

The summer weather is dominated by maritime tropical air masses which remain stable for several days at a time, creating high pressure systems. Spring and fall are milder and are dominated by quickly changing air masses. The mean annual temperature is in the range of 55 to 57 degrees Fahrenheit. The annual precipitation for the area is about 45 inches, with the average monthly rainfall amounting to three or more inches. Temporary droughts are not uncommon. Continental, polar air masses in the winter produce rapidly moving fronts and intense weather patterns. The area is susceptible to strong beach eroding storms as a result of these weather patterns. Nor'easters are the more frequent storm type, originating in a low pressure area as an offshore air mass that rotates counterclockwise with winds blowing northeast-to-southwest over the region. Hurricanes average about once every 5.5 years.

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).

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).

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 27).

Table 27 – 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		
	Intra-monthly Variability	Models' mean reproduces correctly, but there is a large spread among the individual models		
	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		
	Intra-monthly Variability	Mean reasonably captures, but too low in the summer		
Extreme Precipitation	Short Term Drought	Slight low bias	Substantial increases, but less than ¼ of models show declines	Medium
	Heavy Precipitation	Slight low bias		
Growing Season Length		Predicts accurately	Substantial increase by end of century	High
Number of Frost Days		Somewhat high	Substantial decline	High

The Delaware Estuary 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, 1997), similar to expectations for the Chesapeake Bay (Zhong *et al*, 2008).

Some regional variation in sea level results from gravitational forces, local land subsidence, wind, and water circulation patterns. Sea level is expected to increase 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 subsiding 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.

It is anticipated that the global mean sea level will continue to rise over the next 100 years. To include the direct and indirect physical effects of projected future SLC on design, construction, operation and maintenance of coastal projects, USACE follows guidance provided in the form of Engineering Regulation (ER) 1100-2-8161 (developed with assistance of coastal scientists from the NOAA National Ocean Service and the U.S. Geological Survey), and Engineering Technical Letter (ETL) 1100-2-1 Procedures to Evaluate Sea Level Change: Impacts, Responses and Adaptation. Three estimates are required by the guidance; a Baseline (or "Low") estimate, which is based on historic sea level rise and represents the minimum expected SLC, an intermediate estimate, and a high estimate representing the maximum expected SLC.

4.3 WATER RESOURCES

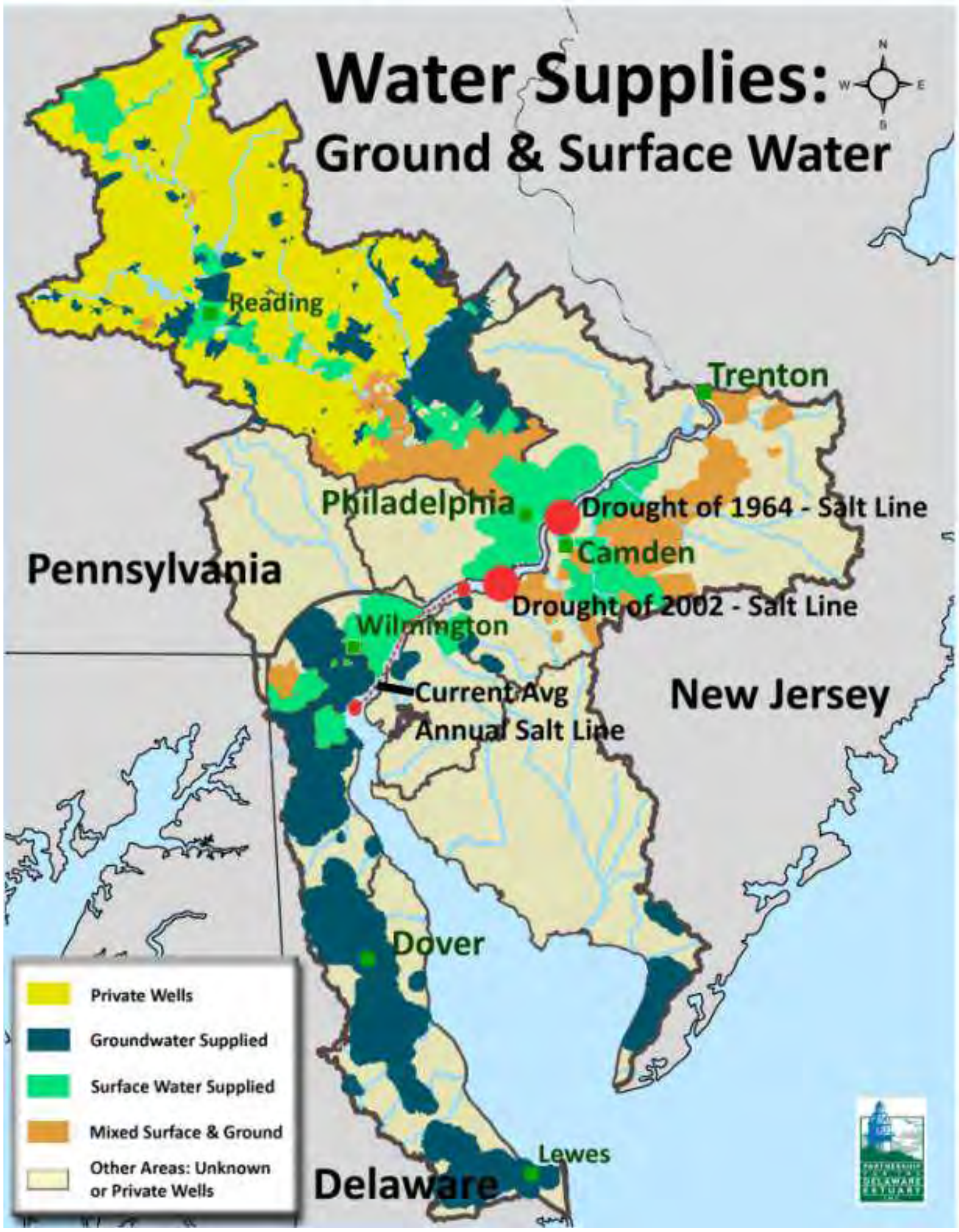
4.3.1 Groundwater Quality and Public Water Sources

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 8 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 13 shows a map of the watershed and service areas of community water supplies.

Figure 13 - 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

Nutrient monitoring is conducted by NJDEP within the Delaware Estuary. NJDEP (1999) has compiled over a decade worth of physical and nutrient monitoring in New Jersey State waters, including the lower Delaware Estuary. The report findings are that physical parameters of temperature, salinity and Secchi depth are typical of what would be expected in the freshwater riverine portion of the upper study area, the turbidity maximum zone of the middle section of the study area (upper Delaware Bay) and in the lower bay where oceanic influences dominate many physical parameters. Spring temperatures typically vary from 10 – 20° C, while summer temperatures range from 20 - 25° C. Temperatures during the fall tend to be near 15° C. Many Delaware Estuary stations did not show a seasonal component to Secchi depth, but seasonal and often daily fluctuations for oxygen and nutrient levels. There were several stations spread throughout the estuary that occasionally failed to achieve the NOAA minimum dissolved oxygen standard (minimum 5.0 mg/L), particularly during the summer. Nutrient levels in the Delaware Estuary exhibit seasonal patterns and spatial distribution where both ammonia and phosphorus were higher in the summer and total nitrogen and nitrate were elevated in the fall. Nutrient levels were highest close to the shoreline, and are likely attributed to anthropogenic activities (NJDEP, 1999).

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 proposed project area includes the lower portion of the Delaware Estuary. Surface 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. 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 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 DRBC Water Quality Regulations (18 CFR 410).

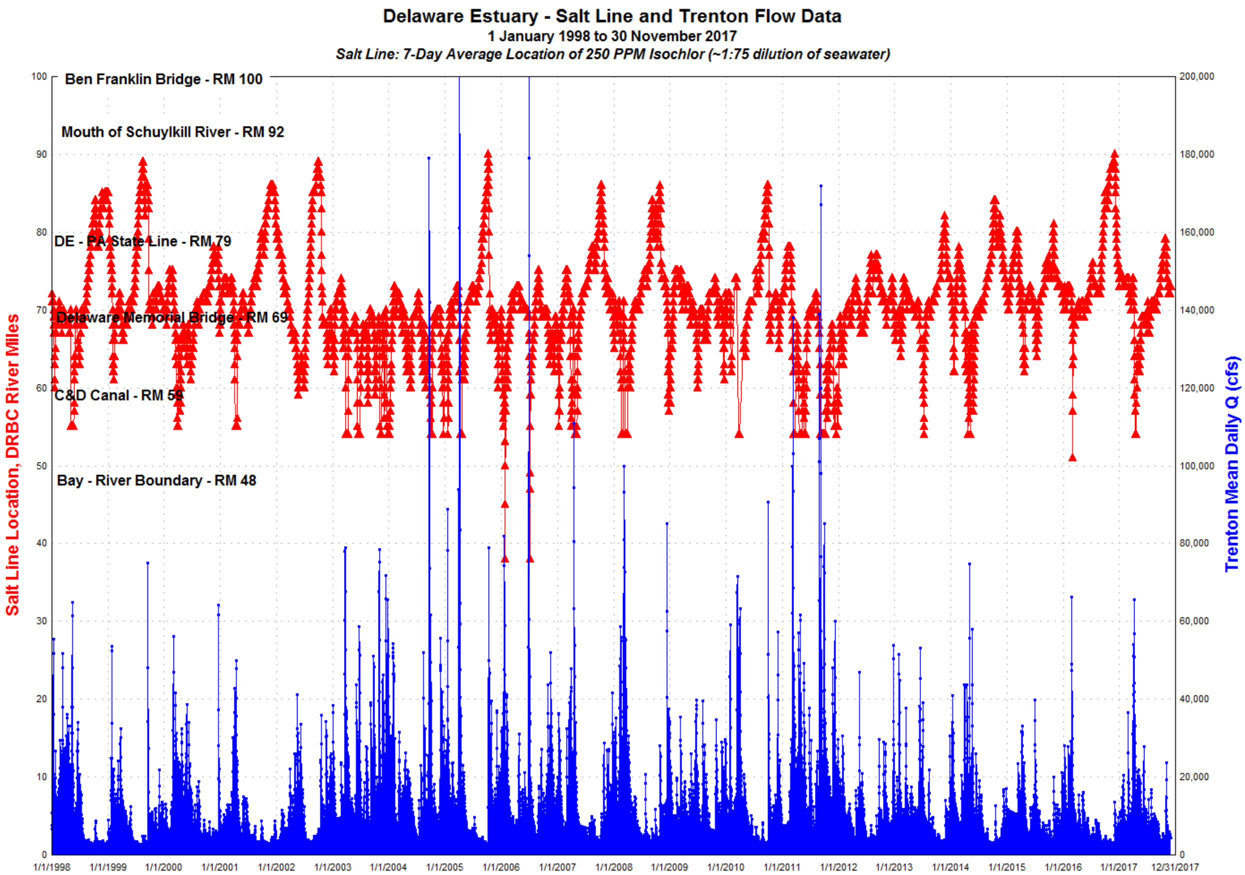
The composite aquatic life assessment for 2012 yields a result of "Not Supporting" for aquatic life (DRBC, 2012). It is important to note, however, that this result is largely driven by DRBC's requirement to categorize as not meeting criteria with 1 exceedance plus 1 confirmatory exceedance and based 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).

<u>Salinity</u>. 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 14).

Figure 14 - 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, 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*) are also present.

As previously mentioned in Section 4.3.2, 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 down bay. 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 (https://www.aswm.org). 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 study 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 1,331 acres (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 (*Callinectes sapidus*) commonly occur in Delaware Bay, but have been reported to occur above Wilmington but are more common in the higher salinity waters of the bay (Helser and Kahn, 2001). The blue crab inhabits nearshore coastal and estuarine habitats. Generally the crabs reside in shallow lower salinity waters in spring and summer and higher salinity deeper waters in winter.

One 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

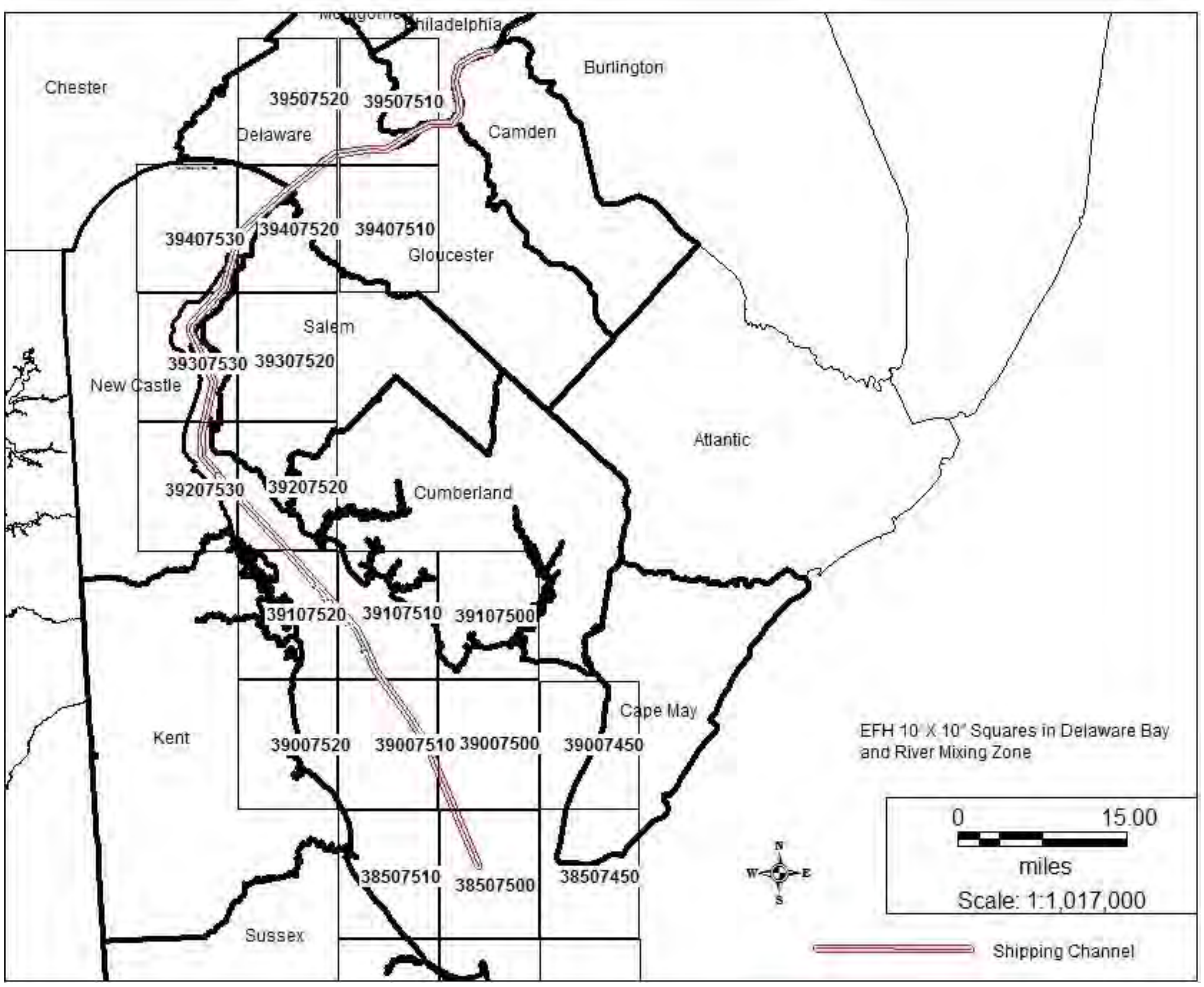
The Delaware Estuary also supports over 200 fish species, both residents and migrants: freshwater species, freshwater species that occasionally enter brackish water; estuarine species that remain in the estuary their entire life cycle, anadromous and catadromous species passing through different salinity 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 (MSA), 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 (FMPs) and their important prey species. EFH regulation 50 CFR 600.905 mandates the preparation of EFH assessments. The map depicted in Figure 15 shows the locations of the 10 minute x 10 minute squares within the Delaware Estuary identified by the National Marine Fisheries Service (NMFS) as EFH.

Figure 15 - Delaware Estuary Mixing Zone Essential Fish Habitat



The study area contains EFH for various life stages for 18 managed fish species (NMFS letter dated 16 October 2017). Table 28 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 28 – Summary of Essential Fish Habitat Designated Species & Their Life Stages

Managed Species	Eggs	Larvae	Juveniles	Adults	Spawning Adults
Red Hake (Urophycis chuss)				X	
Winter Flounder (Pleuroncectes americanus)	X	X	X	X	X
Windowpane flounder (Scopthalmus aquosus)	X	X	X	X	X
Atlantic sea herring *(Clupea harengus)*			X	X	
Bluefish (Pomatomus saltatrix)			X	X	
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	
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		X	

Managed Species	Eggs	Larvae	Juveniles	Adults	Spawning Adults
		neonates*			
Dusky shark (Carcharhinus obscurus)		X neonates*			
Sandbar shark (Carcharhinus plumbeus)		X neonates* (HAPC)	X (HAPC)	X (HAPC)	

Notes:

1.) Neonates* indicates sharks and skates 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).

Birds. 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.

Neotropical songbirds also migrate in and out of the study area in the spring and fall. Species observed in 1990 included the red-bellied woodpecker (*Centurus carolinus*), blue jay (*Cyanocitta cristata*), tree swallow (*Iridoprocne bicolor*), versper sparrow (*Pooecetes gramineus*), American robin (*Turdus migratorius*) and eastern bluebird (*Sialia sialis*). Other species known to inhabit the area are the savannah sparrow (*Passerculus sandwichensis*), song sparrow (*Melospiza melodia*), mourning dove (*Zenaida macroura*), gray catbird (*Dumetella carolinensis*), northern mockingbird (*Minus polyglottos*), redwinged blackbird (*Agelaius phoenicues*) and brown thrasher (*Toxostoma rufum*). Many of these birds remain to breed in the vast woodlands along the coast. The geographical location and the healthy, expansive upland edge of the wetlands of the lower estuary provide critical resting and feeding opportunities to neotropical migrants.

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 shrubland and 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 USACE Philadelphia District coordinates with the USFWS and the NMFS regarding Federally-listed threatened and endangered species in the study area. Extensive bayshore shorelines, adjacent marshes and woodlands, and shallow and deep water habitats are prevalent within the study area, and provide habitat for several endangered and threatened animal species.

The Delaware Estuary is within the historic range of 22 Federally-listed threatened or endangered species: 17 animals and 5 plants (Table 29).

Table 29 – 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	Squirrel, Delmarva Peninsula fox Entire, except Sussex Co (*Sciurus niger cinereus*)
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. 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).

Red Knot. 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).

Sea turtles. 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 proposed project area.

Whales. 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 (BGEPA) and both birds are protected under the Migratory Bird Treaty Act (MBTA).

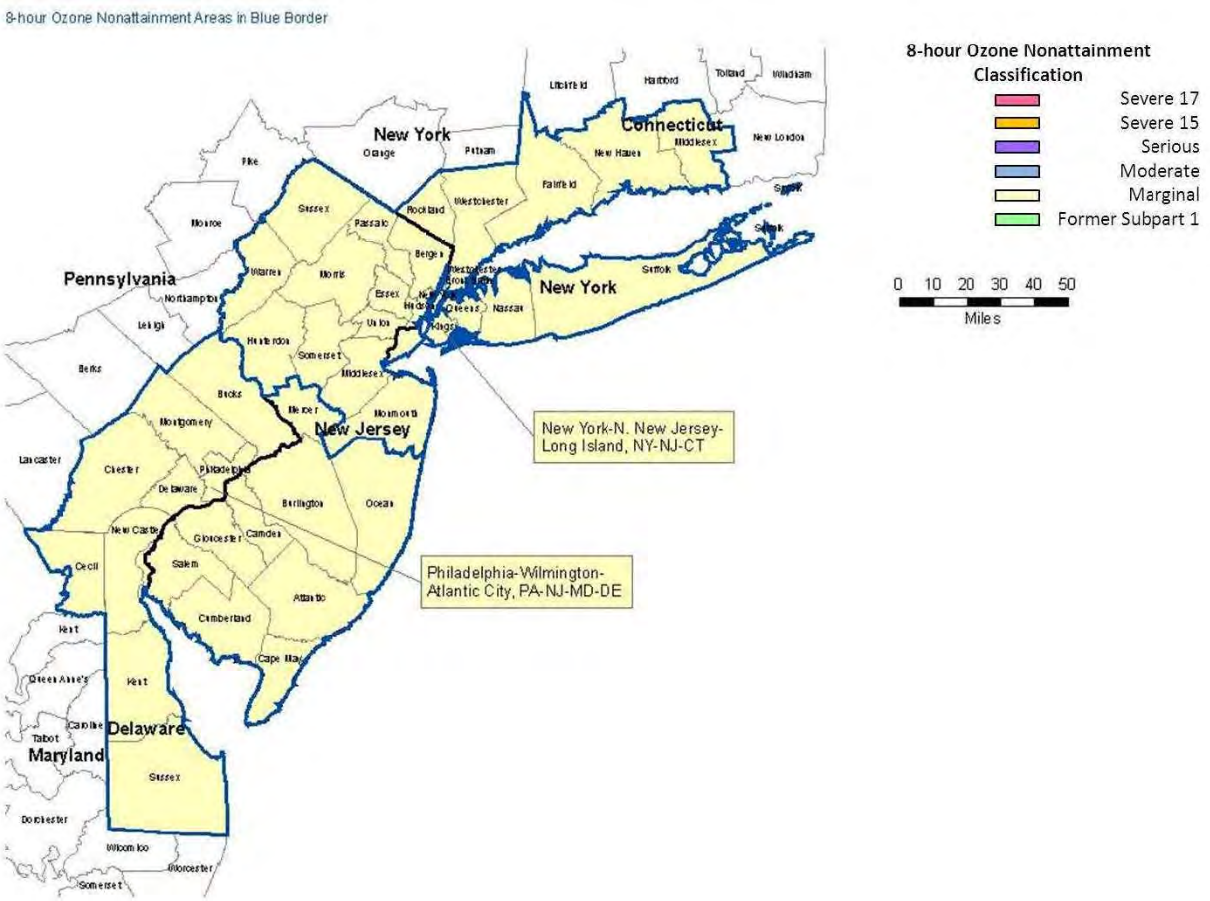
For a list of the State of Delaware threatened and endangered species, see www.dnrec.delaware.gov/fw/NHESP/information/Pages/Endangered.aspx.

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 16. Ground-level ozone is created when nitrogen oxides (NOx) and volatile organic compounds (VOCs) react in the presence of sunlight. NOx is primarily emitted by motor vehicles, power plants, and other sources of combustion. VOCs 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 16. The entire state of Delaware is in non-attainment and is classified as being "Marginal."

Figure 16 - Non-Attainment Areas for Ozone



Greenhouse gases (GHG) trap heat in the atmosphere. Carbon dioxide is the most abundant GHG and enters the atmosphere through burning fossil fuels (coal, natural gas and oil), solid waste, trees and wood products, and also as a result of certain chemical reactions (e.g. manufacture of cement). Carbon dioxide is removed from the atmosphere (or "sequestered") when it is absorbed by plants as part of the biological carbon cycle. Methane is emitted during the production and transport of coal, natural gas and oil. Methane emissions also result from livestock and other agricultural practices and by the decay of organic waste in municipal solid waste landfills. Nitrous oxide is emitted during agricultural and industrial activities, as well as during combustion of fossil fuels and solid waste. Hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and nitrogen trifluoride are synthetic, powerful greenhouse gases that are emitted from a variety of industrial processes. Fluorinated gases are sometimes used as substitutes for stratospheric ozone-depleting substance (e.g., chlorofluorocarbons, hydrochlorofluorocarbons, and halons) (USEPA, 2016).

The largest source of GHG emissions from human activities in the United States is from burning fossil fuels for electricity, heat and transportation. The USEPA tracks total U.S. emissions and reports the total national GHG emissions and removals associated with human activities.

4.6 NOISE

Noise is of environmental concern because it can cause annoyance and adverse health effects to humans and animals. 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.

In-water noises occur in the Delaware River and Bay. The predominant noises are anthropomorphic and occur primarily in the upper regions of the estuary (where the river is more heavily industrialized) and in the shipping channel and lower bay anchorage. The Delaware Estuary is home to the fifth largest port complex in the United States in terms of total waterborne commerce. A study conducted by BOEM at a site offshore of Delaware Bay (Martin *et al*., 2014) noted that ambient noise due to shipping is prevalent and relatively consistent, in the frequency range of 20-500 Hz. However, the study also showed that an increased energy in a particular frequency band was attributed to striped cusk-eel sounds; therefore, the primary cause of seasonal variation in sound levels at their study site was biological activity. The sounds produced by marine animals are many and varied. Marine mammals produce sounds over a wide frequency range, from less than 10 Hz to over 100,000 Hz, depending on the species. Many fishes, such as the oyster toadfish and some marine invertebrates, such as snapping shrimp, also produce sounds.

4.7 VISUAL AND AESTHETIC VALUES

Aesthetics refer to the sensory quality of the resources (sight, sound, smell, taste and touch) and especially with respect to judgment about their pleasurable qualities (Canter, 1993; Smardon *et al.*, 1986). The aesthetic quality of the study area is influenced by the natural and developed environment. Aesthetic values are high in the study area due to the predominance of expansive salt marshes, open water, beaches and the presence of Delaware Bay maritime communities consisting of fishing boats, docks and related facilities. The presence of dilapidated structures damaged from erosion, flooding and damaged revetments along the shoreline may detract from the high aesthetic value of the area. Eroded, scarped sandy beaches with exposed underlying peat also detracts from the natural aesthetic quality of the shoreline.

4.8 HAZARDOUS, TOXIC AND RADIOACTIVE WASTE

The USACE contracted with Environmental Data Resource, Inc. (EDR) to produce environmental database, mapping and aerial photograph searches for the original 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 was 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 locations and EDR will provide updates electronically should any new environmental records become available.

4.9 CULTURAL RESOURCES

As a Federal agency, the USACE has certain responsibilities for the identification, protection and preservation of cultural resources that may be located within the Area of Potential Effect (APE) associated with this project. Present statutes and regulations governing the identification, protection and preservation of these resources include the National Historic Preservation Act of 1966 (NHPA), as amended; the National Environmental Policy Act of 1969; Executive Order 11593; the regulations implementing Section 106 of the NHPA (36 CFR Part 800, Protection of Historic Properties, August 2004); Executive Order 13007, Executive Order 13175, the Presidential Memo of 1994 on Government to Government Relations and appropriate Delaware Statutes, and the USACE identification and Administration of Cultural Resources (33 CFR 305). Significant cultural resources include any material remains of human activity eligible for inclusion on the National Register of Historic Places (NRHP). This work is done in coordination with the Delaware State Historic Preservation Office (DESHPO), Tribal Nations and other consulting parties. The Proposed Action is in compliance with the goals of the NHPA.

Cultural resources investigations, effects determinations and SHPO consultation were completed for the MCD, which will be the source of the dredged material for the recommended plan. The Section 106 process is complete for the MCD and can be found in the 1992 EIS (USACE, 1992), the 1997 SEIS (USACE, 1997), the 2009 EA (USACE, 2009), the 2011 EA (USACE, 2011) and the 2013 EA (USACE, 2013).

A Phase IA Cultural Resources Investigation was conducted within a one-mile radius around each of the proposed dredged material placement sites in the recommended plan. The site file review identified a limited number of archaeological sites and historic architectural properties at Pickering Beach, Kitts Hummock, Bowers Beach, South Bowers Beach, Slaughter Beach and Prime Hook Beach. The one-mile study area around Lewes Beach contained two NRHP-listed Historic Districts, one State Scenic and Historic Byway and seven NRHP-listed buildings. The Lewes Beach study area also contains one NRHP-listed Archaeological District and 15 previously recorded archaeological sites; however, none of these sites are within the proposed project's APE.

The APE is considered to be located along the alignment of the proposed beach restoration templates described in Section 3.6. The APE for archaeology, historic structures and historic landscapes has been defined as those areas along the proposed beach restoration template that would likely be directly impacted by project construction. The APE for historic structures and historic landscapes includes also those locations that would be anticipated to have impacts visually from the completed project. At this time, there are no staging areas, access roads or other ancillary features defined for the study, but these areas will be considered within the APE once they are defined.

Pickering Beach

Known Historic Properties:

Below-Ground

Pickering Beach is considered to possess low sensitivity for the presence of previously unrecorded prehistoric and historic period archaeological resources. This assessment is based on four factors; (1) the low number of archaeological sites identified proximal to the APE; (2) the low value of key environmental factors on a beach setting; (3) the location of the APE at the eastern margin of an eroding Pleistocene headland (Kraft and John 1976:49) and, (4) the landward migration of the shoreline has exposed potential archaeological materials to increased storm surge and wave energy.

Above-Ground

Pickering Beach is situated within one mile of the Byfield Historic District, an area of English colonial settlement. The table below presents relevant information on the historic district and its relation to the Pickering Beach APE. There are no individual historic architectural structures within the study area that are listed on the NRHP. The Byfield Historic District, at its closest to the Pickering Beach APE, lies 8 feet above the elevation of the dune top, and has a calculated visual angle to the proposed Project dune top of approximately 0.101 degrees.

Table 30 - Significant Historic Architecture Properties within 1-mile of Pickering Beach

Name	NRHP Status/ #	Built	Years of Significance	Elevation Difference from top of Dune (ft)	Distance to Dune (ft)	Visual Angle from Resource to dune top (degs)
Byfield Historic District	Listed/ 79003232	-	1650-1750	8	4,545	0.101

Kitts Hummock

Known Historic Properties:

Below-Ground

Kitts Hummock is considered to possess low sensitivity for the presence of previously unrecorded prehistoric and historic archaeological period resources. This assessment is based on four factors; (1) the low number of archaeological sites identified proximal to the APE; (2) the low value of key environmental resources available at the beach; (3) the location of the APE at the eastern margin of an eroding Pleistocene headland (Kraft and John 1976:49) and, (4) the landward migration of the shoreline that has exposed potential archaeological materials to increased storm surge and wave energy. A localized area of land accretion is present at the northern end of the APE, and implies a short-term overburden of storm and wave-derived sediments. Kraft and John (1976:49-50) provided evidence that prior to development as a barrier island, the APE had been, in part, a salt marsh. Although Native American exploitation of salt marshes for fish, water fowl, and other natural resources was common, most archaeological expressions of prehistoric usage in such settings are likely to be isolated and ephemeral.

Above-Ground

The Kitts Hummock APE lies within one mile of the Byfield Historic District and the Lower St. Jones Neck Historic District. These NRHP-listed historic districts represent Colonial-era settlements. There are no historic architectural structures listed on the NRHP that are located within one mile of the APE. Visual angles of the project from the two historic resources are 0.134 and 0.126 degrees, respectively which indicates that there will be no views of the Project from recorded aboveground cultural resources in the APE.

Table 31 - Significant Historic Architecture Properties within 1-Mile of Kitts Hummock

Name	NRHP Status/ #	Built	Years of Significance	Elevation Difference from top of Dune (ft)	Distance to Dune (ft)	Visual Angle from Resource to dune top (degs)
Byfield Historic District	Listed/ 79003232	-	17th-18th century	7	2,995	0.134
Lower St. Jones Nec Historic District	Listed/ 79003233	-	1650–1760	7	3,177	0.126

Bowers Beach

<u>Known Historic Properties:</u>

Below-Ground

Bowers Beach is considered to possess low sensitivity for the presence of previously unrecorded prehistoric and historic period archaeological resources. This assessment is based on four factors; (1) the low number of archaeological sites identified proximal to the APE; (2) the low value of environmental resources present along the beach; (3) the location of the APE at the eastern margin of Murderkill Neck, an eroding Pleistocene headland (Kraft and John 1976:52) and, (4) the ebb and flow of accretion and erosion of the shoreline. The recent accretion of shoreline observed from cartographic analysis is a consequence of the Murderkill River jetty that maintains the navigational channel into Delaware Bay.

Above-Ground

Two historic architectural properties are present within the Bowers Beach study area; the Saxton United Methodist Church, built in 1879, and the Lower St. Jones Neck Historic District, which represents early Colonial settlement of eastern Kent County, Delaware. Both resources are NRHP-listed. The low-lying elevations of the church and historic district relative to the proposed dune top means that the proposed Project would not be visible from the historic properties.

Table 32 - Significant Historic Architecture Properties within 1-Mile of Bowers Beach

Name	NRHP Status/ #	Built	Years of Significance	Elevation Difference from top of Dune (ft)	Distance to Dune (ft)	Visual Angle from Resource to dune to (degs)
Saxton United Methodist Church	Listed/ 90001070	1879	1875–1899	0	2,168	0
Lower St. Jones Neck Historic District	Listed/ 79003233	-	1650–1760	0	2,880	0

South Bowers Beach

Known Historic Properties:

Below-Ground

South Bowers Beach is considered to possess low sensitivity for the presence of previously unrecorded prehistoric and historic period archaeological resources. This assessment is based on four factors; (1) the low number of archaeological sites identified proximal to the APE; (2) the low value of environmental resources available at the beachfront; (3) the location of the APE on an in-filled tidal marsh (Kraft and John 1976:52) and, (4) the landward migration of the shoreline that has exposed potential archaeological materials to increased storm surge and wave energy. The tidal marsh that preceded the creation of the barrier island is unlikely to contain archaeological resources aside from isolated finds.

There have been no previous terrestrial archaeological surveys undertaken within the study area. Marine survey suggests the presence of shipwrecks in the near-offshore precinct of the study area (Watts 1985).

Table 33 - Previous Archaeological Surveys within 1-Mile of South Bowers Beach

Survey	Type	Results
Watts 1985	Marine	potential shipwrecks

Above-Ground

The Saxton United Methodist Church is the only historic architectural property located within the South Bowers Beach study area. The calculated visual angle from the church to the proposed dune top is 0.119 degrees, indicating that the Project will essentially not be visible from the church.

Table 34 - Significant Historic Architecture Properties within 1-Mile of South Bowers Beach

Name	NRHP Status/ #	Built	Years of Significance	Elevation Difference from top of Dune	Distance to Dune (ft)	Visual Angle from Resource to dune top (degs)
Saxton United Methodist Church	Listed/ 90001070	1879	1875–1899	4	1,930	0.119

Slaughter Beach

Known Historic Properties:

Below-Ground

Slaughter Beach is considered to possess low sensitivity for the presence of previously unrecorded prehistoric and historic period archaeological resources. This assessment is based on four factors; (1) the low number of archaeological sites identified proximal to the APE; (2) the low value of environmental resources available on barrier beaches; (3) the location of the APE on an in- filled Holocene tidal marsh and lagoon; and, (4) bayward accretion across most of the APE, attributed to placement of timber groins and the installation of the Mispillion River inlet jetty (French 1990:92–97). Kraft and John (1976:60–62) examined a sediment core drilled at Slaughter Beach that indicated deep (52 feet) Holocene deposits of salt marsh and lagoonal muds beneath recent beach sediments. A marsh/lagoon setting is considered to be very unlikely to contain archaeological remains other than isolated finds.

Above-Ground

The file review identified one NRHP-listed historic architectural resource within the study area, the Mispillion Lighthouse and Beacon Tower. The lighthouse was built in 1873 and deactivated in 1929, when the steel Beacon Tower replaced it. The lighthouse was demolished in 2002. The Beacon Tower, unique among navigational lights in Delaware, was itself deactivated in 1984, and remains listed on the NRHP (NPS 2017). The ground surface at the tower base is at near-sea level elevation, forming a visual angle with the proposed dune top of 0.069 degrees. There would be no view of the proposed project from the ground level of the Beacon Tower.

Table 35 - Significant Historic Architecture Properties within 1-Mile of Slaughter Beach

Name	NRHP Status/ #	Built	Years of Significance	Elevation Difference from top of Dune (ft)	Distance to Dune (ft)	Visual Angle fror Resource to dune top (degs)
Mispillion Lighthouse and Beacon Tower	Listed/ 86002919	1873 (lighthouse 1929 (tower)	1873-1984	5	4,136	0.069

Prime Hook Beach

Known Historic Properties:

Below-Ground

Prime Hook Beach is considered to possess low sensitivity for the presence of previously unrecorded prehistoric and historic period archaeological resources. This assessment is based on four factors; (1) the low number of archaeological sites identified proximal to the APE; (2) the low value of environmental resources available to prehistoric period hunters-gatherers at the APE; (3) the position of the APE at the easternmost margin of the eroding Prime Hook Neck, a Pleistocene headland; and, (4) the APE exhibits both bayward accretion and landward erosion, producing a shoreline containing highly intermixed sediments. Kraft and John (1976:60–65) examined a sediment core drilled on the beach that revealed deep sands deposited during a Pleistocene marine highstand, topped by recent Holocene sands and salt marsh deposits. Extensive marsh backs the Prime Hook barrier island landward to Pleistocene uplands.

Above-Ground

The review of site files revealed no significant historic architectural properties within the Prime Hook Beach study area. There will be no known visual effects due to the proposed project to NRHP-eligible or –listed cultural resources.

Lewes Beach

Known Historic Properties:

Below-Ground

Lewes Beach is located on the bayshore near the mouth of Delaware Bay, in the town of Lewes, Delaware. Lewes Beach is the one Project area that is not a barrier island. It is attached to the mainland approximately 1.7 miles west of Cape Henlopen. The sandy beach at Lewes is the product of longshore transport of coastal sediments around Cape Henlopen and of dune and spit sediments from Cape Henlopen. As Cape Henlopen has eroded landward and grown bayward in the past 300 years, the quantity of sediment reaching Lewes has decreased (French 1990:15; Kraft and John 1976:71).

The review of archaeological site files revealed the presence of seven prehistoric archaeological sites within the study area, five historic period sites, two sites with prehistoric and historic components, one site of unknown attribution, and the Cape Henlopen Archaeological District. The NRHP-listed Cape Henlopen Archaeological District comprises 795 acres of dunes and wetlands, and contains seven prehistoric archaeological sites that are NRHP-listed as contributing properties. These sites consist of shell middens and date to the Woodland I and Woodland II periods. The Lewes Sand Flats Site and the Lewes Dump Site are contributing sites to the district, but are not within the Project APE. The Beebe Site is an NRHP-eligible site containing Delmarva Adena and Woodland II occupations. The NRHP-listed DeVries Palisade Site represents the earliest known European settlement of Delaware Bay in 1631, by Dutch whalers. At the mouth of Roosevelt Inlet lies an eighteenth century shipwreck that was discovered during dredging operations in 2004. The wreck was subsequently archaeologically investigated and is NRHP-listed. No sites were identified within the APE.

Table 36 - Previously Recorded Archaeological Sites Located within 1-Mile of Lewes Beach

Site Number	Site Name	Type	NRHP Status/ #
7S-D-004	Miller-Toms	Prehistoric	Unknown
7S-D-005	Lewes School	Prehistoric	Unknown
7S-D-008	Lewes Sand Flats	Prehistoric	Unknown
7S-D-008A,B	Lewes Sand Flats	Prehistoric	Listed/ 78000920
7S-D-011	DeVries Palisade	Historic, circa 1631	Listed/ 72000299
7S-D-012	Railway	Prehistoric and Historic	Unknown
7S-D-016	Old House	Historic	Unknown
7S-D-026	Fort	Historic	Unknown
7S-D-027	Lewes Dump	Prehistoric	Listed/ 78000920
7S-D-045	Marsh Grass	Prehistoric and Historic	Eligible
7S-D-068	Green Hill Light	Unknown	Unknown
7S-D-073	Beebe	Prehistoric	Eligible
7S-D-084	Beach Plum Island Wreck	Historic	Unknown
7S-D-091	Roosevelt Inlet Shipwreck	Historic	Listed/ 06001056
7S-D-096	-	Prehistoric	Unknown
S00770	Cape Henlopen Archaeological District	Prehistoric	Listed/ 78000920

Lewes Beach is considered to possess low sensitivity for the presence of previously unrecorded prehistoric and historic period archaeological resources. This assessment is based on three factors; (1) the absence of previously recorded archaeological sites located within the APE; (2) the low value of environmental resources available on a beach; and (3) the extensive impacts upon the shoreline by human inputs to create and maintain a harbor and inlet at Lewes. These human inputs include, the breakwaters for the Harbor of Refuge and the Breakwater Harbor, a jetty at the eastern margin of the APE that extends into the Breakwater Harbor, excavation of the Roosevelt Inlet at the western margin of the APE and jetties to stabilize the inlet, and placement of over one-half million cubic yards of sand as beach replenishment between 1954 and 1963. The sand beach at Lewes (coincident with the APE) was the product of sediment drift around Cape Henlopen during the period circa AD 1600 to 1800. As Cape Henlopen has extended northward and bayward during the past 300 years, this flow of sediment has decreased. The breakwaters and jetties have further disrupted the circulation of sediments at the bay mouth, causing accretion of approximately 500 feet to occur at the eastern end of the APE, and an equivalent amount of erosion at the APE's western end.

Above-Ground

The site file review identified nine historic architectural properties listed on the NRHP, and a scenic and historic byway. The properties include two historic districts: (1) the National Harbor of Refuge and Delaware Breakwater Harbor Historic District, and (2) Lewes Historic District. The former is situated almost entirely within Delaware Bay and encompasses two nineteenth century breakwaters constructed of quarried granite blocks, two lighthouses, navigational lights, and the former Coast Guard station built in 1938, the only element of the historic district located on land (DelSordo 1988). The Lewes Historic District comprises the core of the Colonial and nineteenth century city of Lewes, Delaware, and includes the Coleman House, Lewes Presbyterian Church and cemetery, Colonel David Hall House, William Russell House, and an unnamed residence as contributing resources. The Lewes Scenic and Historic Byway is a network of roads that traverses Lewes and includes New Road, Pilottown Road, Cape Henlopen Drive, Savannah Road, King's Highway, and Gills Neck Road, portions of which, each, are within the Lewes Beach study area. The Project registers exceedingly low visual angles to the various resources, and is considered to be outside the visual range from each of the resources. The exception to this is the Lewes Scenic and Historic Byway, which at its closest approach to the Project (559 feet), registers a visual angle to the dune top slightly greater than 1 degree. This is equivalent to viewing the Washington Monument, without obstructions, from a distance of six miles.

Table 37 - Significant Historic Architecture Resources within 1-Mile of Lewes Beach

Name	NRHP Status/ #	Built	Years of Significance	Elevation Difference from top of Dune (ft)	Distance to Dune (ft)	Visual Angle from Resource to dune top (degs)
National Harbor of Refuge and Delaware Breakwater Harbor Historic District	Listed/ 89000289	1828–1901	1825–1949	15	0-17,000	-
Lewes Historic District	Listed/ 77000393	-	1750–1874	5	3,020	0.095
Coleman House	Listed/ 77000392	1810	1800–1824	0	4,618	0
Lewes Presbyterian Church and Cemetery	Listed/ 77000394	1832	1825–1899	0	3,880	0
dwelling	Listed/ NA CRS# S1239	1880	1875–1899	1	3,286	0.017
Col. David Hall House	Listed/ 76000395	1790	1750–1799	0	3,282	0
William Russell House	Listed/ 77000395	1803	1800–1824	2	2,424	0.047
Thomas Maull House	Listed/ 70000175	1740	1700–1749	6	2,105	0.163
Fisher’s Paradise	Listed/ 72000298	1740	1700–1749 1800–1824	6	1,726	0.199
Lewes Scenic and Historic Byway	DelDOT Byway Program	-	-	11	559	1.127

This DMU study was coordinated with the DESHPO and with the Federally recognized Tribes in a letter dated March 16, 2016. Enclosed with the letter were the proposed project location maps and a draft PA for their review and comment.

The following Tribal Nations were provided the initial information: The Delaware Nation, the Delaware Tribe of Oklahoma, the Eastern Shawnee Tribe of Oklahoma, the Oneida Indian Nation, the Seneca Nation of Indians, the Stockbridge-Munsee Band of Mohican Indians and the St. Regis Mohawk Tribe. The Stockbridge-

Munsee responded that the Project impacts are not in their area of concern. No other Tribes responded to the initial letter. The DESHPO did not formally comment on the PA via letter, but agreed to continued coordination and negotiation of the draft PA as the project progresses in a voice communication with the USACE Philadelphia District Cultural Resource Specialist and Tribal Liaison on June 10, 2016. After submitting the optimized plans and continued coordination with the DESHPO, the DESHPO agreed to continued consultation as the project progresses. No Federally recognized Tribes responded with the need for continued consultation.

4.10 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.

The Delaware Estuary provides numerous economic benefits to the region. The Delaware River Port Complex (including docking facilities in Pennsylvania, New Jersey and Delaware) is the largest freshwater port in the world. According to testimony submitted to the U.S. House of Representatives subcommittee in 2005, the port complex generates $19 billion in annual economic activity. It is one of only 14 strategic ports in the nation transporting military supplies and equipment by vessel to support our troops overseas. The Delaware Estuary is home to third largest petrochemical port as well as five of the largest east coast refineries. Nearly 42 million gallons of crude oil are moved on the Delaware River on a daily basis. There are approximately 3,000 deep draft vessel arrivals each year and it is the largest receiving port in the United States for very large crude carriers (tank ships greater than 125,000 deadweight tons). It is the largest North American port for steel, paper and meat imports as well as the largest number of cocoa beans and fruit on the east coast. Over 65% of Chilean and other South American fruits imported into the United States arrive at terminal facilities in the tri-state port complex. Wilmington, Delaware is home to the largest U.S. banana importing port, handling over one million tons of this cargo annually from Central America. According to the Real Admiral Sally Brice-O'Hara, District Commander of the Fifth Coast Guard District, "The port is critical not only to the region, but also to the nation" (Kaufman, 2011).

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 38 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 38 – 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.

Environmental Justice. In accordance with Executive Order 12989 dated February 11, 1994 (Environmental Justice in Minority Populations), a review was conducted of the populations within the affected areas. The USEPA definition for Environmental Justice is: "the fair treatment and meaningful involvement of all people regardless of race, color, national origin or income with respect to the development, implementation and enforcement of environmental laws, regulations and policies." 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. As in Sussex County, the majority of the homes fronting the Delaware Bay in Kent County are also occupied seasonally. 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.

None of the alternatives will have a disproportionately high adverse effect on minority or low income populations as the beach communities addressed in the study are not known to have predominantly minority or disadvantaged populations.

5 EFFECTS ON SIGNIFICANT RESOURCES*

This section evaluates impacts that may occur as a result of the CSRM alternative plans, including the recommended plan. Impacts resulting from the O&M dredging activities (that will serve as the CSRM dredged material source) are fully evaluated in several NEPA documents developed specifically for the Delaware River Main Stem Navigation Channel (see Section 1.5), and in the interest of brevity, are incorporated by reference instead of being repeated in this report. It should be noted that the maintenance dredging schedule for the Delaware River Main Channel Lower Reach E is predicated on storm events and shoaling rates and cannot be determined at this time. Therefore, potential impacts to resources are conservatively presented in the following subsections inclusive of a construction period that may occur during any month of the year. In addition to the No Action Plan, alternatives considered during the alternative analysis included the Levee/Dike Plan; the Beach Restoration Plan; the Beach Restoration with Groin(s) Plan; the Beach Restoration with Breakwater Plan and the Beach Restoration with Groin(s), Breakwater, Living Shoreline and Wetland Plan.

Given the presence of tidal marshes with sandy beach barriers at each of the southern reach CSRM problem areas, the USACE focused the alternative impacts analysis on the Beach Restoration Plan and the No Action Plan.

Analysis indicated that the additional features, such as wetlands or living shorelines, would provide minimal additional CSRM compared to the added cost. Regarding living shorelines, data from the NACCS indicated that they are generally applicable to relatively low current and wave energy environments. 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; thereby, minimizing the potential effectiveness of living shorelines. This limited effectiveness coupled with a $1,415 cost per linear feet of living shoreline construction (as estimated in the NACCS) also limits the efficiency of the living shoreline feature.

Per the NACCS, wetlands can slow the advance of storm surge somewhat and slightly reduce the surge landward. In addition, wetlands can dissipate wave energy; however, evidence suggests that slow-moving storms and those with long periods of high winds that produce marsh flooding reduce this benefit (Resio and Westerink, 2008). This limited effectiveness coupled with a $2,593 cost per linear feet of wetland construction (as estimated in the NACCS) also limits the efficiency of the wetland feature.

Relatively high beach erosion rates and losses are typically required to support the addition of groins and breakwaters to beach restoration projects. However, stand-alone beach restoration yielded higher AANB because of the added initial construction cost associated with groins and breakwaters.

Levees and dikes are embankments of sediments to raise elevation in a linear fashion paralleling a water body and reduce flooding for the lands behind the structure. The Levee/Dike Plan was evaluated New Castle; however, this alternative was eliminated based on the grain size incompatibility of the source material and the cost of augmenting the material to meet USACE levee construction criteria.

5.1 PHYSICAL ENVIRONMENT

5.1.1 Land Use

The communities along the Delaware Estuary shoreline have a long history of economic activity provided by the waterway. The Delaware River continues to serve as a principal corridor for commerce as well as a major strategic port for national defense. The economies of the towns have changed over the years from ship building and oyster harvesting to primarily fishing, crabbing and tourism. The Delaware Estuary shoreline communities have changed from rural farmsteads to seasonal vacation destinations and year-round residential communities in the larger towns. 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. Continued erosion of the narrow sandy beaches along the bay coastline will leave adjacent salt marshes, farmland and residential communities (*e.g.* homes and roadways) vulnerable to frequent inundation, flooding and loss of vegetation.

The action alternative entailing beach restoration would provide beneficial effects by establishing an added buffer beach to provide protection to upland infrastructure and populations against storms and flooding. Sand nourishment also creates additional habitat for beach flora and fauna, added inundation protection to interior wetlands and more opportunities for recreational activities. The recommended plan entails beach restoration at Pickering Beach, Kitts Hummock, Bowers Beach, South Bowers Beach, Slaughter Beach, Prime Hook Beach and Lewes Beach. The recommended plan to provide CSRM with beach restoration will help the shoreline communities be resilient against future storms and help provide economic sustainability, recreational use and natural habitat restoration.

Generally, the proposed project would likely produce more favorable economic conditions than exist at present, although construction operations will produce some minor adverse effects on land use. These effects would primarily be temporary in nature, and land uses would continue as they had been under pre-construction conditions after placement operations and construction.

5.1.2 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 MCD 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 recommended plan). The 1998 Inland Testing Manual (EPA-823-B-98-004) provides national guidance on the evaluation of dredged material under the Clean Water Act. It states that no chemical analysis is required if there is a "*reasonable assurance that the proposed discharge material is not a carrier of contaminants…For example, dredged material is most likely to be free of contaminants if the material is composed primarily of sand, gravel or other inert material and is found in areas of high current of wave energy [230.60(a)].*" For the MCD project, the sediments tested within these 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). 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.

As indicated on Figure 17, Reach E was divided into 9 subsections. For sub-Reach E-7 through E-9 (the Miah Maull and Brandywine Ranges), 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) (USACE, 2013).

For the No Action Plan, future maintenance dredging sand from Lower Reach E will be placed at Buoy 10 open water disposal site for approximately 10 more years. 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. Continued erosion of the beach and dune system will result in exposure of the underlying peat and clay layers.

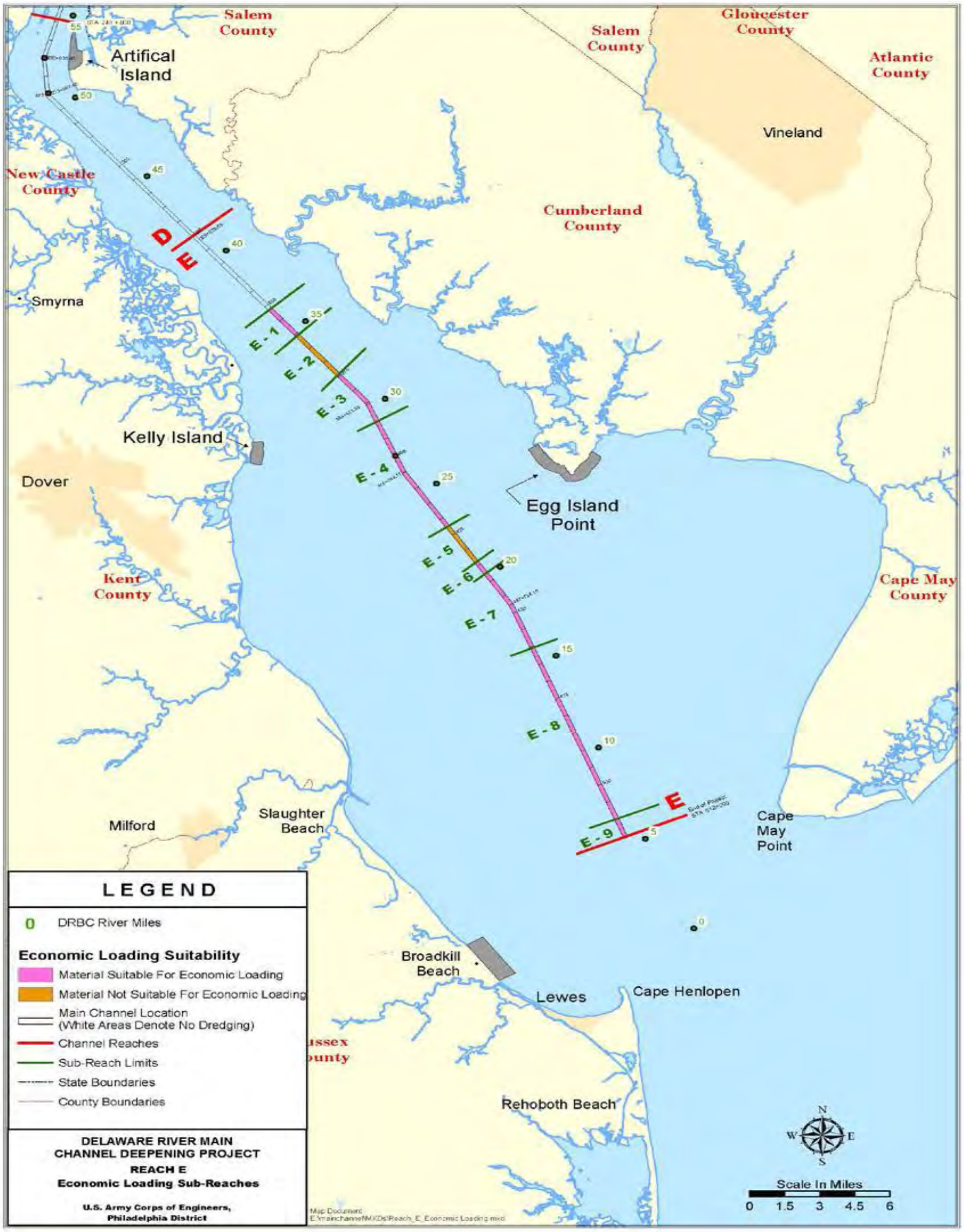
Sediments are a critical component of the estuarine system as they constitute the substrate for most hydraulic, geochemical and biogenic processes that affect the overall "health" of the estuary. The estuary acts as a sink for sediments eroded from the watershed above the head of tide. The seaward portion 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).

Beach nourishment is not expected to impact sediment quality. As discussed in Section 3.5, grain size of the projected source material is anticipated to be similar to that which occurs on the proposed placement beaches and materials with large grains sizes (>90% sand) do not require chemical analysis for contamination.

Under the recommended plan, the use of sand dredged from lower Reach E for beach nourishment will provide a tangible economic benefit (*i.e.* CSRM benefit) to the study area shoreline while restoring the sediments typical of a healthy sandy beach shoreline.

Figure 17 - Reach E Sub-Reaches



5.1.3 Physiography and Geology

Erosion and flooding are the primary coastal hazards that adversely impact the estuarine shoreline. Under the No Action Plan, tidal action and 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 barrier beach can also result in flood inundation to interior salt marshes, forests and neighboring farmland.

Alternative plans that include a hardened structure (such as a groin) perpendicular to the beach will not impact the area geology, but may alter the physiography of the beach. Groins deflect alongshore currents resulting in greater accumulation of transported sediments on the updrift side. Groins impede longshore sand transport, which may provide a benefit to navigation when positioned adjacent to inlets and may also provide additional CSRM for structures located on the updrift side of the groin. Erosion and extreme weather events will continue to be the primary drivers of flooding events.

The recommended plan involves the restoration of the berm and dune system at Pickering Beach, Kitts Hummock, Bowers Beach, South Bowers Beach, Slaughter Beach, Prime Hook Beach and Lewes Beach. Beach nourishment restores that natural physiography and habitat that existed along the shoreline fronting these communities. In addition, beach nourishment using compatible grain size materials does not adversely impact the geology of the study area.

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 39long-term tide gauge data recorded during the past century shows an average global sea level rise of approximately 1-2 mm/yr. Within the study region, the National Ocean Service (NOS) tide gage at Lewes, DE has measured an average rate of sea level rise of 3.4 mm/yr over a 97-year period of record. At the west end of the Cape May Canal, the NOS tide gage has measured 4.6 mm/yr of SLC over a 51-year period of record.

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 SLC increases (Rosen, 1978; Stevenson and Kearney, 1996). SLC 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 SLC. While SLC 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 SLC. Both the recommended plan and the other action alternatives involving beach restoration are expected to reduce the adverse impacts of SLC on communities and beach habitat quality.

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 SLC since they are able to migrate landward as the shoreline retreats and wetlands accrete sediment and build in elevation. However, the combination of SLC 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 CDFs. 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 as there is significant uncertainty in the rate and timing of climate change as well as the effects it may have on these species. SLC 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. Interior maritime forest habitat for passerine birds and wading birds is also at risk due to seawater inundation once barrier beaches are eroded. 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. Sea turtle nesting north of Virginia is relatively rare and is not expected to 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 developed areas 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 notable.

A study by Galbraith *et al.* (2005) illustrates the potential effect of SLC on prime migratory shorebird habitat. The study used the SLAMM version 4 to investigate the effect of SLC 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 SLC 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 recommended plan to conduct beach nourishment operations best mimics the natural shoreline habitat while affording additional defense against SLC. The beach restoration alternative lowers the risk of flooding to the developed bayshore communities by providing an elevated beach berm and vegetated dune buffer while reducing the rate of sediment loss in highly erosional areas.

5.2 WATER RESOURCES

Under the No Action Plan, inundation of flood waters along with storm waves on the Delaware bayshore causes erosion during storms, thereby raising turbidity, reducing water quality and clarity, which is further exacerbated by additional losses of vegetated land cover. Turbidity is the measure of the cloudiness of the water caused by suspended matter such as clay, silt and organic matter, thereby blocking the passage of light within the water columns. Continued erosion of the sandy beach eventually results in exposing the underlying peat and clay layers which are repeatedly inundated with each flood event, causing continued degradation of water quality and reducing beach, intertidal and shallow water habitats.

Beach nourishment on sandy beaches typically results in a temporary nearshore impact (i.e. swash zone) to water quality as placement operations elevate turbidity. While larger sand particles settle out more quickly, finer sediments will remain suspended for longer periods, or even indefinitely in coastal turbulent waters (Adriaanse and Coosen, 1991). Suspended particles can interfere with the biological function of some organisms, such as feeding, respiration, reproduction and predator avoidance. High turbidity and silt loads in the water can have detrimental impacts on filter feeding organisms associated with nearshore areas such as polychaetes, amphipods, isopods, decapods and mollusks. The longer duration of diminished light penetration can detrimentally affect the photosynthetic activity of phytoplankton, the primary producers of energy production.

A robust dune and beach sand berm reduces turbidity as a result of the higher proportion of larger grain sizes of sand particles to fine silts and clays and settles more quickly from turbulence during storm events. A healthy beach and dune system is the first line of defense for bayfront infrastructure, including homes, roads and utilities. They are also the first line of defense to reduce inundation to adjacent marshes. 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.

Physical and biological impairments to water quality can result from the placement operations due to increases in turbidity in the effluent run-off. Increased turbidity results from the resuspension of sediments during operations and is temporary, but as noted, 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 at the placement sites can be minimized through the creation of a temporary sand dike surrounding the outfall pipe during pumping operations. 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. The larger grain sizes of the proposed material source reduce the amount of time the material stays in suspension.

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 construction site 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 (Figure 18) 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. Impacts resulting from dredging operations are thoroughly presented in the NEPA documentation for the MCD navigation project (USACE, 1992, 1997, 2009).

Figure 18 - Hopper Dredge

Hopper dredges are self-propelled ships equipped with propulsion machinery, hoppers for dredged material storage and dredge pumps (Figure 18). Dredged material is hydraulically raised through trailing dragarms which "vacuum" water and sediment in contact with the channel bottom and discharge it 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.

As was previously mentioned in Section 5.1.3, 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. The environmental effects of economic loading (*i.e.* turbidity) and the economic benefits are presented in the 2013 EA (USACE, 2013) for the deepening project of the Delaware Main Navigation Channel.

A Section 401 Water Quality Certificate under the Clean Water Act of 1977 (PL 95-217), as amended, and a concurrence of USACE's consistency determination under the Coastal Zone Management act are required from the state of Delaware. 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. In the southern reach of the study area, 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 Plan is expected to exacerbate the loss of coastal vegetation and cause excessive inundation of neighboring wetlands with erosion of the barrier beachfront. The beach nourishment alternatives will enhance protection of adjacent wetlands and enable dune vegetation to establish with the resultant higher berm and dune elevations. The proposed project may result in minimal short-term impacts to the vegetation that covers the existing dunes in areas where the fill will join the existing dune. The proposed nourishment project will temporarily stabilize the beach and dune vegetative communities and prevent further erosion-related losses. The beach fill will furnish additional material to existing dune vegetation so the plants can collect and bind wind-blown and storm-driven sand into dune formations. The preferred plan entails planting American beach grass on the dune.

5.3.2 Planktonic and Benthic Organisms

With the No Action Plan, low quality intertidal habitat would continue to exist at the beach placement sites due to severe erosion and exposed peat. With the proposed plan, infaunal organisms within the dredged material intertidal placement zone will be impacted by burial during the construction period (although some species are capable of migrating up through the sand), as they will be smothered but the community will re-establish through recruitment from neighboring unaffected areas. By pumping dredged material onto the beach above the MHWL and constructing a temporary sand berm seaward of the placement pipe outfall, water quality impacts to intertidal infauna can be minimized by reducing run-off and turbidity back into the bay. Phytoplankton and zooplankton within this reach may incur some turbidity-induced mortality during the construction period. Despite the resiliency of intertidal benthic fauna that are adapted to high energy turbulent environments within the swash zone, the initial effect of beachfill will result in some mortalities of infaunal species.

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). The ability of a nourished area to recover depends on grain size compatibility of the material pumped onto 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. As noted in Section 5.2, the temporary berm established above the MHWL during construction serves to reduce elevated turbidity within the intertidal dredged material placement zone.

Recolonization depends on the availability of planktonic 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. 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; Maurer *et al.,* 1986; Saloman *et al*., 1982; Van Dolah *et al*., 1984) through larval transport and settlement and based on seasonality and species' life history characteristics (Shull, 1997; Thrush *et al*., 1996; Zajac and Whitlatch, 1991). T

Larval recruitment and 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. Oysters are not present within the proposed construction areas. Notable species that may be present include:

Sabellaria vulgaris is a sandbuilder worm that has evolved to establish small aggregations under the dynamic conditions of the subtidal zone near the low tide line on sandy beaches in lower Delaware Bay. These beaches have continued to erode under severe and frequent storm conditions, rendering many areas unsuitable for the sandbuilder worms. Reef distribution patterns can vary widely depending on changing physical factors such as storm activity and shifting substrates. Sabellaria is an opportunistic species exhibiting rapid colonization in clumps and can be short-lived, subject to destruction by severe storm events. Recolonization is depending on larval supply in the water column and suitable substrate.

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 placement sites.

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. Beach restoration projects that reduce risk to developed areas provide habitat for horseshoe crab spawning. The NMFS recommends that placement operations avoid the 15 April through 30 September period when horseshoe crabs begin migrating to the shallow water to spawn (NMFS, 2018).

In the lower Delaware Bay, migratory shorebird staging habitat was severely impacted by Hurricane Sandy in 2012 and to a lesser extent by subsequent nor'easter storms. Beach erosion has been a primary concern due to the loss of the horseshoe crab spawning habitat along the thin veneers of coarse sandy bay beaches. Horseshoe crabs are dependent upon access to beaches for spawning, with preferred grain size sediment ranges and beach slope, both of which can be significantly impacted by flooding and erosion.

In addition to CSRM, beach nourishment of fronting bayshore communities will provide improved habitat for horseshoe crab spawning along the beach face for important migratory shorebird stopover sites. Restoring eroded beaches where horseshoe crabs spawn are 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 a suitable grain size (>0.3 mm) and slope (1H:10V), and is deep enough (>7 feet) promote horseshoe crab spawning habitat.

5.3.3 Fish

Under the No Action Plan adult fish occurring in the nearshore zone of the bay are not likely to be adversely impacted as fish occurring in this area are habituated to high energy wave environments and elevated turbidity from waves. If erosion of the barrier beach continues, larval and juvenile fish stages are likely to be adversely impacted if adjacent salt marshes incur lower habitat quantity and quality through the potential loss of wetland vegetation from frequent flooding. Juvenile life stages rely on salt marshes as nursery areas. A robust berm and dune system is the first line of defense for salt marshes. Healthy productive wetlands also provide increased diversity of prey species for fish relative to barren mudflats. With the proposed placement project, larval and juvenile fish may be temporarily adversely impacted by elevated turbidity levels within the nearshore zone at the project site, but fish are motile and will likely leave the area temporarily. 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 within the lower Delaware Bay has been designated as "Habitat Areas of Particular Concern" by the NMFS for the sandbar shark (*Carcharhinus plumbeus*). 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 nearshore area. Indirect and temporary 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 15 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 could be more able to avoid the sand placement operations and likely to move into deeper waters. Since this environmental window, in combination with the Corps' objective to avoid sensitive periods for other coastal species (*e.g.* horseshoe crab, blue crab) may result in an insufficient amount of remaining time necessary for the dredging and placement operations, the USACE will continue to coordinate the bay channel maintenance dredging schedule with DNREC and NMFS to determine how best to minimize or avoid potential adverse impacts to HAPC.

As mentioned previously, for the beach restoration alternatives, including the recommended plan, a sand dike that is 200 to 300 feet in length is typically constructed with existing beach material above the MHWL 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 the MHWL for that section of beach under construction. The slurry is also controlled by the dike along the shoreline. 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. The dredge pipe will be placed on pontoons for a minimum of 1,000 feet, extending offshore to avoid disrupting young sandbar sharks mobility close to the shoreline during the 1 May through 15 September period.

The beach placement sites within the shallow intertidal areas will 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 the placement 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 temporarily disrupts food resources in the impact areas (Hackney *et al*., 1996). Rapid recolonization by macroinvertebrates typical of highly dynamic environments will occur in the short-term within the proposed sand placement sites. Depending on the time of year, benthos food resources can recolonize 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 construction is completed before seasonal increases in larval abundance and adult activity in the spring and early summer (Herbich, 2000).

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 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 Plan and the beach restoration alternative have been described in the previous sections in reference to water quality and benthic invertebrate prey species for both the intertidal and shallow water placement zones. Impacts from placement operations can impact EFH in several ways: smothering 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 construction 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 minute x 10 minute squares, which encompass the project area was completed and coordinated with the NMFS (M. Magliocca, pers. comm.) and subsequently by Karen Greene in letters dated 16 October 2017 and 20 February 2018. The following is an evaluation of the potential effects associated with this project on EFH species:

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

Atlantic sea herring: No adverse effect is anticipated as adults and juveniles occur in pelagic waters and are not likely to be in the 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. 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 and not within the intertidal zone.

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. A temporary disruption to benthic food prey organisms may occur in the shallows of the proposed placement areas. No direct physical adverse impact is anticipated for juveniles or adults as these stages are expected to move out of the immediate impact area during the temporary construction period, particularly if placement activities occur predominantly off-season.

Impacts may occur to larvae though they are not likely to leave the project area during the construction period. Juveniles and adults are highly mobilie. Temporary disruption of benthic food prey organisms may occur within the placement area.

Cobia: No adverse effect is anticipated for all life stages as they are all pelagic and construction activities will take place on the nearshore 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. Adults are highly migratory and mostly congregate offshore. No adverse impacts are anticipated for juveniles or adults as these stages are unlikely to be in the shallow waters of the nearshore zone but if present, are expected to move out of the immediate impact area during the temporary construction period. Some adverse impact to neonate stages may occur if placement operations in the nearshore and intertidal zone occur during the spring and summer pupping season due to elevated water turbidity and burial of forage prey species.

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. 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. In spring and summer, red hake move into waters less than 100 meters. They are most abundant between Georges Bank and northern New Jersey. Eggs are pelagic. During winter they tend to move into deeper waters offshore. Red hake are not frequently found in Delaware Bay's inshore waters.

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. The sandbar shark is identified by NMFS as a Species of Concern. Minimal 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. Some adverse impact to neonate stages may occur if placement operations in the nearshore and intertidal zone occur during the spring and summer pupping season due to elevated water turbidity and burial of forage prey species. The dredge pipe may be floated on pontoons to avoid disrupting movements of young sharks if dredging occurs during the spring and summer. Sand will be pumped onto the beach above the MHWL 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. The sand tiger is identified by NMFS as a Species of Concern. 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. If placement activities occur during the spring and summer, the dredge pipe may be floated on pontoons to avoid disrupting movements of young sharks. Sand will be pumped onto the beach above the MHWL 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 placement area during temporary construction. Any increase in turbidity at the placement site will be minimal with pumping above the MHWL. Prey species composition may be temporarily impacted due to 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 construction. Impacts within the placement area are minimized due to pumping of material onto the beach above the MHWL 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. Prey species composition may be temporarily impacted during placement operations. 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 MHWL 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. A temporary disruption to benthic food prey organisms may occur in the shallow water of the proposed placement areas.

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 not anticipated to occur in the project area. 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. Sand tiger and dusky sharks have been listed as Species of Concern by NOAA. Species of Concern are those about which NOAA has concerns regarding status and threats, but for which insufficient information is available to indicate a need to list the species under the Endangered Species Act (ESA). NOAA's goal is to improve proactive conservation efforts for these species in order to preclude the need to list them under the ESA in the future. Additionally, the study area has also been designed as a Habitat Area of Particular Concern (HAPC) for sandbar shark. HAPCs are discrete subsets of EFH that provide important ecological functions and are vulnerable to degradation. The NMFS recommends dredging and beach nourishment activities be avoided from 1 May to 15 September when sandbar sharks use the area as a pupping and nursery ground. Potential impacts are minimized if dredging can be conducted during the cooler, nonbreeding months of the year (*i.e*. fall and winter). As noted previously, the O&M dredging schedule for the Delaware River Main Channel Lower Reach E is predicated on storm events and shoaling rates and cannot be determined at this time. The USACE will continue to coordinate with NMFS with regard to determining the future dredging schedule in an effort to avoid impacted EFH/HAPC to the maximum extent practicable. To further reduce the potential for impacts to juvenile shark species, the dredge pipe may be floated to avoid disruption of movements if placement operations occur between 1 May and 15 September, following procedures recommended by the NMFS. Based on the findings of Field Evaluation of Hopper Dredge Overflow for the Delaware River (USACE, 2013) and sediment quality information provided (USEPA, 2002; and Hartwell and Hameedi, 2006), there is no evidence that temporary elevated turbidity created from sediments greater than 90 percent coarse grained material adversely effects water quality or aquatic life. Therefore, the proposed beach restoration plan is not expected to have significant adverse effects on the EFH and HAPC shark species for the affected life stages.

At the beach placement site, the slurry of dredged material and water pumped onto the beach typically result 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 MHWL 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. NMFS recommends avoiding construction from March through mid-May for diadromous fish species in areas adjacent to river or creek inlets.

The adverse impact on benthic organisms (including fish food prey items) in the placement areas is considered to be localized, temporary and reversible as benthic studies have demonstrated recolonization following placement operations within a few months to a few years. Authorized maintenance dredging within Reach E in the bay Main Channel will remove approximately 930,000 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 Plan, wildlife species would continue to incur further losses in habitat quality and quantity due to ongoing flooding and erosion. Several mammals, reptiles, amphibians, and birds utilize the beach and dune habitat of the proposed project areas. Erosion will continue and may result in beaches with undesirable exposed peat and clay or grain size less favorable to migratory shorebirds for feeding and resting (USFWS, 2016). Birds that use the beach for nesting and breeding are more likely to be adversely impacted under the No Action Plan as beach erosion continues. The No Action Plan poses no benefits to diamondback terrapins as beach habitat would erode, reducing available suitable nesting habitat. Additionally, the No Action Plan does not restore a protective barrier beach berm and dune system that provides CSRM to neighboring salt marshes, scrub shrub and interior forest habitats during severe coastal storm events.

Under the proposed plan, species are expected to leave the immediate impact area temporarily during construction. The intent of the recommended plan 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. Beach nourishment restores beach habitat that is critical to all coastal wildlife, including horseshoe crabs, migratory shorebirds, diamondback terrapins and beach foraging animals. Specifically, the beach restoration plan will provide added protection to interior shrub and forested habitats adjacent to the bayshore communities.

Birds. Widespread population declines of many 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. Robust healthy beaches provide CSRM and reduce the potential for saltwater intrusion and inundation of these critical coastal habitats. 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. Beach nesting species are more likely to be adversely impacted by beach nourishment activities than those species that use the area for feeding and resting during migration if construction occurs during the nesting season. 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 or temporary exclusion fencing helps to reduce the potential for adverse impact for any construction alternative involving beach access by construction personnel and equipment, which have the potential to crush eggs or hatchlings or induce adults to abandon nest sites. The USFWS (2016) has recommended avoiding sand placement operations for the 15 April through 31 August period for migratory shorebirds. Coarse sand or sand 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). Sand historically dredged from the lower reaches of the Delaware Bay has been determined to be compatible with existing beach sand.

The species listed in Table 1 of the CBFO PAR (located in Appendix E) 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. Some of these 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 ESA of 1973 (87 Stat. 884, as amended; 16 U.S.C. 1531 *et seq*.).

Migratory shorebirds are heavily dependent on successful horseshoe crab spawning to fuel the remaining leg of their migration to arctic breeding grounds. A habitat suitability mapping study (Lathrop *et al.*, 2013) showed that Hurricane 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. It is possible that beach restoration can enhance or inhibit horseshoe crab spawning by changing grain size. The recommended plan will provide sand grain size and slope that are within the preferred range for spawning horseshoe crabs. Adding sand to eroded beaches with compatible grain size renders bay beaches more favorable than existing conditions. Spawning horseshoe crabs will avoid beaches with exposed peat, which in turn, may reduce attraction of migratory shorebirds, including the red knot (an imperiled species that 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 and washover spits are preferred nesting habitat for the piping plover. Beach nourishment activities can provide positive benefits to listed species by restoring preferred beach habitat.

The recommended plan of beach restoration is not likely to have an impact on these species. Beach restoration may temporarily divert birds away during the construction period but offer longer term nesting opportunities for some shorebirds and colonial nesting waterbirds, particularly American oystercatcher (*Haematopus palliates*, state endangered) and black skimmer (*Rynchops niger*, State endangered). Red knots (*Calidris canutus rufa)*, Federally threatened and State endangered) will likely use these beaches in greater number for foraging (USFWS, 2016).

Reptiles. 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 brackish waters of coastal salt marshes, 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. The recommended plan would provide improved nesting habitat for terrapins with an enlarged beach. Beach restoration is not expected to result in adverse impact to diamondback terrapins if construction occurs outside of the nesting season. However, if construction occurs during nesting season, the presence of construction equipment and activities may displace nesting terrapins from nesting in the area. 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). However, nesting success can be inhibited in developed areas where predators such as dogs are more likely to occur (USFWS, 2016).

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 Plan will result in continued erosion of beaches and flood risk to bayfront communities. Eroded beaches, particularly those with exposed underlying peat and scarped dunes offer degraded habitat for wildlife.

The Federally-listed species under USFWS purview that may occur in the study area vicinity include the plant swamp pink (*Helonias bullata*) and the migratory shorebirds: the piping plover (*Charadrius melodus)* and the *rufa* subspecies of the red knot (*Calidris canutus*). None of the proposed alternative plans nor the recommended plan will effect swamp pink at the project area does not include suitable habitat (USFWS, 2017).

Piping plover. Prime Hook Beach and Lewes Beach are the only bay shorelines that have the potential to impact endangered piping plovers; however, the risk of the recommended plan or the beach restoration with hardened structure alternative impacting 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. The USFWS indicated in a letter dated 3 January 2017 that project as proposed is not likely to adversely affect the piping plover because nesting habitat for this species is located approximately 847 feet from the western end of the Lewes Beach site and although piping plovers have nested here in the past, there has not been an observed nest for more than 15 years. The next nearest piping plover nesting site is 1.76 miles northeast of the eastern end of the proposed Lewes Beach site.

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 historically known nesting locations, 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 would need to be closely coordinated with USFWS. 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 alternative plans from Pickering Beach south to Lewes Beach could impact threatened *rufa* subspecies of the red knot 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. In a letter date 3 January 2017, USFWS noted that the project as proposed would have no effect on red knot with adherence to a time-of-year restriction for project activities conducted on the beaches between 15 April and 7 June when red knots forage. The USFWS does not recommend the placement of hardened structures along the bay shoreline. 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.

Horseshoe crab spawning is directly intertwined with migratory shorebird reproductive success. The crabs spawn on bay beaches fronting residential development but will avoid spawning on beaches that have insufficient sand depth over peat (USFWS, 2016) and migratory shorebirds feast on horseshoe crab eggs to fuel their northern migration to the Arctic breeding grounds. The recommended plan restores migratory bird foraging habitat and 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).

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. Beach restoration involving the construction of a hardened structure can reduce available coastal foraging habitat within its footprint.

<u>Sea turtles</u>. 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 No Action plan is not expected to adversely affect sea turtles. 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. Sea turtles rarely frequent the intertidal and near shore shallow zone of the proposed construction area for the beach restoration alternatives. Sea turtle are capable of leaving the area during the temporary construction period.

Potential impacts near the construction area in the marine environment may result from elevated turbidity levels of the beach restoration alternatives that may impact foraging, migration or prey species, burial 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 proposed placement sites; 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.

As presented in Section 4.4.2, water quality impacts are anticipated to be minor and temporary at the 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 beach placement operations may affect turtle behavior or turtle prey behavior but turtles are highly mobile and are likely to avoid areas of increased suspended solids.

<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 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.

The No Action Plan will not impact Atlantic sturgeon, and the species is not likely to be adversely impacted by beach placement operations of the beach restoration alternatives. The majority of impact studies conducted on the species assess potential dredging impacts, such as possible entrainment of cutterhead suction dredges of ship strikes by large vessels.

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.

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.

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. The No Action Plan and the beach restoration alternatives, including the recommended plan, are not likely to adversely impact shortnose sturgeon.

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 all times while material is being placed on the beach. Assuming use of a Hopper dredge, visual inspections of the interior and exterior of the beach basket are performed after each in-flow cycle. The use of munitions screens further reduces the likelihood of entrainment of fish or sea turtles (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, 2017) for the DRMCD project that no Atlantic or shortnose sturgeon are likely to be injured or killed during hopper dredging operations in Reach E.

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 in the proposed placement areas. 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 preparation of the November 2017 B.O., NMFS was consulted under ESA for the DE DMU study and no issues were identified for the proposed beach placement operations. The 17 November 2017 B.O. from NMFS concludes that consultation. 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 endangered New York Bight, Chesapeake Bay, or South Atlantic 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) and terms and conditions to be taken, necessary to minimize and monitor take of shortnose and Atlantic sturgeon and sea turtles. The proposed action is likely to adversely affect, but not likely to adversely modify or destroy critical habitat designated for the New York Bight DPS of Atlantic sturgeon. USACE will abide by NMFS' RPMs and terms and conditions as specified through re-initiation of consultation.

5.4 HAZARDOUS, TOXIC AND RADIOACTIVE WASTE

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 either the No Action Plan or the proposed beachfill projects at the 7 dredged material placement locations.

5.5 AIR QUALITY

Air quality is generally good in the Delaware Bay region. No impacts to air quality would result from the No Action Plan. Emissions of criteria pollutants, greenhouse gases, and other hazardous air pollutants would result from the beach restoration alternatives, including the TSP, due to the 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.*"

The No Action Plan would pose no impact on GHG. Maintenance dredging will continue to occur with or without the current proposed plan. However, the future implications of climate change will likely pose significant adverse effects in the study area on both coastal storm risk to communities and loss of beach habitat under the No Action scenario. The structural alternatives and the recommended plan would similarly pose impacts on GHG in the study area by contributing construction equipment emissions. All of the remaining CSRM alternatives respond to severe storm actions that erode beaches along the Delaware Bay shoreline. The degree to which the recommended plan and beach nourishment with hardened structure alternatives impact GHGs is dependent on the duration of the construction period (i.e. the amount of construction equipment emissions). Beach nourishment alone would emit less emissions than the alternatives of beach nourishment involving construction of a hardened structure since the latter require additional equipment and duration of operations. Cumulative emissions are reduced because the current study intends to beneficially use sand that will be dredged during maintenance operations of the main navigation channel. Combining these projects reduces GHG emissions as the primary contributor: the dredge is mobilized once to accomplish two goals- maintenance dredging for navigation and coastal storm risk management on beaches. Additionally, the recommended plan entails dune grass planting which serves to reduce GHGs through carbon sequestering.

5.6 NOISE

No additional noise will result from the No Action Plan over existing and natural background noise levels. The recommended plan will generate additional noise at the dredged material placement sites as construction will consist of the sound of dredged material passing through pipes 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. Construction activities will be monitored to minimize noise impacts. The dredging contractor is responsible for complying with the provisions of the State of Delaware and all local ordinances.

Several researches have examined the effects of human-related noise and activities on wildlife. Burger (1981) examined the direct and indirect effects on birds at a coastal bay refuge along the Atlantic coast. In a refuge, people are present daily for various activities such as birdwatching, fishing or walking.

Burger noted that human activities involving rapid movements or close proximity to birds caused them to flush. Slow-moving or low consistent sounds, resulted in far less birds flushing. Fletcher and Busnel (1978) assembled a number of studies of noise impacts on a variety of species. For marine species, acoustical signaling is an important means of communication over long distances. Ship traffic is the predominant source of underwater noise, except under heavy sea conditions when natural noise predominates. As with human reactions, they found that abrupt loud noises (*i.e.* a sonic boom or siren) will cause wildlife alarm reactions more so than human-induced noises of a consistent pattern, such as repeating take-offs and landings at a busy airfield where wildlife (birds, rabbits, *etc.*) grow accustomed to the routine noises. Familiar anthropomorphic noises are also known to attract wildlife. In Norway and Sweden, steam-engines attracted elk to the railroad lines, while bison were attracted to railway engines in the U.S. This necessitated the fitting of cow-catchers on the train engines. At sea, some porpoise and dolphin species are attracted to moving ships. The researchers concluded that many animal species acclimate to continuous and intermittent sounds of 100 dB or less.

Popper and Hastings (2009) evaluated multiple studies conducted on the effects of pile driving noise on the health and well-being of fish. Unlike the low continual hum of dredging, underwater pile driving sounds are characterized by multiple rapid increases and decreases in sound pressure over a very short period of time. Fish mortality has been observed in areas of pile-driving, with a number of fish showing bleeding and damage to the swim bladder. In controlled studies of exposing caged fish to pile-driving noise (Abbott *et al.*, 2005; Ruggerone *et al.*, 2008; Nedwell *et al.*, 2006) results showed no difference in mortality or pathology or behavioral differences in fish. Other researches address noise impacts to marine mammals as well as fish and have documented that sounds can adversely impact behavior, hearing and physiology, depending on distance from the sound source (Popper, 2003; Popper *et al.*, 2004; Popper and Hastings, 2009; Houghton and Mundy, 1987; Goertner *et al.*, 1994; Govoni *et al.*, 2008).

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 sediment removal operation will occur 6-7 miles offshore in the bay's center. 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.

5.7 CULTURAL RESOURCES

As the feasibility analysis progressed, the USACE issued a Task Order for the completion of a Phase IA for 8 proposed project areas in Delaware. The report titled, *Phase IA Cultural Resources Investigations, Beneficial Use of Dredged Material for the Delaware River, Delaware Bay Coast, Delaware* was prepared by Tetra Tech (dated August 2017) and was provided to the DESHPO for review in a letter dated February 6, 2018 along with a set of the proposed feasibility-level plans.

No previously recorded cultural resources were within the project APE, and due to the highly dynamic system subject to SLC, land subsidence, wave effects, storm impacts and human impacts, the 7 proposed project areas have low potential for intact archaeological deposits potentially eligible for the NRHP.

In the northern planning reach, a historic hotel site exists at Woodland Beach; however, this would not be impacted by the No Action Plan. Also, the levee/dike plan will have no impact because this plan was not proposed at Woodland Beach. For the beach restoration plan, beach restoration with groin(s) plan, beach restoration with breakwater plan and beach restoration with groin(s), breakwater, living shoreline & wetland plan there will be no impact because these plans will not be implemented at Woodland Beach. Also, the historic hotel site could have been successfully avoided during construction with the use of buffer areas.

In the southern planning reach, no archaeological sites eligible for or listed on the NRHP would be affected by the No Action Plan. However, if no action is taken there is a potential for adverse effects to historic properties, such as historic structures and historic districts, due to SLC. Also, the levee/dike plan will have no impact because this plan was not proposed in the southern planning reach. The recommended plan (beach restoration) will have No Adverse Effect on archaeological sites eligible for or listed on the NRHP within the current APE. In addition, the recommended plan will have No Adverse Effect on historic structures eligible for or listed on the NRHP within the current APE; however, there may be some viewshed impacts to historic structures or historic districts eligible for or listed on the NRHP depending on the final design of each beach restoration location. The beach restoration with groin(s) plan, beach restoration with breakwater plan and the beach restoration with groin(s), breakwater, living shoreline & wetland plans there have no impact because these plans will not be implemented in the southern planning reach.

With the implementation of the recommended plan, dredged material will be placed along the existing shoreline in varying design of dune and berm beach restoration at each of the 7 proposed locations. The following items will need to be completed depending the project's final design and for construction access and staging:

- Preparatory avoidance measures for nearshore submerged resources to ensure their protection during construction
- Project design review and comment from DESHPO to minimize potential visual impacts
- If needed, develop additional investigation reports and/or monitoring plans (develop cooperatively with the DESHPO) as project design and construction specifications are further developed
- Construction activities will employ best management practices to avoid impacts to the maximum extent practicable
- An Unanticipated Discovery plan will be developed for implementation

The above items will form the stipulations of the continued consultation with DESHPO for completion of the Section 106 process.

5.8 SOCIOECONOMIC RESOURCES

Erosion and flooding are the primary coastal hazards that adversely impact the estuarine shoreline and lead to the loss of lives or damage to property and infrastructure in developed areas. One of the greatest threats from coastal storms is flooding caused by storm surge. Coastal flooding is the inundation of land along the estuarine or oceanic shoreline by seawaters above the normal tidal range, resulting in significant economic loss through the destruction of buildings, roads, infrastructure, natural resources and wildlife habitats.

For the No Action Plan, 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 Plan 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.

The recommended plan would provide more resilient beaches that 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 beach restoration include erosion control, water quality enhancement, storm protection, habitat provision for wildlife and recreation.

Environmental justice is the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. All interested parties and residents have equal access to the current report review and comment process. Appropriate measures will be taken to ensure consistency with local, regional, state, and Federal regulations. All of the alternative plans, including the recommended plan, would achieve the same degree of protection from environmental and health hazards for all races, ethnicities and income levels. Implementation of the recommended plan is not anticipated to result in any significant or negative human health or safety impacts. None of the alternatives will have a disproportionately high adverse effect on minority or low income populations as the beach communities addressed in the study are known to have predominantly minority or disadvantaged populations. The recommended plan is in compliance with EO 12898. The project would generally have beneficial social and economic effects and would generally affect all persons equally.

Protection of Children. Appropriate measures will be taken to ensure the protection of children by assessing the health and safety risks of the proposed project that could disproportionately affect children. Appropriate safety buffer zones will be established around construction activities with effective fencing and other barriers.

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.

This analysis considers the impacts associated with beach placement of high quality sand relative to the cumulative nature of these activities along Delaware's bayshore. Several construction actions have occurred previously in the project area and vicinity. The state of Delaware has been conducting beach nourishment activities along bayshore beaches by truck haul or hydraulic pipeline dredge since the early 1960s. By its nature, beach nourishment is a repetitive process by which placed sand along shorelines sacrificially protects structures, dissipating energy across the surf zone. Coastal storms erode constructed sand berms rather than inflict structural damage to the residential homes within these small bayshore communities. Delaware's DNREC developed a Management Plan for Delaware Bay Beaches (PBS&J, 2010) due to shoreline erosion processes occurring to varying levels. The primary shore protection recommendation in the PBS&J (2010) report is beach nourishment.

The impact of manmade structures, primarily for navigation purposes, has influenced the Delaware Bay coastline. Jetties have been erected at both the Murderkill and Mispillion Rivers. Jetties influence longshore transport of sediments to adjacent beaches in and around the inlets. Other structures, such as two nearshore parallel experimental breakwaters at Kitts Hummock have not had a noticeable effect on beach shape. Groins constructed perpendicular to the shoreline at a few of the bayshore communities have resulted in just a localized effect on the beach (PBS&J, 2010). Delaware Bay beaches are characterized as narrow ribbons of sand overlying a peat base and backed by extensive saltmarsh and inland wetland systems. The proposed beach communities are interspersed on a 30-mile narrow strand of beach between the Bay and the wetland and upland ecosystems landward of the beach.

The following provides a description of the aforementioned structures and historical beach nourishment actions that have been implemented in the project area vicinity by DNREC and the USACE in the past century, with beach nourishment occurring since the 1960s.

Pickering Beach. A floating tire breakwater (USACE) was placed as a demonstration project in 1978 but now resides on the bottom. Beach nourishment has been implemented by DNREC since 1962 for a total of approximately 200,000 cy by both hydraulic dredge and truck haul.

Kitts Hummock Beach. A terminal groin and drainage structure (DNREC) occur at the south end of the community that is retaining sand with an erosional offset of the shoreline on the south side of the structure. Beach nourishment events (DNREC) have occurred here since 1961 for an approximate total of 300,000 cy of material placed to date by hydraulic dredge and truck haul. Three breakwaters were constructed (USACE) in 1978, approximately 700 feet offshore. Currently, only two structures remain.

Bowers Beach. The community is bordered at both ends by two rivers: the St. Jones River inlet (unstructured) to the north and the Murderkill River inlet (structured) to the south. Jetties were constructed with grout-filled bags at the north and south ends in 1976 (DNREC). Improvements were implemented to the south jetty in 2009, and subsequently in 2015 the jetty was rehabilitated with quarry-stone to widen and raise the height. The first beach nourishment occurred in 1962. To date, approximately 400,000 cy of sand have been placed on the beach by hydraulic dredge and truck haul.

South Bowers. The community is bordered on the north end by the Murderkill River. A grout-filled sandbag jetty was constructed at this inlet and a groin at the southern end of the community in 1976. A portion of the inlet has been subject to sand transport over the jetty (which is partially buried), creating a sand shoal inside the inlet. DNREC has indicated that it plans to construct a larger rock jetty in the future, similar to the replacement rock jetty on the north side of the inlet. The state initiated beach nourishment in 1961 and 100,000 cy have been added to the beach fronting the homes.

Slaughter Beach. The community is bordered by the Mispillion River to the north. Timber frame and rock jetties 3,000 feet long were constructed at the inlet (USACE) beginning in 1908-1911 (south jetty) and 1912-1914 (north jetty), with extensions coming later in 1920 and 1939, respectively. Local interests had attempted to stabilize the inlet with timber pile and brush as early as 1859 but failed within 20 years. By 1963, significant deterioration of the north jetty had occurred, and the shoreward 700 feet of the jetty were basically non-existent. The timber cribbing placed between 1912 and 1914 had rotted and crumbled and the rubble fill had settled roughly 3 feet on average. The only part of the jetty in good condition was the 1939 construction. Extensive repairs were made in 1964, when the deteriorated timber cribbing section was replaced by a rubble mound jetty. The timber cribbing is currently in a dilapidated condition and very porous (Moffatt & Nichol, 2008).

DNREC began restoration efforts in 2016 and completed the work in early 2018. The work included restoration of the shoreline of Mispillion Harbor with over 2700 feet of stone, installation of several groins, and restoration of over 3,500 beach for spawning horseshoe crabs and migratory shorebirds. Delaware's Division of Fish & Wildlife are interested in pursuing further restoration efforts in the Mispillion Inlet area as additional funding becomes available. Beach nourishment events on Slaughter

Beach began in 1958 and to date, approximately 900,000 cy have been placed by hydraulic dredge and truck haul. Mispillion Inlet and the adjacent Cedar Creek were last federally dredged in 2009 for navigation and dredged sand was placed along the northern shore to reduce the potential for breaching.

Prime Hook Beach. DNREC initially placed approximately 20,000 cy of sand at Prime Hook Beach as an emergency fill in 1962. All subsequent beachfills of small quantities (truckloads) were carried out by private property owners between 1992-2016. Adjacent to the bayshore community of Prime Hook is the 10,144 acre Prime Hook National Wildlife Refuge (PHNWR), established in 1963 under the authority of the Migratory Bird Conservation Act. The PHNWR has national conservation significance as a designated RAMSAR Wetland of International Significance Site (1999), American Bird Conservancy: Important Bird Area (2000), and a Western Hemisphere Shorebird Reserve Network Site (1986). Several nor-easterly storms in the 1990s/early 2000s resulted in erosion and breaching along the PHNWR shoreline. The eroded shoreline condition was exacerbated by Hurricane Irene (2011) and Superstorm Sandy (2012). Refuge lands experienced rapid inundation, killing freshwater vegetation in the impoundments and enhanced elevation subsidence, biochemical changes and significant habitat loss. The USFWS sought to restore tidal marsh in 2015. The work consisted of beach nourishment (berm and dune creation) via hydraulic pipeline dredge of 6,375 linear feet of shoreline (1.1 million cy) and 400 linear feet of adjacent saltmarsh platform restoration. Interior to the shoreline, the restoration work entailed dredging approximately 113,739 linear feet of shallow channels to re-establish tidal circulation and to create side-casting mounds for wetland vegetation to establish.

Lewes Beach. The largest of the bayshore communities, both DNREC and USACE have conducted numerous beach nourishment events on various sections of Lewes Beach. DNREC alone has placed over 3 million cy since 1953, the majority of which was completed by hydraulic pipeline dredge. Beginning in 1975, the USACE conducted beachfill operations on 8,000 linear feet of Lewes Beach. At the northern end of the proposed placement area at Lewes Beach is Roosevelt Inlet, a federal navigation project (Inland Waterway from Rehoboth Bay to Delaware Bay, Sussex County, DE) providing a channel and protected by two parallel jetties at the inlet. The combined total amount of sand placed on Lewes beach between 1975-1985 was 363,400 cy. Repairs were made to the inlet jetties in 1993 to improve navigable access. The north side jetty was extended 920 feet (stone) while the south side jetty was extended 420 feet in length. The USACE had continued to utilize sand dredged from Roosevelt Inlet, nearby borrow areas, and truck hauls for placement operations in 2004, 2012, 2013, and 2017 on Lewes Beach. In 2018, the USACE completed a beneficial use project by placing maintenance dredged sand from Roosevelt Inlet into the nearshore zone of Lewes Beach using a split-hull hopper dredge.

The USACE beneficially used sand dredged from lower Reach E during the Main Channel Deepening Project (*i.e.* initial construction) in 2014 to pump 1.8 million cy of sand onto 14,600 linear feet at Broadkill Beach, located north of Prime Hook Beach. The project demonstrates the value of beneficially using clean sand, compatible with existing beach sand, dredged from the Main Navigation Channel for coastal storm risk management. The majority of the various construction projects that have occurred previously in the project area are nature-based features (*i.e*. berm and dune construction) and have been constructed for both CSRM and habitat restoration purposes. The Delaware Bay shoreline is valued for its diverse natural resources and the beaches provide habitat for resident shorebirds, migratory birds and waterfowl, horseshoe crabs, and other marine macroinvertebrates. The sandy beaches provide protection to the valuable wetlands and upland forests and farmlands west of the shoreline. Aside from the minimally developed small bayshore residential communities, the majority of the Delaware Bay shoreline remains in a natural (undeveloped) state, surrounded by saltmarshes with forested uplands and farmland interior. These undeveloped lands are highly valued for their ecological and recreational opportunities that it affords to wildlife and humans, respectively. For these reasons, beach nourishment has consistently remained the predominant (nonstructural) method of addressing CSRM problems for decades in the Delaware bay. The initial construction year (*i.e.* maintenance dredging of Lower Reach E) is scheduled for 2020 with periodic renourishment thereafter approximately every six years.

As noted earlier, the NJ DMU will also utilize Lower Reach E sand dredge during alternate maintenance dredging years, as described in the current New Jersey Beneficial Use of Dredged Material for the Delaware River Draft Feasibility Report and Integrated Environmental Assessment (USACE, 2017). The draft feasibility report and integrated EA evaluates CSRM issues in various New Jersey communities.

The Philadelphia District USACE is responsible for operation and maintenance of the Delaware River navigation channel for deep-draft commercial vessels transiting the bay up to the Ports at regional port facilities. The objective of the current study is to use the high quality sand dredged from the lower bay beneficially for CSRM purposes. The proposed plan provides a supplemental sand source to the aforementioned beach placement operations in the vicinity and thereby augments prior placement operations.

Many factors unrelated to beach nourishment may affect marine resources. The factors can be a result of natural events such as natural population cycles or as a result of favorable or negative weather conditions, major storms or hurricanes, and climate change. Nor'easters are common storm events in the Delaware Bay region. These storm events have a far greater impact on coastal areas and their resources at the population level than relatively local activities such as beach nourishment. Primary human-induced factors affecting fish stocks are over fishing and degradation of water quality due to pollution. When examining the cumulative effect of these perturbations, they outweigh the potential incremental effects of beach nourishment actions. Unlike the majority of ocean beaches, Delaware Bay beaches are typically not raked or scraped, thereby leaving the sandy coastline in its natural habitat condition. The proposed periodic renourishment schedule of 6 years allows for the rapid macroinvertebrate colonizers to establish equilibrium with the dynamic forces of the coast.

Beach quality sand is a valuable resource that is highly sought by beach communities to provide wide beaches for recreation, tourism, coastal habitat as well as to provide hurricane and wave protection for public and private property in these communities. When beach quality sand is dredged from navigation projects, it has become more of a common practice by the USACE to make this resource available to beach communities when applicable laws, regulations, funding and other considerations allow.

Placement of this sand on beaches represents return of sediment to the littoral system. The design of beach placement sites generally extends the elevation of the natural berm seaward, while tides and currents shape the constructed berm to its typical bay beach profile.

As discussed in previous sections, placement of beach fill may create impacts in the marine water column in the immediate vicinity of the activity, potentially affecting the surf zone and nearshore zone. These impacts may include minor and short-term suspended sediment plumes and related turbidity. Cumulative effects of multiple simultaneous beach nourishment operations could potentially impact fishes of the surf zone. However, the high quality of the sediment selected for beach fill and the small amount of beach affected at any point in time, relative to the 30 mile stretch of beach of the Delaware Bay coastline, would not suggest that this activity poses a significant nor long-term threat to marine and waterbird species. The intertidal zone within the proposed beach nourishment areas serves as habitat for invertebrates including mole crabs, coquina clams, amphipods, isopods, and polychaetes. These organisms are adapted to the high energy, sandy beach environment, including the significant shifting of sand, beach profiles and elevated turbidity levels common to coastal storms. Fish species that use nearshore shallow water zone as a migratory or feeding area are expected to temporarily relocate to lower turbidity areas. Though a short-term reduction in prey availability may occur in the immediate disposal area, only a small area is impacted at any given time, and once complete, organisms can recruit into the nourished area fairly quickly. Beach nourishment projects typical occur during the months of the year that avoid a majority of the peak recruitment and abundance time period of surf zone fishes and their benthic invertebrate prey source.

Table 39 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).

Table 39 – 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. The recommended plan does not pose adverse impact to existing shoreline stabilization features.
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. The recommended plan poses positive impacts through restoration of natural beach habitat.
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; no adverse impacts to overall water quality.

Unavoidable Adverse Environmental Impacts. Unavoidable adverse environmental impacts associated with beach placement operations include temporary loss (burial) of benthic organisms in the beach, intertidal and shallow nearshore zone. Temporary water quality impacts result from the suspension of sediments during pump out. Species of relatively non-motile infaunal invertebrates that inhabit the placement area will be buried. Motile organisms such as fish and crabs should be able to escape. 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 create more productive healthy coastal habitat and CSRM to communities.

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 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. In 2017, Buoy 10 was estimated to be at or near capacity; however, the USACE requested and received from NJDEP a permit to expand the footprint and gain an approximate 10 years of additional capacity. A new Coastal Zone Management Act Consistency Determination (CZM) and WQC were received on 24 January 2018. 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 40 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 CSRM to Bayfront communities. Dredging and placement operations both place some stress on the aquatic environment (*i.e.* elevated turbidity and loss of benthic resources) 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. Beach placement operations would involve utilization of time and fossil fuels, which are irreversible and irretrievable. Adverse environmental impacts associated with placement operations are short-term in nature and will subside after construction is completed.

Placement of dredged material at the beneficial use sites is not irreversible. The project would provide added CSRM to Bayfront communities from severe storm events but is not irreversible as storms will continue to occur, and in combination with SLC, 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 is a full disclosure document of the effects of the recommended plan and evaluated alternative plans, and serves as the Environmental Assessment. It was subjected to public review and comment for a 30-day period. This public coordination and environmental impact assessment complies with the intent of NEPA. The recommended plan 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 recommended plan falls under the scope of the 27 November 2017 Biological Opinion – Deepening and Maintenance of the Delaware River Federal Navigation Channel (NMFS, 2017). Consultation was reinitiated by the USACE with NMFS on 16 August 2016 for the modification to beneficially use the dredged material from Lower Reach E to place on the bay front beaches identified in the recommended plan for this study. The 17 November 2017 B.O. from NMFS concludes that consultation. The USACE will abide by NMFS' RPMs and terms and conditions as specified through re-initiation of consultation.

Coordination with USFWS was initiated on 24 November 2014 with the 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.

Section 7 consultation with USFWS was completed on 03 January 2017. The project as proposed will have “no effect” if dredging and placement operations do not occur between April 15 and June 7. 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 was completed by the USFWS on 20 February 2018 and submitted to USACE. 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 recommended plan 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 recommended plan is also in compliance.

6.2.2.5 Clean Water Act of 1972

USACE initially requested a Section 401 water quality certification (WQC) from DNREC upon release of the draft feasibility report in November 2016. In February 2018, DNREC provided a letter of support for the project indicating that as the dredging and associated dredged material placement schedule becomes more definitive, continued coordination with DNREC will initiate the public outreach process for the issuance of a Section 401 WQC. A Section 401 WQC will be obtained prior to construction. All state water quality requirements will be met. A Section 404(b)(1) 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 recommended plan will not significantly impact air quality. The requirements of this rule are not applicable to this recommended plan 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

The USACE coordinated with the Delaware Coastal Management Program (DCMP) and determined that the activity is consistent with the program. A Federal consistency determination, in coordination with 15 CFR 930 Subpart C, was received from the DCMP on 31 January 2017 and the DCMP concurs with the USACE’s consistency determination. Prior to construction, the USACE will coordinate with the DCMP in adherence with NOAA regulations (15 CFR, part 930.46).

6.2.2.8 Farmland Protection Policy Act of 1981

No prime or unique farmland would be impacted by implementation of this recommended plan. 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 not applicable to 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 recommended plan. 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 recommended plan 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 recommended plan is consistent with the purposes of this Act.

6.2.2.12 Federal Water Project Recreation Act

This Act provides funds for land acquisition or directs non-Federal agencies to administer project land and water areas for recreation and fish and wildlife enhancement. In addition, while investigating and planning a Federal navigation, flood control reclamation, hydroelectric or multi-purpose water resource project, full consideration must be given to the opportunities when the project affords for outdoor recreation and fish and wildlife enhancement. This recommended plan is consistent with the purposes of this Act.

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. NMFS identified fish species with Essential Fish Habitat Management Plans; identified ESA species and recommended avoiding sturgeon spawning habitat in the upper Delaware River. An Essential Fish Habitat Assessment was prepared for the current EA (beneficial use placement areas). In a letter date 20 February 2018, NMFS recommended that construction be avoided during the 1 May to 15 September period for sandbar shark and sand tiger shark. NMFS also requested that dredging and dredged material placement be avoided from April 15 to September 15 to minimize adverse effects to horseshoe crabs. The USACE has agreed to reinitiate consultation with NMFS once revised highly migratory species EFH designations are finalized. The recommended plan has been 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. The recommended plan is in full compliance with CBRA and CBIA, in accordance with the conditions described below:

Per the USFWS letter dated 03 January 2017, the southern end of Pickering Beach and a small portion of the northern section of Kitts Hummock Beach are within Little Creek CBRA System Unit DE-01. The southern section of South Bowers Beach, the southern section of Slaughter Beach and the northern and southern sections of Prime Hook Beach are located within CBRA System Unit Broadkill Beach H00. While Federal funds for beach restoration may not be expended for projects located in CBRA System Units, coordination between USFWS and USACE have identified exceptions for the proposed project. With the exception of the northern end of Kitts Hummock and the northern end of Prime Hook Beach, the proposed dune and berm will not enter the CBRA system units. At the northern end of Kitts Hummock the dune/berm project may enter the system unit because the two properties in this area were built prior to the establishment of this CBRA system unit. At the northern end of Prime Hook Beach, USFWS will also permit the CSRM dune and berm to tie into the existing Prime Hook National Wildlife Refuge project located within a CBRA system unit. For all other beach projects adjacent to a system unit, USFWS determined that the berm tapers at each of the aforementioned locations are not restricted from entering the CBRA system units, as they do not represent an added line of CSRM but rather serve to stabilize the adjacent CSRM project footprint.

USACE received an email from USFWS on May 11, 2018 stating that “the proposed beach nourishment plans/berm and dune structures at Pickering Beach, Kitts Hummock Beach, Bowers Beach, South Bowers Beach, Slaughter Beach, Prime Hook Beach, and Lewes Beach, are all in compliance with the Coastal Barrier Resource Act (CBRA). However, the U.S. Fish and Wildlife Service reserves the right to revisit CBRA compliance for this project prior to construction based on the potential for changes in land use and regulations.”

Figure 19 - Little Creek CBRA System Unit DE-01 Adjacent to Pickering Beach

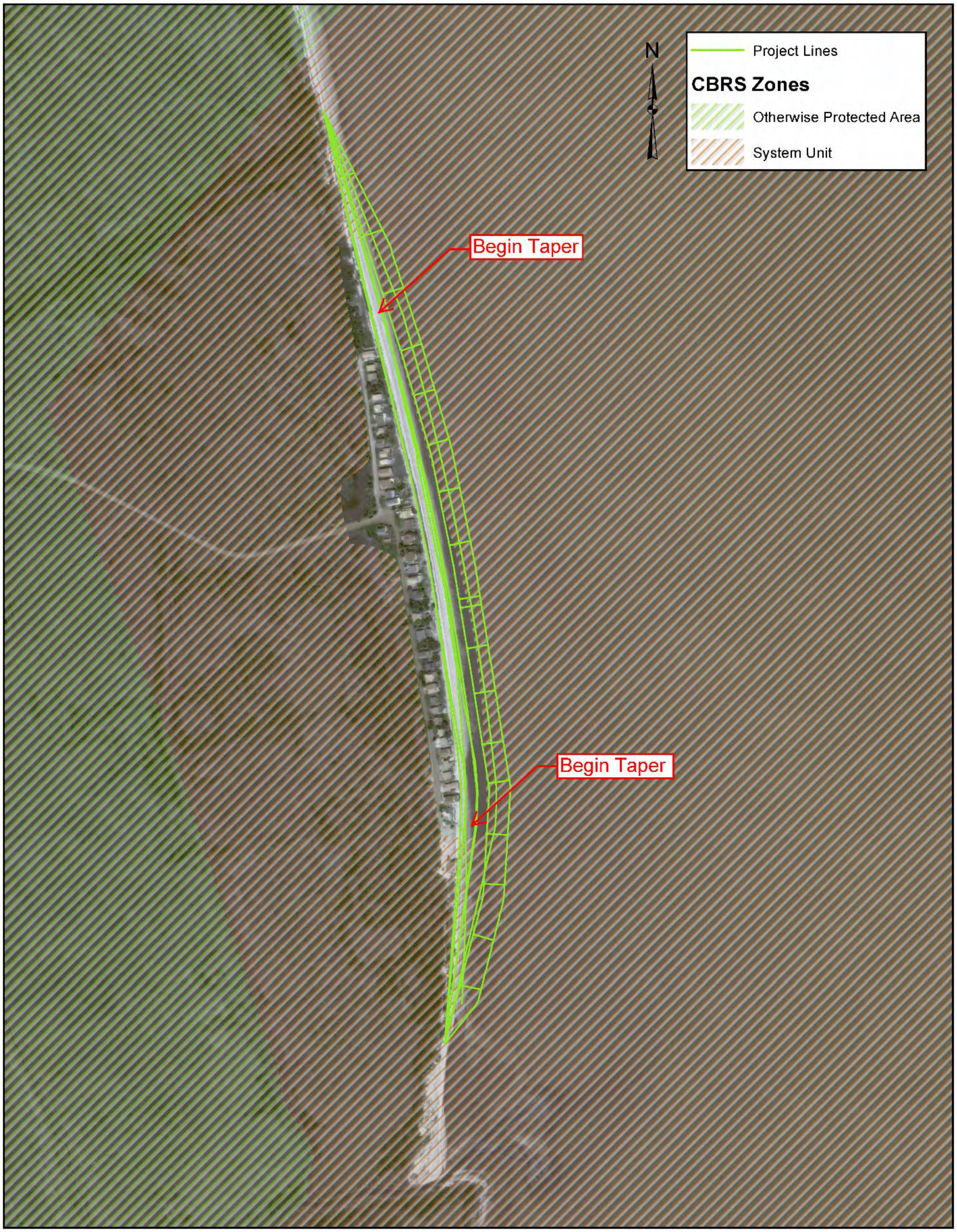


Figure 20 - Little Creek CBRA System Unit DE-01 Adjacent to KItts Hummock


N
Project Lines
CBRS Zones
Otherwise Protected Area
System Unit

Figure 21 - CBRA System Unit Broadkill Beach H00 Adjacent to South Bowers Beach

Figure 22 - CBRA System Unit Broadkill Beach H00 Adjacent to Slaughter Beach

Figure 23 - CBRA System Unit Broadkill Beach H00 Adjacent to Prime Hook Beach

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 recommended plan 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 could be minimally affected by dredging at the proposed sand source locations, contingent on the O&M dredging schedule. 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 recommended plan 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 adversely affected by the recommended plan. This plan is in compliance with the goals of this Executive Order because it may reduce excessive inundation and flood risk to adjacent wetlands.

6.2.2.22 Executive Order 11988, Floodplain Management

Executive Order 11988 requires federal agencies to avoid, to the extent possible, the long and short term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative. In accomplishing this objective, "each agency shall provide leadership and shall take action to reduce the risk of flood loss, to minimize the impact of floods on human safety, health, and welfare, and to restore and preserve the natural and beneficial values served by floodplains in carrying out its responsibilities.

The Water Resources Council Floodplain Management Guidelines for implementation of EO 11988, as referenced in USACE ER 1165-2-26, requires an eight step process that agencies should carry out as part of their decision making on projects that have potential impacts to, or are within the floodplain. The eight steps and project-specific responses to them are summarized below:

1. **Determine if a proposed action is in the base floodplain (that area which has a one percent or greater chance of flooding in any given year).** The proposed action is within the base floodplain; however, the project is designed to reduce damages property and infrastructure located landward of the proposed project.
2. **If the action is in the base floodplain, identify and evaluate practicable alternatives to the action or location of the action in the base floodplain.** Chapter 3 of this document presents an analysis of potential alternatives. Practicable measures and alternatives were formulated and evaluated against the Corps of Engineers guidance, including non-structural measures.
3. **If the action must be in the floodplain, advise the general public in the affected area and obtain their views and comments.** There has been extensive coordination with pertinent Federal, State and local agencies. The draft report was released for public review on 23 November 2016.

4. **Identify beneficial and adverse impacts due to the action and any expected losses of natural and beneficial floodplain values. Where actions proposed to be located outside the base floodplain will affect the base floodplain, impacts resulting from these actions should also be identified.** The anticipated impacts associated with the recommended plan are summarized in Chapter 5 of this report. Beneficial use of dredged material (consisting of predominantly coarse to medium-grained clean sand) for placement on sandy beaches along the Delaware Bay will not only reduce flood risks, but will restore or enhance the natural bayshore habitat. The nourished sandy beach will reduce damages to fish, wildlife and other natural resources within this coastal barrier system through restoration of habitat lost to erosion.
5. **If the action is likely to induce development in the based floodplain, determine if a practicable non-floodplain alternative for the development exists.** The project provides benefits solely for existing and previously approved development, and is not likely to induce development.
6. **As part of the planning process under the Principles and Guidelines, determine viable methods to minimize any adverse impacts of the action including any likely induced development for which there is no practicable alternative and methods to restore and preserve the natural and beneficial floodplain values. This should include reevaluation of the No Action Alternative.** There is no mitigation to be expected for the selected plan. The project will not induce development in the floodplain and the project will not negatively impact the natural or beneficial floodplain values. Chapter 3 of this report summarizes the alternative identification, screening and selection process. The No Action Plan was included in the plan formulation phase.
7. **If the final determination is made that no practicable alternative exists to locating the action in the floodplain, advise the general public in the affected area of the findings.** The Draft Feasibility Report and Integrated Environmental Assessment was provided for public review on 23 November 2016. Each comment received was addressed and, if appropriate, incorporated into the Final Report. A record of all comments received is also included in the Pertinent Correspondence Appendix.
8. **Recommend the plan most responsive to the planning objectives established by the study and consistent with the requirements of the Executive Order.** The recommended plan is the most responsive to all of the study objectives and the most consistent with the executive order.

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 recommended plan 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 recommended plan.

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 recommended plan 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 40 - Project Delivery Team

Name	Discipline
Scott Sanderson	USACE – Project Manager
Barbara Conlin	USACE – Environmental Coordinator
Preston Oakley	USACE – Economics
Mark Gravens	USACE – ERDC
Rob Hampson	USACE – Hydrology & Hydraulics
Jake Helminiak	USACE – Hydrology & Hydraulics
Mary Cialone	USACE – ERDC
Alison Sleath	USACE – ERDC
Nicole Minnichbach	USACE – Cultural Resources
Patrick Falvey	USACE – Civil Design
Derek Martowska	USACE – Geotechnical Engineering
William Harris	USACE – GeoEnvironmental
Alfredo Montes	USACE – Cost Engineering
Heather Sachs	USACE – Real Estate
Steve Long	USACE – GIS & Floodplain Management
Amanda Phily	USACE – Office of Counsel
Tony Pratt – Non-Federal Sponsor	DNREC
Jesse Hayden – Non-Federal Sponsor	DNREC

8 IMPLEMENTATION REQUIREMENTS

8.1 Institutional Requirements

The completion of the feasibility study and recommendation by the District Engineer are the first steps toward implementing the design and construction of the CSRM project along the Delaware shoreline of the Delaware Bay. Upon approval by the ASA (CW), the project will be considered for design and construction with funding made available through P.L. 113-2 and/or a Water Resources Development Act (WRDA).

Upon receipt of 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. The nourishment of the CSRM project will be cost-shared 65% by the Federal government and 35% by the non-Federal sponsor, while periodic renourishment will be cost-shared 50/50, as summarized on Table 41:

Table 41 – Cost Apportionment for the Recommended Plan

Delaware Beneficial Use of Dredged Material for the Delaware River - Cost Sharing (October 2017 Price Level)					
Item	Federal Cost	Federal Cost Share %	Non-Federal Cost	Non-Federal Cost Share %	Total Cost
Nourishment					
2020	$23,400,000	65%	$12,600,000	35%	$36,000,000
2026	$29,400,000	65%	$15,900,000	35%	$45,300,000
Real Estate (LERR&D)	N/A	0%	$17,300,000	100%	$17,300,000
Periodic Renourishment	$114,950,000	50%	$114,950,000	50%	$229,900,000
Estimated Cost Share (50 years)	$167,750,000	51%	$160,750,000	49%	$328,500,000

The non-Federal sponsor (DNREC) must comply with all applicable Federal laws and policies and other requirements, including but not limited to:

- Provide a minimum of 35% of initial project costs assigned to coastal and storm damage reduction, plus 100% of initial project costs assigned to protecting undeveloped private lands and other private shores which do not provide public benefits, and 50% of periodic renourishment costs assigned to coastal and storm damage reduction, plus 100% of periodic renourishment costs assigned to protecting undeveloped private lands and other private shores which do provide public benefits, and as further described below:
    - Provide, during design, 35% of design costs allocated to coastal and storm damage reduction in accordance with the terms of the PPA entered into prior to commencement of design work for the project;

- Provide all lands, easements, rights-of-way, including suitable borrow areas, and perform or assure performance of all relocations, including utility relocations, as determined by the Federal government to be necessary for the initial construction, periodic renourishment or operation and maintenance of the project;
- Provide, during construction, any additional amounts necessary to make its total contribution equal to 35% of initial project costs assigned to coastal and storm damage reduction plus 100% of initial project costs assigned to protecting undeveloped private lands and other private shores which do not provide public benefits;

- Perform, or cause to be performed, any investigations for hazardous substances as are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Public Law (PL) 96-510, as amended, 42 U.S.C. 9601-9675, that may exist in, on, or under lands, easements, or rights-of-way that the Federal government determines to be required for the construction, operation, and maintenance of the project.
- Coordinate all necessary cleanup and response costs of any CERCLA-regulated materials located in, on, or under lands, easements, or rights-of-way that the Federal government determines to be necessary for the construction, operation, or maintenance of the project.
- Coordinate mitigation and data recovery activities associated with historic preservation, that are in excess of one percent of the total amount authorized to be appropriated for the project.
- Operate, maintain, repair, replace, and rehabilitate the completed project, or functional portion of the project, including mitigation features, at no cost to the government, in a manner compatible with the project's authorized purposes and in accordance with applicable Federal and state laws and any specific directions prescribed by the government in the Operations, Maintenance, Replacement, Repair and Rehabilitation (OMRR&R) manual and any subsequent amendments thereto.
- Provide the Federal government a right to enter, at reasonable times and in a reasonable manner, upon property that the non-Federal project partner, now or hereafter, owns or controls for access to the project for the purpose of inspection, and, if necessary after failure to perform by the non-Federal project partner, for the purpose of completing, operating, maintaining, repairing, replacing, or rehabilitating the project. No completion, operation, maintenance, repair, replacement, or rehabilitation by the Federal government shall operate to relieve the non-Federal project partner of the responsibility to meet the non-Federal project partner's obligations, or to preclude the Federal government from pursuing any other remedy at law or equity to ensure faithful performance.
- Hold and save the United States free from all damages arising from the construction, operation, maintenance, repair, replacement, and rehabilitation of the project and any project-related betterments, except for damages due to the fault or negligence of the United States or its contractors.
- Keep, and maintain books, records, documents, and other evidence pertaining to costs and expenses incurred pursuant to the project in accordance with the standards for financial management systems set forth in the Uniform Administrative Requirements for Grants and

Cooperative Agreements to State and Local governments at 32 codes of Federal regulations (CFR) Section 33.20.

- As between the Federal government and the non-Federal project partners, the non-Federal project partner shall be considered the operator of the project for the purpose of CERCLA liability. To the maximum extent practicable, operate, maintain, repair, replace and rehabilitate the project in a manner that will not cause liability to arise under CERCLA.
- Comply with applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1790, Public Law 91-646, as amended by Title IV of the Surface Transportation and Uniform Relocation Assistance Act of 1987 (Public Law 100-17), and the uniform regulations contained in 49 CFR Part 24, in acquiring lands, easements, and rights-of-way, required for construction, operation, and maintenance of the project, including those necessary for relocations, borrow materials, and dredged or excavated material disposal, and inform all affected persons of applicable benefits, policies, and procedures in connection with said Act.
- Comply with all applicable Federal and state laws and regulations, including, but not limited to, Section 601 of the Civil Rights Act of 1964, Public Law 88-352 (42 U.S.C. 2000d), and Department of Defense directive 5500.11 issue pursuant thereto, as well as Army regulation 600-7, entitled "Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted of Conducted by the Department of the Army.
- Participate in and comply with applicable Federal floodplain management and flood insurance programs and comply with requirements in Section 402 of the Water Resources Development Act of 1986, as amended.
- Not less than once each year inform affected interests of the extent of protection afforded by the project.
- Publicize floodplain information in the area concerned and provide this information to zoning and other regulatory agencies for their use in preventing unwise future development in the floodplain and in adopting such regulations as may be necessary to prevent unwise future development and to ensure compatibility with the protection provided by the project.
- Prevent obstructions of or encroachments on the project (including prescribing and enforcing regulations to prevent such obstructions or encroachments) which might hinder its operation and maintenance, or interfere with its proper function, such as any new development on the project lands or the addition of facilities which would degrade the benefits of the project.
- Provide and maintain necessary access roads, parking areas, and other public use facilities, open and available to all on equal terms.
- Comply with Section 221 of Public Law 91-611, Flood Control Act of 1970, as amended, and Section 103 of the Water Resources Development Act of 1986, Public Law 99-662, as amended, which provides the Secretary of the Army shall not commence the construction any water resources project or separable element thereof, until the non-Federal project partner has entered into a written agreement to furnish its required cooperation for the project or separable element.

- At least twice annually and after storm events, perform surveillance of the Line of Protection and determine any physical variances from the project design section and provide the results of such surveillance to the Federal government.
- Inform affected interests, at least annually, of the extent of protection afforded by the structural flood damage reduction features.
- Assume, as between the Federal government and the non-Federal sponsor, complete financial responsibility for all necessary cleanup and response costs of any hazardous substances regulated under CERCLA that are located in, on, or under lands, easements, or rights-of-way required for construction, operation, maintenance, repair, rehabilitation, or replacement of the project.
- Not use funds from other Federal programs, including any non-Federal contribution required as a matching share therefore, to meet any of the non-Federal sponsor's obligations for the project unless the Federal agency providing the funds verifies in writing that such funds are authorized to be used to carry out the project.

8.2 Public Access Plan

Engineering Regulation (ER) 1165-2-130, Federal Participation in Shore Protection Projects, requires that reasonable public access be provided in accordance with the recreational use objectives of the particular area and public use is "construed to be effectively limited to the within one-quarter mile from available points of public access to any particular shore." No two public access points can be further than ½ mile apart, and no visitor can be further than ¼ mile from an individual access point. ER 1165-2-130 also discusses parking requirements and states that parking on free or reasonable terms should be available within a reasonable walking distance of the beach. Public access and parking available and/or needed to comply with ER 1165-2-130 in each community of the recommended plan is described below:

Pickering Beach – Current public access at Pickering Beach is limited to a single point at the intersection of Pickering Beach and South Sandpiper Drive, as shown in Appendix G. Two additional public access points will be required at the northern and southern ends of the project.

Kitts Hummock – Current public access at Kitts Hummock is limited to a single point at the eastern end of Kitts Hummock Road, as shown in Appendix G. There is also an existing easement to allow beach access for vehicles. Two additional public access points will be required at the northern and southern ends of the project.

Bowers Beach – At Bowers Beach, public access exists at three points (one of which is also used as vehicular access), as shown in Appendix G. One additional public access point will be required at the northern end of the project.

South Bowers Beach – At South Bowers Beach, current public access exists at two points (one of which is also used as vehicular access), as shown in Appendix G. One additional public access point will be required at the northern end of the project.

Slaughter Beach – Currently, there are 14 public access points at Slaughter Beach (one of which is also used as vehicular access), as shown in Appendix G.

Prime Hook Beach – There is no current public access at Prime Hook Beach. Five public access points will be required.

Lewes Beach – Current public access at Lewes Beach consists of 23 public access points (one of which can also be used as vehicular access), as shown in Appendix G. No additional public access points are required.

With the exception of Lewes Beach, additional public access is required for the beach restoration sites in the recommended plan. DNREC is committed to provide the necessary public access and associated reasonable parking to comply with ER 1165-2-130.

8.3 Implementation Schedule

Before design and construction may be initiated, the report must be approved and submitted to the Office of Management & Budget. Further, the PPA must be executed by USACE and the non-Federal sponsor. The following provides the current schedule for study approval and PPA execution:

Final Feasibility Report & Integrated EA to Corps Higher Authority for Approval	March 2018
Chief's Report submitted to ASA (CW)	October 2018
ASA (CW) Final Feasibility Report & Integrated EA Approval	December 2018
ASA (CW) submits report to OMB	December 2018
Final Report to Congress	December 2018
Start Plans and Specifications (Design Phase)	July 2019
Execute PPA with non-Federal Sponsor	July 2019
Finalize Plans and Specifications for Contract	February 2020
Real Estate Certification for Contract	March 2020
Ready to Advertise Contract	June 2020
Award Construction Contract with Notice to Proceed	August 2020

8.4 Cost Summary

The estimated cost for the recommended plan is $328,500,000 (October 2017 price level) which includes real estate acquisition costs (including administration costs); planning, engineering and design (PE&D); construction management (S&A); Operation, Maintenance, Repair, Replacement and Rehabilitation (OMRR&R); and associated contingencies. A summary of estimated project costs is provided on Table 42.

Table 42 – Estimated Project Cost Summary

ESTIMATED COSTS FOR THE RECOMMENDED PLAN	
Period of Analysis	2020 to 2070 (50 Years)
Price Level	October 2017
Discount Rate	2.75%
Base Year	2020
Nourishment Costs	
2020 (including Real Estate)	$53,300,000
2026	$45,300,000
Interest During Construction	$1,885,000
Periodic Renourishment Costs	
2026	$14,900,000
2032 through 2070	$215,000,000
AVERAGE ANNUAL COSTS	
Nourishment Costs	
2020 (without Interest During Construction)	$1,975,000
2026 (without Interest During Construction)	$1,288,000
Interest During Construction	$70,000
Periodic Renourishment	$3,819,000
Subtotal Average Annual Costs	**$7,152,000**
Monitoring Costs – 2020	$146,000
Monitoring Costs – 2026	$244,000
Monitoring Costs – 2032 through 2070	$118,000
OMRR&R	$27,000
Total Average Annual Cost	**$7,687,000**

Notes:

1. Major rehabilitation costs are not included due to the required major rehabilitation quantity (165,900 cubic yards) being less than periodic renourishment quantity of 413,600 cubic yards.
2. Mid-point of construction is 2020 Q4 and 2026 Q4 for nourishment.

In accordance with the Water Resources Development Act of 1986, as amended, the cost sharing for initial construction is 65% Federal and 35% non-Federal, which includes cash and credits associated with obtaining the required lands, easements, rights-of-way, and relocations (LERR). Periodic renourishment is cost-shared 50% Federal and 50% non-Federal. OMRR&R is a 100% non-Federal responsibility and is included in the calculation of annualized project costs for economic purposes. The Federal government will design the project, prepare detailed plans/specifications and construct the project, exclusive of those items specifically required of the non-Federal partner.

8.5 Views of Non-Federal Sponsor

The non-Federal sponsor (Delaware Department of Natural Resources and Environmental Control – DNREC) fully supports the recommended plan.

9 RECOMMENDATIONS

The recommended plan consists of beach restoration at 7 dredged material placement locations in the southern reach of the study area. The 7 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, Slaughter Beach, Prime Hook Beach and Lewes. Dune elevations and berm widths from the Beach-fx optimization are presented in Table 23. All of the design profiles consisting of both dune and berm have a dune slope of 1V:5H, foreshore slope of 1V:10H, and a berm elevation of +7 ft NAVD88. The berm elevations is selected to match the natural berm elevations in the study area. The results of the Beach-fx optimization show that Pickering and Kitts Hummock do not need a dune to maximize net benefits. However, a wider design berm is required since there is no dune. Slaughter optimized to a relatively low dune at +8.5 ft NAVD88 that matches the existing dune conditions and the remaining sites optimized to a design dune elevation of +12 ft NAVD88. Additional 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 recommended plan 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 recommended plan 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 Table 43:

Table 43 – Summary of Costs & Benefits

Site	AAC	AAB	AANB	BCR
Pickering	$986,000	$1,775,000	$789,000	1.8
Kitts Hummock	$837,000	$1,405,000	$568,000	1.7
Bowers	$959,000	$1,295,000	$336,000	1.4
South Bowers	$862,000	$963,000	$101,000	1.1
Slaughter Beach	$1,472,000	$2,739,000	$1,267,000	1.9
Prime Hook	$1,344,000	$2,430,000	$1,086,000	1.8
Lewes Beach	$1,226,000	$1,624,000	$398,000	1.3
Total Project	**$7,687,000**	**$12,231,000**	**$4,545,000**	**1.6**

Note: The cost and benefit values in Table 43 cover a 50-year period of analysis with a base year of 2020.

The recommended plan reflects information available at the time and current USACE policies governing formulation of coastal storm risk management projects. These recommendations may be modified before they are transmitted to Congress as proposals for authorization and implementation funding. However, prior to transmittal to Congress, the Sponsor, the States, interested Federal agencies, and other parties will be advised of any modifications and will be afforded the opportunity to comment further.

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