# Delaware River
# Main Stem and Channel Deepening Project
# Environmental Assessment



April 2009

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Main Channel Deepening Project
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## 1.0 Summary

### 1.1 Purpose

The purpose of this Environmental Assessment (EA) is to evaluate the impacts of changes to the Congressionally authorized project for the Delaware River Main Stem and Channel Deepening Project, which are the result of detailed Preconstruction, Engineering and Design (PED) studies, as well as changes to the existing conditions in the project area from those described in the 1992 Environmental Impact Statement (EIS), 1997 Supplemental Environmental Impact Statement (SEIS), and 1998 Record of Decision (ROD), and to consolidate in one document the results of post-SEIS monitoring and data collection efforts.

Evaluations of impacts on resources addressed previously in the Environmental Impact Statement and Supplemental Environmental Impact Statement are not discussed in this Environmental Assessment and are incorporated by reference. Where appropriate, potential areas of concern have been re-evaluated and updated.

### 1.2 Changes to the Authorized Project:

a. Due to significant reduction of dredged material quantities the project will be constructed using only existing Federal dredged material disposal sites. Four new dredged material disposal sites identified in the SEIS (15D, 15G, 17G, and Raccoon Island) are no longer needed and have been eliminated, thus reducing disposal related impacts;

b. The current plan also includes placement of sand dredged in the Delaware Bay directly on Broadkill Beach rather than offshore sand stockpiling as stated in the SEIS. This change was in response to concerns raised by resource agencies regarding the impacts of sand stockpiling and is consistent with the 1998 ROD;

c. Deferment of Egg Island Point restoration. The authorized project supported by the 1997 SEIS included restoration of approximately 145 acres of intertidal habitat adjacent to Egg Island Point utilizing approximately 2,600,000 cubic yards of material dredged from the Delaware Bay navigation channel. However, due to the reduction in estimated quantities of dredged material, this element of the project is being deferred until such time as sufficient dredged material quantities are available to support its construction.

### 1.3 Changes to the Affected Environment Since the 1997 SEIS

a. Athos oil spill. The January 2009 Draft Damage Assessment and Restoration Plan and Environmental Assessment for the November 26, 2004, M/T Athos I Oil Spill (NOAA, 2009) concluded that the Athos Oil Spill only temporarily (14 months) contributed to an increase in toxicity of sediments in the Delaware River. Similarly, sediment sampling conducted by the Corps in 2005 (Versar, 2005b) also indicates that there has been no change in sediment quality. Therefore, it has been determined that the Athos Oil Spill will have no significant adverse effect on construction or maintenance of the deepening project.

b. Shortnose sturgeon. Additional environmental concerns not addressed in the EIS, the SEIS, or the 2001 Biological Opinion from the National Marine Fisheries Service regarding distribution of the Federally listed shortnose sturgeon: Based on recent surveys (Versar, 2005a), a significant expansion in the number and distribution of the shortnose sturgeon in the Delaware River appears likely. Consequently, there is potential for shortnose sturgeon to be in the vicinity of the Marcus Hook rock blasting area. The Corps has determined that with implementation of appropriate monitoring measures and with the restriction that work is limited to the period between December 1 and March 15, there will not be an adverse effect on the shortnose sturgeon or its habitat. Coordination with the National Marine Fisheries Service is ongoing. NMFS is currently in the process of preparing a Biological Opinion under Section 7 of the Endangered Species Act concerning project impacts to the shortnose sturgeon. It is anticipated that the Corps will comply with all project-related conditions recommended by NMFS in order to minimize any potential adverse effects on the shortnose sturgeon.

## 1.4 Conclusion

Based on the information presented in this Environmental Assessment and based on evaluation and consideration of comments received in response to the Public Notices (CENAP-PL-E-09-01 and CENAP-PL-E-09-02 dated 17 December 2008 and 31 December 2008, respectively), it is concluded that any changes to the project or changes to the physical conditions where the project will be constructed would have no significant, adverse effects on the human environment, over and above the potential environmental effects already addressed in the earlier EIS, SEIS, and ROD. No significant adverse environmental effects are expected to occur as a result of the issues addressed in this EA.

The Corps is committed to work closely with Federal and State resource agencies, prior to and during project construction to continue monitoring and collection of additional environmental data, provide relevant supplemental information as needed, and to apply adaptive management and best management practices as appropriate.

## 1.5 Relationship to Environmental Statutes

Compliance with applicable Federal Statutes, Executive Orders, and Executive Memoranda, were discussed in the 1992 Environmental Impact Statement and the 1997 Supplemental Environmental Impact Statement. Table 1-1 is a complete listing of compliance status relative to environmental quality protection statutes and other environmental review requirements.

Table 1-1 Compliance with Environmental Quality Protection Statutes and Other Environmental Review Requirements.

| FEDERAL STATUTES | COMPLIANCE W/PROPOSED PLAN |
|---|---|
| Archeological and Historical Preservation Act, as amended | Full |
| Clean Air Act, as amended | Full |
| Clean Water Act of 1977 | Partial (coordination ongoing) |
| Coastal Barrier Resources Act | Full |

| FEDERAL STATUTES | COMPLIANCE W/PROPOSED PLAN |
|---|---|
| Coastal Zone Management Act of 1972, as amended | Full |
| Endangered Species Act of 1973, as amended | Partial (coordination ongoing) |
| Estuary Protection Act | Full |
| Federal Water Project Recreation Act, as amended | N/A |
| Fish and Wildlife Coordination Act | Partial (coordination ongoing) |
| Land and Water Conservation Fund Act, as amended | N/A |
| Marine Protection, Research and Sanctuaries Act | Full |
| Magnuson-Stevens Fishery Conservation and Management Act | Partial (coordination ongoing) |
| National Historic Preservation Act of 1966, as amended | Full |
| National Environmental Policy Act, as amended | Full |
| Rivers and Harbors Act | Full |
| Watershed Protection and Flood Prevention Act | N/A |
| Wild and Scenic River Act | N/A |
| **Executive Orders, Memorandums, etc.** | |
| EO 11988, Floodplain Management | Full |
| EO 11990, Protection of Wetlands | Full |
| EO12114, Environmental Effects of Major Federal Actions | Full |
| EO 12989, Environmental Justice in Minority Populations and Low-Income Populations | Full |
| County Land Use Plan | Full |



**Full Compliance** - Requirements of the statute, EO, or other environmental requirements are met for the current stage of review.
**Partial Compliance** - Some requirements and permits of the statute, E.O., or other policy and related regulations remain to be met.
**Noncompliance** - None of the requirements of the statute, E.O., or other policy and related regulations have been met.
**N/A** - Statute, E.O. or other policy and related regulations are not applicable.

1.5.1 Coastal Zone Consistency Determination

Based on the information developed during preparation of the Supplemental Environmental Impact Statement it was determined in accordance with Section 307 (c) of the Coastal Zone Management Act of 1972 that construction of the Delaware River Main Stem and Channel Deepening Project complies with and would be conducted in a manner that is consistent with the approved Coastal Zone Management Programs of the States of Pennsylvania, Delaware and New Jersey. The States provided their concurrence with this determination of Coastal Zone

Consistency in letters dated: February 4, 1997 (Pennsylvania); May 1, 1997 (Delaware); and August 29, 1997 (New Jersey).

1.5.2 Section 404 of the Clean Water Act

In order to implement the requirements of Section 404 of the Clean Water Act, an exemption was granted under Section 404(r) when the project was authorized by Congress in October 1992, under the Water Resources Development Act of 1992. Section 404(b)(1) evaluations were prepared as part of the 1992 Environmental Impact Statement and the 1997 Supplemental Environmental Impact Statement. These evaluations concluded that the proposed action would not result in any significant environmental impacts relative to the areas of concern under Section 404 of the Clean Water Act. An updated Section 404(b)(1) evaluation is provided in Section 6.0 of this document.

1.5.3 State SHPO Consultation

Based on the results of cultural resources investigations, the Philadelphia District determined that the project will have "No Effect" on significant cultural resources. The District plans to completely avoid three identified targets (the Canal Barge Site (E-1, 1:5), the "Excelsior" Steamboat Site (E-2, 4:16) and the Egg Island Point Lighthouse Site) by placing a 200 foot buffer around each location and then monitoring each site to ensure that no impacts occur to these sites during construction.

A draft report of the final cultural resources investigation (Cox & Hunter 1995) and the District's finding of "No Effect" was submitted to the Pennsylvania, New Jersey and Delaware SHPO's in September and October, 1995. The Pennsylvania and New Jersey SHPO'S concurred with the District's finding in letters dated November 21, 1995 (PASHPO) and December 23, 1996 (NJSHPO).

In a letter dated February 4, 1997, the DESHPO provided a review of the DSEIS and concurred with the District's finding of "No Effect" for Delaware project areas at Reedy Point North and South, Buoy 10, Kelly Island, and proposed sand stockpiling locations MS-19 and LC-5. However, the DESHPO expressed the strong opinion that the project would have an adverse effect on archaeological deposits located along the shoreline of Pea Patch Island. It was ultimately determined that the deepening of the Delaware River main channel to a depth of 45 feet would have an adverse effect upon historic Fort Delaware on Pea Patch Island. Both the fort and the island are properties listed in the National Register of Historic Places. Pursuant to Section 106 of the National Historic Preservation Act of 1966, as amended, the District Engineer signed a memorandum of agreement in 1999 with the Delaware State Historic Preservation Officer (SHPO) and the Advisory Council on Historic Preservation in which the Corps committed to the installation of extensive shoreline erosion control measures (See Section 3.4.1). These shoreline erosion control measures have been constructed and it is concluded that deepening the navigation channel to 45 feet will not increase shoreline erosion on Pea Patch Island, and consequently, will not impact significant cultural resources along the shoreline. In a letter dated September 10, 1996, the DESHPO concurred with the District's finding of "No Effect" for the Broadkill Beach beach nourishment project.

1.5.4 Endangered Species Act

In September 1995 the Philadelphia District initiated formal consultation with the National Marine Fisheries Service under Section 7 of the Endangered Species Act of 1977 (16 U.S. C. 1531 et seq.), with regard to all dredging activities within Philadelphia District boundaries. "A Biological Assessment of Federally Listed Threatened and Endangered Species of Sea Turtles, Whales, and the Shortnose Sturgeon within Philadelphia District Boundaries: Potential Impacts of Dredging Activities" was forwarded to the National Marine Fisheries Service (NMFS) for their review.

A Biological Opinion was issued by the NMFS on November 26, 1996 (Montanio, 1996) for all dredging projects permitted, funded, or conducted by the District. The Opinion stated that dredging projects within the Philadelphia District may adversely affect sea turtles and shortnose sturgeon, but are not likely to jeopardize the continued existence of any threatened or endangered species under the jurisdiction of the NMFS.

In May 2000 the Philadelphia District again initiated formal consultation under Section 7 of the Endangered Species Act for the rock blasting component of the Main Stem and Channel Deepening Project. NMFS provided a Biological Opinion in January 2001. That Opinion concluded that the proposed rock blasting may adversely affect, but is not likely to jeopardize the continued existence of any threatened or endangered species under the jurisdiction of the NMFS.

The Philadelphia District has prepared an updated Biological Assessment for the entire Main Stem and Channel Deepening Project. Formal consultation under Section 7 of the Endangered Species Act is ongoing and will be concluded prior to the start of construction.

In October 1995 the Philadelphia District initiated formal consultation under Section 7 of the Endangered Species Act with the U.S. Fish and Wildlife Service for potential effects of the Main Stem and Channel Deepening Project on the bald eagle and peregrine falcon. The Biological Assessment concluded that there would be no impact that would jeopardize the continued existence of these species, or their critical habitat. In a letter dated January 18, 1996, the U.S. Fish and Wildlife Service concurred with this determination. Since that time both species have been removed from the Federal Endangered Species list. There are no threatened or endangered species under the jurisdiction of the U.S. Fish and Wildlife Service within the project area. No additional consultation is required.

2.0 Needs and Objectives of Action

2.1 Project Authorization

The Delaware River Main Stem and Channel Deepening Project, Pennsylvania, New Jersey, and Delaware, was authorized by Public Law 102-580, Section 101(6) of the Water Resources Development Act of 1992. The project was modified by Section 308 of the Water Resources Development Act of 1999, Public Law 106-53, and further modified by Section 306 of the Water Resources Development Act of 2000, Public Law 106-541. The Philadelphia Regional Port

Authority (PRPA) is the non-Federal sponsor for this project. The Project Partnership Agreement (PPA) with USACE and the PRPA, was executed on June 23, 2008. The project is being prepared to start construction in Federal fiscal year 2009, which ends on September 30, 2009.

2.2 Project Objectives

The major problem with the existing Delaware River, Philadelphia to the Sea, federal navigation project is an insufficient channel depth to accommodate the design drafts of larger vessels in the fleet. Commodity categories with constrained vessels transport liquid bulk, container, and dry bulk cargo.

Existing channel dimensions reduce the economic efficiency of larger ships moving through this major commercial area. Crude oil and refined petroleum products account for the largest tonnage category moved through the Delaware River port system. The refineries located along the Delaware River are significant contributors to U.S. refinery capacity and provide petroleum products throughout the Mid-Atlantic and Northeastern parts of the country. A large amount of the crude oil that comes into the Delaware River facilities is lightered. Tankers with sailing drafts greater than 40 feet must transfer a portion of their cargo in the lower Delaware Bay prior to navigating upriver to the refineries. In addition, many container and dry bulk vessels are also constrained by the current channel depths. A deeper channel depth will allow these vessels to either carry more cargo or enabling the chartering of a larger vessel class, thus more efficiently apportioning operating costs over a greater magnitude of tonnage (resulting in transportation savings).

2.2.1 Previous NEPA Coordination

The final Feasibility Report and Environmental Impact Statement for the Delaware River Comprehensive Navigation Study Main Channel Deepening Project was completed in February 1992. The Record of Decision for the final Environmental Impact Statement dated December 17, 1992, indicated that supplementary environmental analyses were planned for the Preconstruction, Engineering and Design phase of project development to verify conclusions reached during feasibility investigations by either gathering additional data and/or using more sophisticated modeling techniques.

These analyses included:

- Three-dimensional hydrodynamic modeling of the Delaware Estuary to evaluate potential changes in salinity and circulation patterns;
- Benthic invertebrate sampling to assess habitat quality at selected beneficial use sites in Delaware Bay;
- Biological effects based testing to determine the impact of open water disposal on aquatic ecosystems;
- Detailed environmental assessments of selected upland dredged material disposal sites;

- Consultation with both the U.S. Fish and Wildlife Service and the National Marine Fisheries Service, pursuant to Section 7 of the Endangered Species Act;
- Cultural resource investigations in dredging and disposal locations; and
- Coordination with regional oil spill response teams to review the adequacy of existing Delaware River spill contingency plans.



The Corps of Engineers worked closely with Federal and State resource agencies to complete the required investigations. Pursuant to the National Environmental Policy Act, a final Supplemental Environmental Impact Statement that presented the findings of these investigations was completed in July 1997. The recommended plan of improvement remained the same as presented in the original Environmental Impact Statement, with additional details regarding beneficial use sites in Delaware Bay. The final Supplemental Environmental Impact Statement evaluated the use of Delaware Bay dredged material from initial project construction for wetland restoration at Egg Island Point, New Jersey and Kelly Island, Delaware, and for stockpiling of sand for later beach nourishment work at selected beaches in the State of Delaware. The Record of Decision for the final Supplemental Environmental Impact Statement, dated December 18, 1998, indicated that due to fishery and habitat related concerns expressed by resource agencies, the Corps would consider placement of sand directly on Delaware beaches in lieu of offshore stockpiling. This is the current recommended plan of improvement.

The information in this document updates and clarifies the previously published National Environmental Policy Act (NEPA) documents, which are the February 1992 EIS and the July 1997 SEIS. To reduce duplication, only items involving new pertinent information and changes in the plan as previously proposed are addressed in this document. Items covered previously are incorporated by reference and are referenced herein as USACE (1992) and USACE (1997).

2.3 Existing Project

The existing Delaware River, Philadelphia to the Sea, Federal navigation project was adopted by Congress in 1910 and modified in 1930, '35, '38, '45, '54 and '58. The existing project provides for a channel from deep water in Delaware Bay to a point in the bay, near Ship John Light, 40 feet deep and 1,000 feet wide; thence to the Philadelphia Naval Base, 40 feet deep and 800 feet wide, with a 1,200-foot width at Bulkhead Bar and a 1,000-foot width at other channel bends; thence to Allegheny Avenue Philadelphia, PA; 40 feet deep and 500 feet wide through Horseshoe Bend and 40 feet deep and 400 feet wide through Philadelphia Harbor along the west side of the channel. The east side of the channel in Philadelphia Harbor has a depth of 37 feet and a width of 600 feet. All depths refer to mean low water. The 40-foot channel from the former Naval Base to the sea was completed in 1942. The channel from the former Naval Base to Allegheny Avenue was completed in 1962.

There are 19 anchorages on the Delaware River. The Mantua Creek, Marcus Hook, Deepwater Point, Reedy Point, Gloucester and Port Richmond anchorages are authorized under the Philadelphia to the sea project. The remaining 13 are natural, deep-water anchorages. The authorized anchorage dimensions are as follows:

Mantua Creek: 40' X 2,300' X 11,500' (mean)

| | |
|---|---|
| Marcus Hook: | 40' X 2,300' X 13,650' (mean) |
| Deepwater Point: | 40' X 2,300' X 5,200' (mean) |
| Reedy Point: | 40' X 2,300' X 8,000' (mean) |
| Port Richmond: | 37' X 500' (mean) X 6,400' |
| Gloucester: | 30' X 400' (mean) X 3,500' |

Mantua Creek anchorage is currently maintained to about 60% of the authorized width and a 37-foot depth. The Marcus Hook anchorage, enlarged in 1964, is maintained to authorized dimensions. The anchorage at Port Richmond is about 35 feet deep, as are the Reedy Point and Deepwater Point anchorages. The Gloucester anchorage requires no dredging and is currently deeper than authorized.

There are wide variations in the amount of dredging required to maintain the Philadelphia to the Sea project. Some ranges are nearly self maintaining and others experience rapid shoaling. The 40-foot channel requires annual maintenance dredging in the amount of 3,455,000 cubic yards. Of this amount, the majority of material is removed from the Marcus Hook (44%), Deepwater Point (18%) and New Castle (23%) ranges. The remaining 15 percent of material is spread throughout the other 37 channel ranges. The historic annual maintenance quantities for the Marcus Hook and Mantua Creek anchorages are 487,000 and 157,000 cubic yards, respectively.

The Federal government has the responsibility for providing the necessary dredged material disposal areas for placement of material dredged for project maintenance. There are currently seven upland sites and one open-water site, located in Delaware Bay, that are used for this purpose. The seven confined upland sites are National Park, Oldmans, Pedricktown North, Pedricktown South, Penns Neck, Killcohook and Artificial Island. The open water site in Delaware Bay is located in the vicinity of Buoy 10. This site is only approved for placement of sand and is approximately 1000 acres in size.

The Delaware River system can be entered or exited via the Delaware Bay entrance or through the Chesapeake and Delaware Canal. Two sets of ocean traffic lanes converge at a precautionary area at the bay entrance. Each set of lanes has a separation zone for safety between inbound and outbound vessels. The northern Cape Henlopen - Five Fathom Bank lanes have minimum depths close to the 40-foot main channel depth, and are used primarily by smaller vessels and those engaged in coastwise commerce. The southern Cape Henlopen - Delaware lanes are much deeper, with minimum depths of about 55 feet outbound and 59 feet inbound. These lanes are used by most vessels engaged in foreign commerce including the large bulk carriers and tankers, as well as for coastwise movements to the south. Each set of ocean lanes is marked by a series of buoys centrally located in each separation zone. Some vessels are piloted within the Delaware River system by members of the Pilots' Association for the Bay and River Delaware. They board incoming vessels in the pilot area at the bay entrance and at the Maryland/Delaware line in the C&D Canal.



From the bay entrance vessels can either proceed up the main Delaware River channel to the Philadelphia ports, or through naturally deep waters to the Big Stone Beach anchorage in lower Delaware Bay. This anchorage has been used for over 40 years by large tankers to lighter (primarily crude oil) onto barges. Maximum drafts for tankers entering the bay are 55 ft and

lightering reduces tanker operation drafts to those acceptable for the 40 ft channel. In 1988 this anchorage was reclassified by the U.S. Coast Guard as a general purpose anchorage, however lightering is still the dominant activity.

The 40-foot Delaware River channel provides for two-way traffic up to the Philadelphia Navy Yard where it transitions to a 400-ft width on the west side. Within Philadelphia Harbor the 37 foot east side of the channel allows two-way traffic, with shallower vessels yielding the 40-foot channel to deeper vessels. The 40-foot channel continues upriver to the Fairless Turning Basin in Bucks County, PA as the Philadelphia to Trenton segment of the Delaware River channel. The main channel serves numerous other tributary projects which provide both one-way and two-way access to facilities engaged in foreign, coastwise, and internal commerce. The main channel is connected to the Chesapeake Bay and Port of Baltimore by the Chesapeake & Delaware Canal. The canal is used by container liner services that call at Baltimore as well as by lesser draft domestic vessels, tug and barge traffic, and recreational craft.

The six Federally authorized anchorages as well as the 13 naturally deep U.S. Coast Guard designated areas adjoin the Delaware River channel between Philadelphia and Delaware Bay. Included are general and special purpose anchorages. Vessels are permitted to anchor for a period up to 48 hours (or longer with a Coast Guard permit). Vessel usage is recorded by the U.S. Coast Guard only for the commonly used anchorages at Big Stone Beach, Mantua Creek, Marcus Hook, and Kaighn Point Gloucester in addition to the breakwater area at the bay entrance. Vessel length restrictions are enforced at Mantua Creek (700 feet) anchorage to avoid vessels swinging outside anchorage boundaries during a change of tide. Of the upriver anchorages, only Marcus Hook provides depths compatible with the 40 foot channel. The most heavily used anchorages on the river are Marcus Hook and Mantua Creek. The dominant usage at those anchorages is by tankers for the refineries and bulk vessels, respectively. The anchorages are generally used to avoid accidents during foul weather and poor visibility; during lightering, bunkering or repairs; or while awaiting berth space or favorable tide conditions.

The Pilots Association and Mariners Advisory Committee have established operating procedures for safe vessel movement. Vessel sailing drafts of up to 40 feet inbound and outbound can utilize the present Delaware River, Philadelphia to the Sea project.

Traffic monitoring on the Delaware River system is accomplished by the U.S. Coast Guard, Philadelphia Maritime Exchange, and the Pilots' Association. A major consideration in this effort is tidal conditions. Rising tides are used to maximize cargo while maintaining safe underkeel clearance. The U.S. Coast Guard is notified of vessel arrivals at least 48 hours ahead of time. The Maritime Exchange maintains a record of scheduled arrivals and departures. The pilots coordinate among themselves to ensure safe and efficient vessel movements and they also communicate with the captains of other smaller vessels and tows operating on the river. Pilots also communicate with tug operators to arrange for docking assistance, if required. Tugs will accompany large vessels as they approach and depart port facilities for additional safety.

Vessel operations occur day or night on the major waterways using channel markers, range lights, and other physical references to guide navigation. Raycon (a radar transponder beacon, which emits a characteristic signal when triggered by the emissions of ship's radar) has been

installed at selected locations at the bay entrance and Big Stone Beach anchorage. It enhances the ability of vessel operators to determine vessel location during poor visibility conditions.

Typical vessel speeds in the Delaware River vary between 5 and 12 knots. Larger tankers operate with tug assistance during light traffic situations. Passing/meeting situations are limited at bends depending on vessel and traffic conditions. Traffic keeps in touch with the Maritime Exchange.

Vessels with drafts of 37 feet or less can safely operate without use of the tides. Vessels with drafts in excess of a 37-foot operating depth must rely on the tide. The critical area of concern for deep draft vessel operation in the Delaware River is the Marcus Hook Range, with its rock outcropping in the channel. Typical travel times are about 7-1/2 hours upriver, and 12 hours downriver.

2.4 Authorized Plan

The authorized deepening project as shown on Figure 2-1 provides for modifying the existing Delaware River Federal Navigation channel (Philadelphia to Sea Project) from 40 to 45 feet at Mean Low Water) with an allowable dredging overdepth of one foot, following the existing channel alignment from Delaware Bay to Philadelphia Harbor, Pennsylvania and Beckett Street Terminal, Camden, New Jersey. The channel side slopes are 3 horizontal to 1 vertical. The project also includes deepening of an existing Federal access channel at a 45-foot depth to Beckett Street Terminal, Camden, New Jersey.

The channel width (same as the existing 40-foot project) is 400 feet in Philadelphia Harbor (length of 2.5 miles); 800 feet from the Philadelphia Navy Yard to Bombay Hook (length of 55.7 miles); and 1,000 feet from Bombay Hook to the mouth of Delaware Bay (length of 44.3 miles). The project includes 11 bend widenings at various ranges as listed below as well as provision of a two space anchorage to a depth of 45 feet at Marcus Hook, Pennsylvania. The existing turning basin adjacent to the former Philadelphia Naval Shipyard will not be deepened as part of the 45 foot project.

Note that the Miah Maull – Cross Ledge bend is no longer being widened. Also, included as part of the Federal project is the relocation and addition of buoys at the 11modified channel bends. Ten new buoys are proposed: Philadelphia Harbor (2), Tinicum Range (1), Eddystone Range (1), Bellevue Range (3), Cherry Island Range (1), Bulkhead Bar Range (1), and Liston Range (1).

The following channel bends will be modified:

1. LISTON-BAKER: Maximum width increase on the east edge of 250 feet, over a distance of 4,500 feet south of the apex, and extending 3,900 feet north from the apex (BW2 - channel station 275 + 057);

BAKER-REEDY ISLAND: 100-foot width increase at the west edge apex of the bend over a distance of 3500 feet both north of and south of the apex (BW3 - channel station 265 + 035);

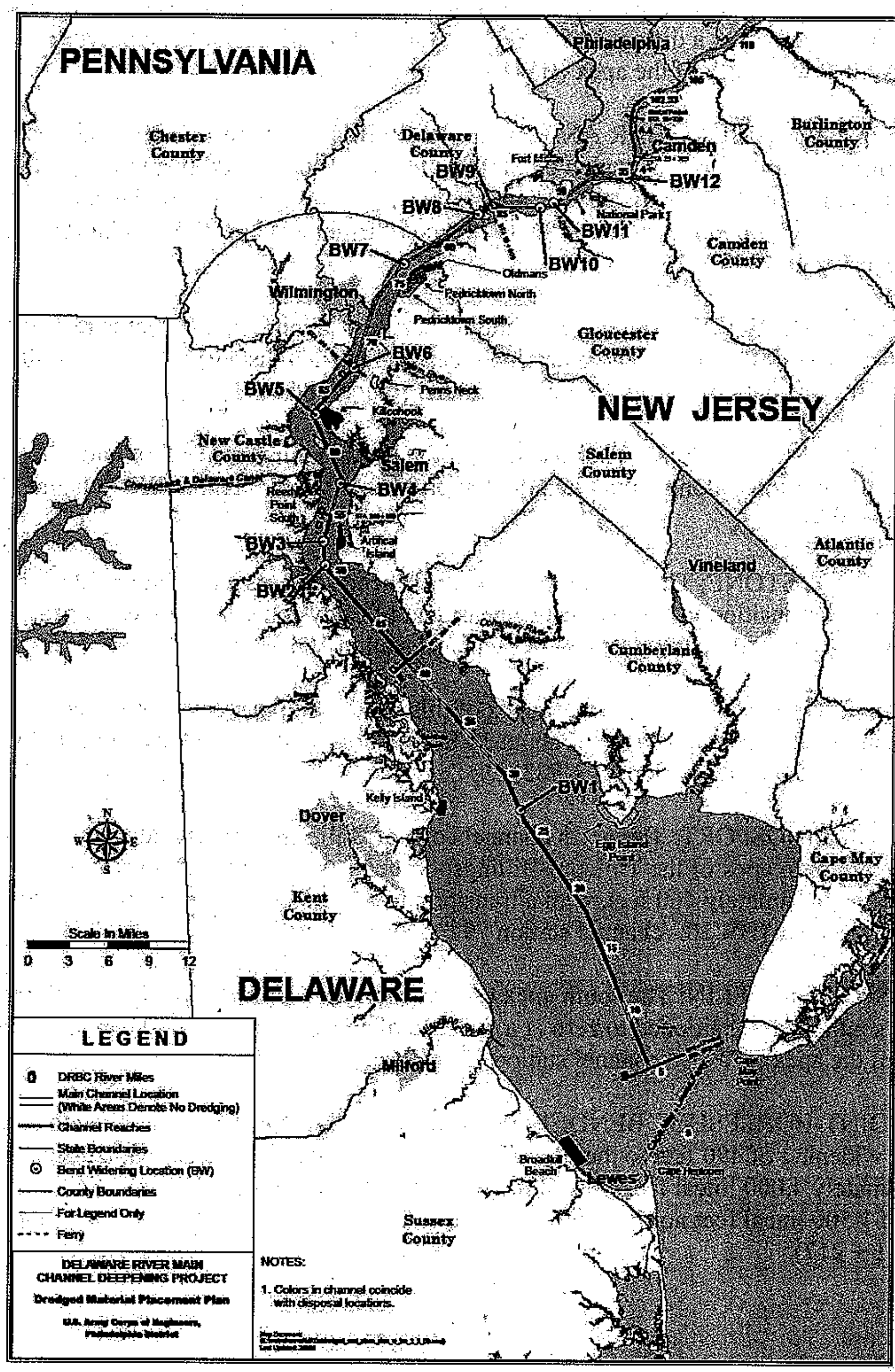


Figure 2-1. Delaware River Main Channel Deepening Project.

3. REEDY ISLAND-NEW CASTLE: Maximum widening of 400 feet at the west apex of the bend, tapering to zero over a distance of 3,200 feet south of the apex and to zero over a distance of 4,000 feet north of the apex (BW4 - channel station 238 + 982);

4. NEW CASTLE-BULKHEAD BAR AND BULKHEAD BAR-DEEPWATER: The west edge of Bulkhead Bar range is extended by 300 feet to the south and 300 feet to the north; the widening tapers to zero at a distance of approximately 3,000 feet south of the south end of Bulkhead Bar and 3,000 feet north of the north end of Bulkhead bar (BW5 - channel station 212 + 592 and 209 + 201);

5. DEEPWATER-CHERRY ISLAND: A maximum channel widening of 375 feet is required at the western apex of the bend. The widening tapers to zero at a distance of about 2,000 feet both north and south of the apex (BW6 - channel station 186 + 331);

6. BELLEVUE-MARCUS HOOK: The east apex of the bend requires a 150 foot widening over existing conditions, along a total length of approximately 4,000 feet (BW7 - channel station 141 + 459);

7. CHESTER-EDDYSTONE: The southwest apex of the bend requires a maximum 225 foot widening, with a transition to zero at the northeast end of Eddystone range, over a linear distance of approximately 6,000 feet (BW8 - channel station 104 + 545);

8. EDDYSTONE-TINICUM: The northeast apex of this bend requires a 200 foot widening, with a transition to zero at a distance of about 1,200 feet northeast and southwest of the bend apex (BW9 - channel station 97 + 983);

9. TINICUM-BILLINGSPORT: The north channel edge of Billingsport was widened by 200 feet. At the northern apex of the Tinicum-Billingsport bend, this results in a maximum widening of approximately 400 feet, with a transition to zero at a distance of about 2,000 feet west of the apex (BW10 - channel station 79 + 567 );

10. BILLINGSPORT-MIFFLIN: The south apex of the bend was widened a maximum of 200 feet to the south, and transitioned to zero at a distance of approximately 3,000 feet northeast of the apex (BW11 - channel station 72 + 574);

11. EAGLE POINT-HORSESHOE BEND: The northwest edge of Horseshoe Bend requires a maximum widening of 490 feet to the north. The widening transitions to zero at a distance of approximately 4,000 lineal feet west of the west end of Horseshoe Bend, and at a distance of 1,500 lineal feet north of the north end of the bend (BW12 - channel station 44 + 820 to 41 + 217).

**Table 2-1 Bend Modification Summary (Listed from Downstream to Upstream)**

| Bend Modifications | Area (Acres) | Substrate | Mean Elevation (Feet) |
|---|---|---|---|
| Liston - Baker | 31.0 | Silt | 43.3 |
| Baker – Reedy Island | 2.8 | Sand | 41.4 |
| Reedy Island – New Castle | 21.7 | Silt | 42.8 |
| New Castle – Bulkhead Bar and Bulkhead Bar - Deepwater | 7.7 | Sand | 41.2 |
| Deepwater – Cherry Island | 12.1 | Silt | 42.6 |
| Bellevue – Marcus Hook | 11.4 | Silt | 43.5 |
| Chester - Eddystone | 12.3 | Silt | 41.1 |
| Eddystone - Tinicum | 11.3 | Sand | 42.1 |
| Tinicum - Billingsport | 55.4 | Silt | 39.6 |
| Billingsport – Mifflin | 7.7 | Sandy-Silt | 43.0 |
| Eagle Point – Horseshoe Bend | 42.5 | Sandy-Silt | 38.3 |
| | | | |
| **Total Area** | **215.9** | | |



2.5 Refinements from Authorized Plan

2.5.1 Dredged Material Disposal Plan for the Delaware River

With regard to identification of suitable dredged material disposal sites, the 1992 Feasibility study and subsequent post authorization detailed engineering and design investigations divided the project area into five reaches (AA/A, B, C, D, and E). Reach AA/A extends from the upper project limit at Allegheny Avenue, Philadelphia PA to Billingsport Range, located near the Philadelphia International Airport. Reach B extends from Tinicum Range, located opposite of the airport to Cherry Island Range, located opposite of Wilmington, DE. Reach C extends from Deepwater Point Range, located below Wilmington, DE to New Castle Range, located at the mouth of the Chesapeake and Delaware Canal. Reach D extends from Reedy Island Range, located south of the Chesapeake and Delaware Canal to Liston Range, located just north of Delaware Bay. Reach E covers the remaining portion of the project area from the lower portion of Liston Range in the upper portion of Delaware Bay to naturally deep water in the lower portion of the bay.

The authorized project for disposal of Delaware River sediments from initial construction of the Delaware River Main Stem and Channel Deepening project was to use two existing Federally owned upland dredged material disposal areas (Reedy Point North and Reedy Point South) and procurement of three new areas identified as 17-O, Raccoon Island, and 15-D. During the Pre-construction, Engineering and Design (PED) Study this disposal plan was reviewed to identify changes in existing conditions. That review indicated that a previously considered site (17-G) was available and a portion of site 15-D (about 200 acres) was no longer available. Site 17-G was evaluated during the Feasibility Study but was not selected because of the expectation that it would be developed prior to initial construction. At the time of the PED Study the previous development plans for site 17-G had been discontinued and site 17-G was substituted for site 17-O, which had some cultural resource concerns. To compensate for the 200 acre reduction in site 15-D, site 15-G was added. This substitution of the two sites (17-G and 15-G) had no impact on the previously estimated project construction costs.

Using sites 17-G, a reconfigured 15-D, 15-G and Raccoon Island, a re-evaluation of the aforementioned disposal plan was made. The analysis included disposal capacity of existing Federal sites currently used for maintenance of the existing 40-foot project, and the required disposal capacity for initial construction of the 45-foot project and subsequent maintenance. The re-evaluation determined that the most efficient manner to construct the riverine portion of the 45-foot project (Reaches AA through D) was to utilize the existing Federal sites (National Park, Oldmans, Pedricktown North, Pedricktown South, Penns Neck, Killcohook, Reedy Point North, Reedy Point South, and Artificial Island) in combination with the four proposed sites (17-G, 15-D, 15-G, and Raccoon Island). Use of the existing, Federally owned Fort Mifflin site in Philadelphia for the disposal of rock removed in the vicinity of Marcus Hook, PA was also included. The use of existing Federal sites and the four new sites for initial construction and subsequent maintenance was found to be a cost effective plan that provided sufficient capacity for initial construction and 50 years of maintenance. The acquisition of sites 17-G, 15-D, 15-G and Raccoon Island would provide the Corps of Engineers with equivalent disposal area capacity to offset the loss of capacity incurred by the deepening project.

Since completion of the Preconstruction Engineering and Design Study and Supplemental Environmental Impact Statement in 1997, further engineering studies have reduced the quantities of material to be dredged (initial and maintenance) thereby reducing the amount of disposal capacity needed. Due to the decrease in overall project quantities, the dredged material disposal capacity that would have been gained from the four new sites (17-G, 15-D, 15-G and Raccoon Island) is no longer needed. Constructing and maintaining the 45-foot project for a period of 50 years utilizing existing Federal disposal sites only is both feasible and cost-effective. At the same time, it will eliminate all environmental impacts associated with construction and utilization of new disposal sites and substantially reduce the overall environmental impact of the project. The current dredged material disposal plan for the riverine portion of the project will only utilize the existing Federal sites (National Park, Oldmans, Pedricktown North, Pedricktown South, Penns Neck, Killcohook, Reedy Point North, Reedy Point South, and Artificial Island). The Fort Mifflin site in Philadelphia will also be used for disposal of rock removed in the vicinity of Marcus Hook, PA. Due to the decrease in initial and projected maintenance material throughout the river, the ultimate elevations for all of the Federal disposal areas are at or below that initially predicted in the 1992 Environmental Impact Statement. The initial assumption for

National Park in the feasibility stage was that dikes would be raised to elevation +70. Due to several renewable capacity contracts at national park which removed material and reconfigured dikes, in addition to changes in total quantities to be dredged initially and during operation and maintenance, the current anticipated final disposal area height after 50 years is +60. Additional details regarding the evolution of the dredged material disposal plan can be found in Appendix A of this document.



## 2.5.2 Beneficial Use of Dredged Material in Delaware Bay

The 1992 Environmental Impact Statement for the Delaware River Main Channel Deepening Project included beneficial use of material dredged in Delaware Bay (Reach E) during initial construction. Wetland restoration, island creation and sand stockpiling for future beach nourishment were proposed, but no specific sites were selected. Additional studies were conducted during the Preconstruction, Engineering and Design phase of project development. The 1997 Supplemental Environmental Impact Statement evaluated wetland restorations at Kelly Island, DE and Egg Island Point, NJ, and sand stockpiling for beach nourishment at Broadkill Beach, DE and Slaughter Beach, DE. The Record of Decision for the final Supplemental Environmental Impact Statement, dated December 18, 1998, indicated that due to fishery and habitat related concerns expressed by resource agencies, the Corps would consider placement of sand directly on Delaware beaches in lieu of offshore stockpiling. Accordingly, the current plan for beneficial use of material dredged in Delaware Bay (Reach E) for construction of the 45-foot project includes wetland restorations at Kelly Island, DE and Egg Island Point, NJ, and direct beach nourishment at Broadkill Beach, DE. Both the wetland restorations and beach placement will help control the severe erosion that is occurring at many areas along the Delaware Bay shorelines.

However, due to the reduction in the quantity of material to be dredged for the deepening project, there is not enough material in Delaware Bay to construct all three beneficial use projects during initial construction. As such, the Egg Island Point wetland restoration will be deferred until such time as sufficient dredged material quantities are available to support this element of the project. While this project feature would provide environmental benefits in Delaware Bay, it was not developed as project justification or as mitigation for project impacts. Therefore, no additional environmental benefits are required to offset deferral of Egg Island Point.

## 2.6 Initial Construction

For the initial deepening, material would be dredged and placed by hydraulic and hopper dredges in confined upland disposal facilities in the Delaware River portion of the project area and for beneficial uses in Delaware Bay (Figure 2-1). In addition, 77,000 cubic yards of rock would be removed in the vicinity of Marcus Hook, Pennsylvania and placed in the Fort Mifflin confined disposal facility in Philadelphia. The initial dredging quantities and placement locations are distributed among the project reaches as follows:

| | | |
|---|---|---|
| Reach AA | 994,000 cubic yards | National Park |
| Reach A | 1,666,600 cubic yards | Pedricktown North |
| Reach B | 4,664,900 cubic yards | Pedricktown North and South, Oldmans |

| | | |
|---|---|---|
| Reach C | 2,502,800 cubic yards | Killcohook, Reedy Point South |
| Reach D | 2,051,100 cubic yards | Reedy Point South, Artificial Island |
| Reach E | 4,081,700 cubic yards | Kelly Island, Broadkill Beach |
| Total | approximately 16,000,000 cubic yards | |

Dredging equipment is described in Sections 3.1.2.3 and 10.4.2.1 of the 1997 Supplemental Environmental Impact Statement. The channel dredging project will use hydraulic hopper and cutterhead dredges. See Section 3.0 of the 1997 SEIS. Rock will be removed from the channel by blasting.

2.6.1 Rock Removal

Approximately 77,000 cubic yards of bedrock from the Delaware River near Marcus Hook, PA (River Mile 76.4 to River Mile 84.6) would be removed to deepen the navigation channel to a depth of 47 ft below mean lower low water. Rock removal will require blasting. In order to remove the rock by blasting, holes drilled into the rock are packed with explosive and inert stemming material at the surface in order to direct the force of the blast into the rock. The depth and placement of the holes along with the size and blast timing delays of the charges control the amount of rock that is broken and energy levels released during the blasting operations. The project would be conducted by repeatedly drilling, blasting, and excavating relatively small areas until the required cross section of bedrock is removed.

The quantity of rock has varied as the project has developed. This is a result of a series of increasingly detailed investigations. The initial estimate (45,000 CY) during feasibility was based on available data at the time. A detailed geophysical investigation was performed during the PED phase which resulted in the quantity estimate rising to 229,000 CY, however there were numerous areas that the data came back questionable due to a high percentage of organic material in the overlying sediments impeding the acoustic and ground penetrating radar signals. A conservative hypothesis was formulated assuming these areas were rock. After the 1997 SEIS was published, confirmatory borings in the river were performed and the quantity of rock was refined to 77,000 CY.

Investigation of the feasibility of using rock for beneficial use resulted in findings that specific rock size was indeterminable due to the likely pulverization of most of the rock during blasting. A mixture of rock, cobbles, gravel, sand and mud would be excavated following the blasting and loaded on to barges. The feasibility of dumping this material in open water is precluded by the variation in material expected. After the rock is excavated and stockpiled on shore, a determination of its suitability and the economics of utilizing it for beneficial use can be made. It is likely that the cost of remanding, separating and transporting this material, will exceed the cost of commercially available supplies.

Adverse impacts to fish will be minimized by conducting blasting between 1 December and 15 March as recommended by the Delaware River Basin Fish and Wildlife Management Cooperative, and using controlled blasting methods such as delayed blasting and "stemming" or surface charges to reduce the amount of energy that would impact fish. In addition, fish

avoidance techniques will be utilized to drive fish away from the proposed blasting area to reduce the detrimental impact to the fish and benthic community. Monitoring of impacts to fish from the blasting will also be conducted to verify that impacts are minimal. The following plan has been coordinated and approved by the National Marine Fisheries Service.

The pre- and post-blast monitoring for fish including the shortnose sturgeon shall be conducted under the supervision of a principal biologist that has at least a Master of Science degree in fisheries biology or similar fields approved by the Contracting Officer. In addition, the principal biologist must have at least 3 years of experience in the estuarine/marine environment, which includes working with shortnose sturgeon, and the principal biologist must have obtained in their name the appropriate ESA permits to work with shortnose sturgeon.

Before each blast, four sinking gillnets (5.5 inch stretched mesh. 328 feet [I00 meters] long, 9.8-13.1 feet [3-4 meters] high) will be set to surround each blast area as near as feasible. These nets shall be in place for at least 3 hours and none of the nets will be removed any sooner than 1 hour before the blast. This may require ovenight sets. The nets shall be manned continuously to prevent obstructing the channel to ship traffic. Any sturgeon removed (shortnose or Atlantic) shall be tagged and released at a location approved by the NMFS.



Within 10 minutes of blast, channel nets (1-2 inch mesh) will be set during daylight hours downcurrent of the blast area and within approximately 300 feet from the blast area in order to capture and document dead or injured fish. The channel net shall have a minimum head rope length of 100 feet and should be retrieved approximately one hour later.

Surveillance for schools of fish will be conducted by vessels with sonar fish finders (with a LCD display screen) for a period of 20 minutes before each blast. The surveillance zone will be approximately circular with a radius of about 500 feet extending outward from each blast set. If fish schools are detected, blasting will be delayed until they leave.

Two scare charges shall be used at each blast. The scare charges shall be detonated in close proximity to each blast. Each individual scare charge shall not exceed a TNT-equivalent weight of 0.1 lb. The detonation of the first scare charge will be at 45 seconds prior to the blast, with the second scare charge detonated 30 seconds prior to the blast. It is necessary to employ the scare charges and conduct the surveillance surveys before each blast, as some fish have been found to recolonize the blast zone soon after a detonation.

All blast holes will be stemmed to suppress the upward escape of blast pressure from the hole. The minimum stemming shall be 2 feet thick. Stemming shall be placed in the blast hole in a zone encompassed by competent rock. Measures shall be taken to prevent bridging of explosive materials and stemming within the hole. Stemming shall be clean, angular to subangular, hard stone chips without fines having an approximate diameter of 1/2-inch to 3/8-inch. A barrier shall be placed between the stemming and explosive product, if necessary, to prevent the stemming from setting into the explosive product.

Blast pressures will be monitored and upper limits will be imposed on each series of 5 blasts.

Average peak pressure shall not exceed 70 pounds per square inch (psi) at a distance of 140 feet.

Maximum peak pressure shall not exceed 120 psi at a distance of 140 feet.

Pressure will be monitored for each blast only at a distance of 140 feet.

The Philadelphia District is currently processing a contract with a geotechnical consultant to conduct a detailed geophysical investigation of the rock-cut areas in the near future. The purpose of this investigation is to perform a specialized type of resistivity survey on the channel floor to obtain additional detailed information on the location, quality and condition of the bedrock materials that underlie the existing channel bottom. This study is being conducted in anticipation that we will acquire additional detailed information on the quantity and integrity of the existing bedrock that has to be removed, and based on review of previous rock core boring performed in the rock-cut areas, will enable us to more accurately focus and limit the amount of rock blasting required.

2.6.2 Kelly Island

The Kelly Island wetland restoration has been refined since the publication of the SEIS (July, 1997) based on coordination with the Delaware Department of Natural Resources and Environmental Control, the National Marine Fisheries Service and the US Fish and Wildlife Service. An updated description appears below.

The Kelly Island Project is a wetland restoration. The main purposes of the project are to restore intertidal wetlands using dredged sediment from the deepening of the Delaware River navigation channel, stem erosion of the Kelly Island shoreline estimated at 20 feet per year, provide extensive sandy beach for spawning horseshoe crabs, and provide continued protection to the entrance of the Mahon River.

Restoring wetlands in this environmentally sensitive area has been a high priority for the State of Delaware. A plan has been developed with the assistance of the Federal and State resource agencies to restore 60 acres of intertidal habitat (Figures 2-2 and 2-3). Between 120 and 140 acres represents the total footprint of the wetland and protective beach associated with the entire Kelly Island project. The site will be constructed as an impoundment and remain as such until the sediments consolidate and vegetation becomes established. At that time, the State of Delaware will decide whether to open the site up to unregulated tidal inundation. The option to convert back to an impoundment will be maintained. Following construction, the site will be monitored to insure that the goals of the project are met and that no adverse impacts occur, particularly impacts to oyster beds.

Features of the project include:

- Sixty acres of wetlands where the substrate will consist of an estimated 55,000 cubic yards of silt and 645,000 cubic yards of sand.

- An offshore containment dike made of 1.7 million cubic yards of sand that will provide up to 5,000 linear feet of sandy beach. The crest of the dike will be at +10 ft MLW providing substantial spawning habitat for horseshoe crabs.
- A geotextile tube within the core of the offshore dike that provides overwash protection and contingency protection against breaching.
- Timber groins to limit sand transport along the beach.
- Options for water level control or free tidal exchange with the bay.



Construction of the sand dikes will begin at the south end gaining access to the site from the Mahon River channel. Once the dikes are constructed, the interior will be filled. Filling will take approximately 4 months. The total time to construct Kelly Island is 6 months. Construction is scheduled to occur between April and September to preclude potential dredging impacts to overwintering blue crabs between December and March. Once the containment area/beach is constructed, fine-grained sediment will be placed first followed by placement of sand. The volume of sediment to be placed in the site will ultimately achieve a surface elevation of +5 feet MLW which is at the upper part of the tidal range. After construction, and possibly for several years, the water levels in the site will be controlled.

The offshore dike will have a crest elevation of +10 feet MLW. This elevation is coincident with the water level for a return interval between 10 and 25 years. It is only during rare events that this sand dike will be overtopped. The dike is expected to provide up to 5,000 linear feet of spawning habitat for horseshoe crabs.

The crest width of the dike will be 200 feet at its narrowest and 350 feet at its widest. The volume of sand in the cross section of the dike will be constant, i.e. 845 cubic yards per linear yard. Therefore, the crest width of the dike in shallow water will be greater than in deeper water. The total volume of sand required for the offshore dike is 1.7 million cubic yards (which includes a quantity sufficient to offset an estimated one foot of settlement). The offshore slope of the dike is estimated to be initially 1:20, and after the first year of "weathering" it should equilibrate to a milder 1:40 slope.

The southern end of the offshore dike will terminate on the island. The elevation of the crest of the dike will transition from +10 feet MLW to the +7 feet MLW (approximate) elevation of the existing marsh. The dike will extend onto the island far enough to prevent southerly waves at high water levels from damaging any portion of the interior of the project. The dike will also extend beyond its connection with the landward dike.

The northern end of the offshore dike will extend approximately 300 feet beyond Deepwater Point roughly parallel to the shoreline. The outlet works for the project will be placed at Deepwater Point, and so the offshore dike will protect that location.

A geotextile tube will be placed within the offshore dike as a factor of safety against a breach in the dike due to an extreme event and overwash. The crest of the tube will be placed to a crest elevation of +7 feet MLW. The tube will then be buried under an additional three feet of sand bringing the crest of the dike up to elevation +10 feet MLW. The protection that the tube

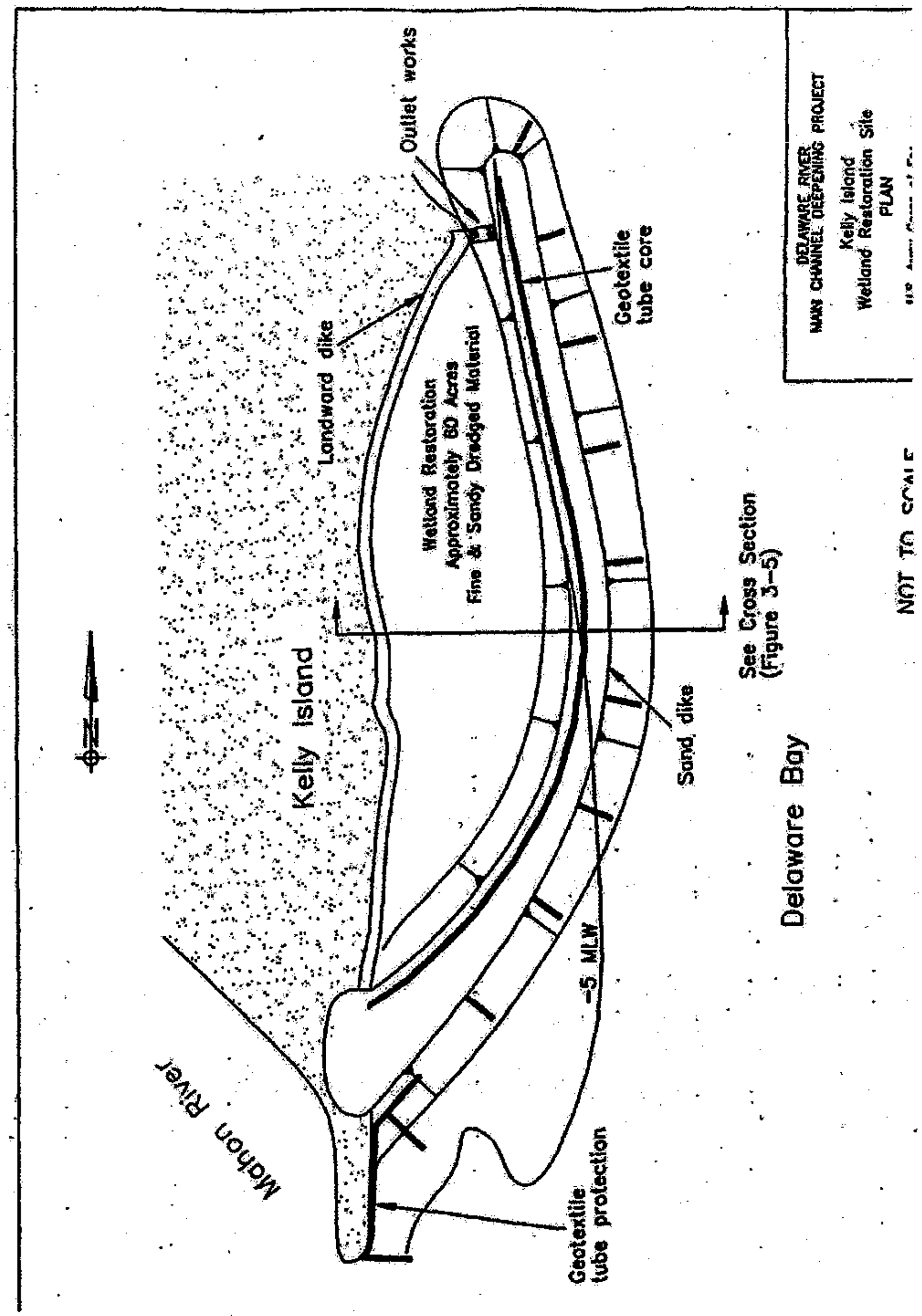




Figure 2-2. Kelly Island Plan.

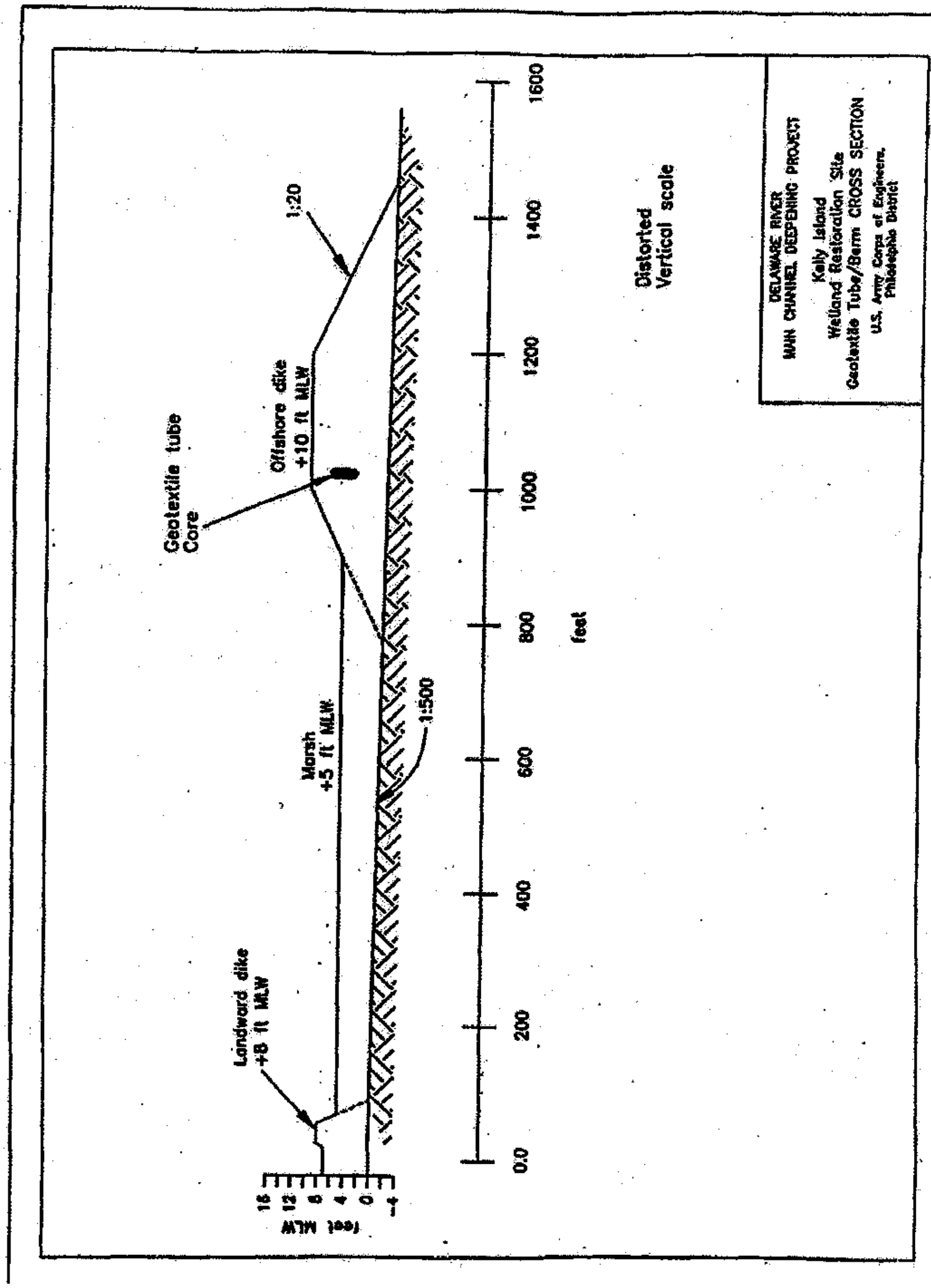


Figure 2-3. Kelly Island Geotextile Tube/Berm Cross Section.

provides should allow time for maintenance or repair work to be planned and executed if a breach should develop due to overwash.

A landward dike will be constructed along the edge of the existing marsh with a crest elevation of +8 feet MLW. The dike crest width will be 20-30 feet. The dike will prevent dredged material from flowing across or settling in the existing marsh. The dike will be built-up by trucking sand from the larger offshore dike to the landward dike during construction. The dike will not be constructed by hydraulic placement of sand. The dike will be left in place after construction to impound the site. In the future, if the State of Delaware decides that the site should function with unregulated tidal exchange with the bay, the landward dike may be removed. However, if the capability to impound the site at some future date is necessary, then the landward dike should not be removed.

Groins made of either timber or vinyl will be placed along the perimeter of the offshore dike to help limit longshore transport. Although the cross-section of the dike is designed to sustain sediment losses for many years without losing any of its function, groins will increase the longevity of the project, reduce potential maintenance, and add a factor of safety against the risk that sand will be transported south along the project into the Mahon River entrance. The groins will extend seaward from the crest of the dike about 240 feet. They will extend landward from the crest of the dike about 50 feet. Therefore, their total length is 290 feet. The groins will follow the initial profile of the dike having a 1:20 slope from the crest of the berm to MLW. The crests of the groins will be nominally about 2 feet above the sand berm initial cross-section. The groins will be spaced about 750 feet apart. At both ends of the project, terminal timber sheet-pile groins will be constructed that are 450 feet long. The groins will be constructed after the sand berm is constructed.

The outlet works for the marsh will be placed through a cross-shore sand dike at the north end of the project extending from the tip of Deepwater Point to the offshore dike. The elevation of the crest of the cross-shore dike will be +8 feet MLW which is sufficient to prevent even the annual highest high-tide from overtopping the dike. This elevation also provides sufficient freeboard so that water levels in the site can be held high if needed. The cross-shore dike does not need additional elevation to prevent wave overtopping because it is protected from waves by the offshore dike. A geotextile tube like the one described for the offshore sand dike will be placed in the core of the cross-shore dike. The flows through the outlet works during dredging depend mainly on the depth of water above the weir crests.

The outlet works will have outflow pipes that pass through the core of the cross-shore dike. The cross-section of the cross-shore dike will be held to a minimum to minimize the length of outlet pipe required. The actual crest width of the dike will depend on the stability of the foundation upon which the dike is built. The dike will be filled until a stable cross-section is achieved. The dike will be constructed by moving sand from the offshore dike with heavy equipment so that steeper side slopes can be achieved which will minimize the dike cross-section.



The outlet works provided at the north end of the project will control release of water during dredging. Several drop inlets are planned. The capacity of the outlet works will depend on the size of the dredge pump and discharge line, the frequency of hopper discharges (cycle time), and

water control requirements for post-construction marsh management. But the potential to release water at a rate as high as 75-100 cfs may be required.

An outlet works at the southern end of the project will not be necessary for dredging purposes. However, tidal connection to the southern end of the site may be desired after the marsh develops and natural flow patterns emerge. Any additional tidal connection will be achieved, for example, through small tidal guts through the existing marsh to the Mahon River and not through the offshore dike. A tidal gut presently exists near the south end of the project and may provide an ideal connection with the Mahon River.

Further description and need for the Kelly Island wetland restoration can be found in Section 3.3.3.2 of the SEIS (July, 1997). Pages 3-50 to 3-53 provide details on project elements including planting, seeding, creation of ponds and ditches.

2.6.3 Egg Island Point

The Egg Island Point wetland restoration is described in detail in Section 3.3.3.2 of the SEIS (July, 1997) and summarized below (Figures 2-4 and 2-5). As previously stated this project feature is being deferred until such time as sufficient dredged material quantities are available to support this element of the project. The appropriate environmental coordination will be conducted with Federal and State resource agencies at that time.

The project features are as follows:

- Southeast side: Create 135 acres of wetlands (500,000 cubic yards of sand). Construct an offshore dike (1.7 million cubic yards of sand) and 700 feet of sandy beach.
- Northwest side: Install staggered alignment of geotextile tube breakwater along 10,000 feet of eroding shoreline. Tubes will be installed on sand foundation/leveling berms using approximately 275,000 cubic yards of sand for the berms and 25,000 cubic yards in the tubes. These quantities are included in the 1.7 million cy total for berm estimate.
- Provide spawning habitat for horseshoe crabs and feeding habitat for migratory shorebirds on the beach face.
- Maximize habitat for winter and summer flounder in the wetlands.

Much of the information for geotextile tubes and structures presented for Kelly Island is applicable to both shorelines of Egg Island Point. The northwest and southeast treatments, configurations, placements, and techniques differ considerably. The Egg Island project will require approximately 20 months to build, with about 14-15 months of continuous depositing of sand. The only time that the contractor would shut down would likely be for a short period in the January-February time frame, and during storm events. It should be noted that only a small portion of the 4 miles of frontage (approximately 1000 feet) for the project would be active at any point in time.

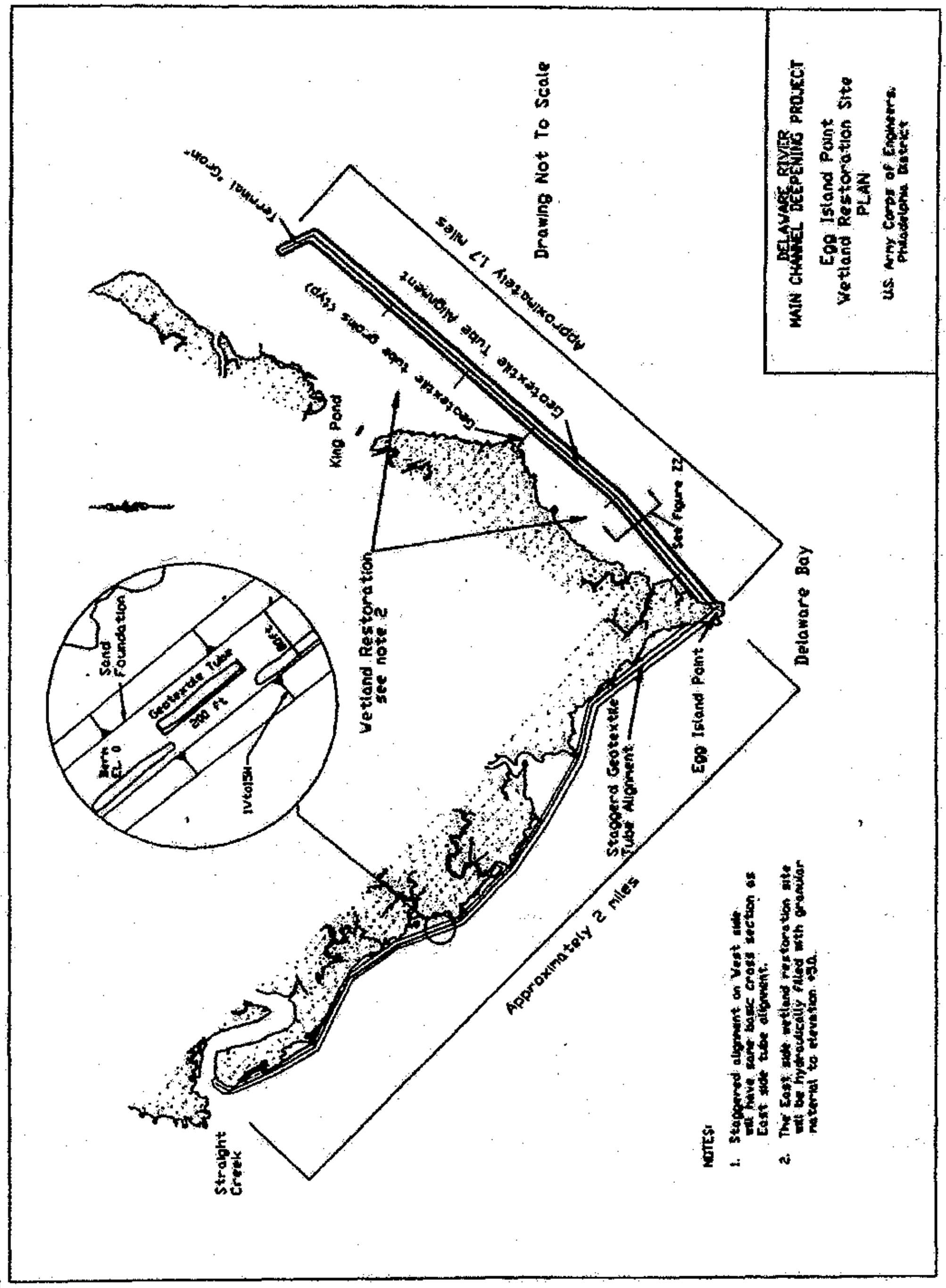




Figure 2-4. Egg Island Point Plan.

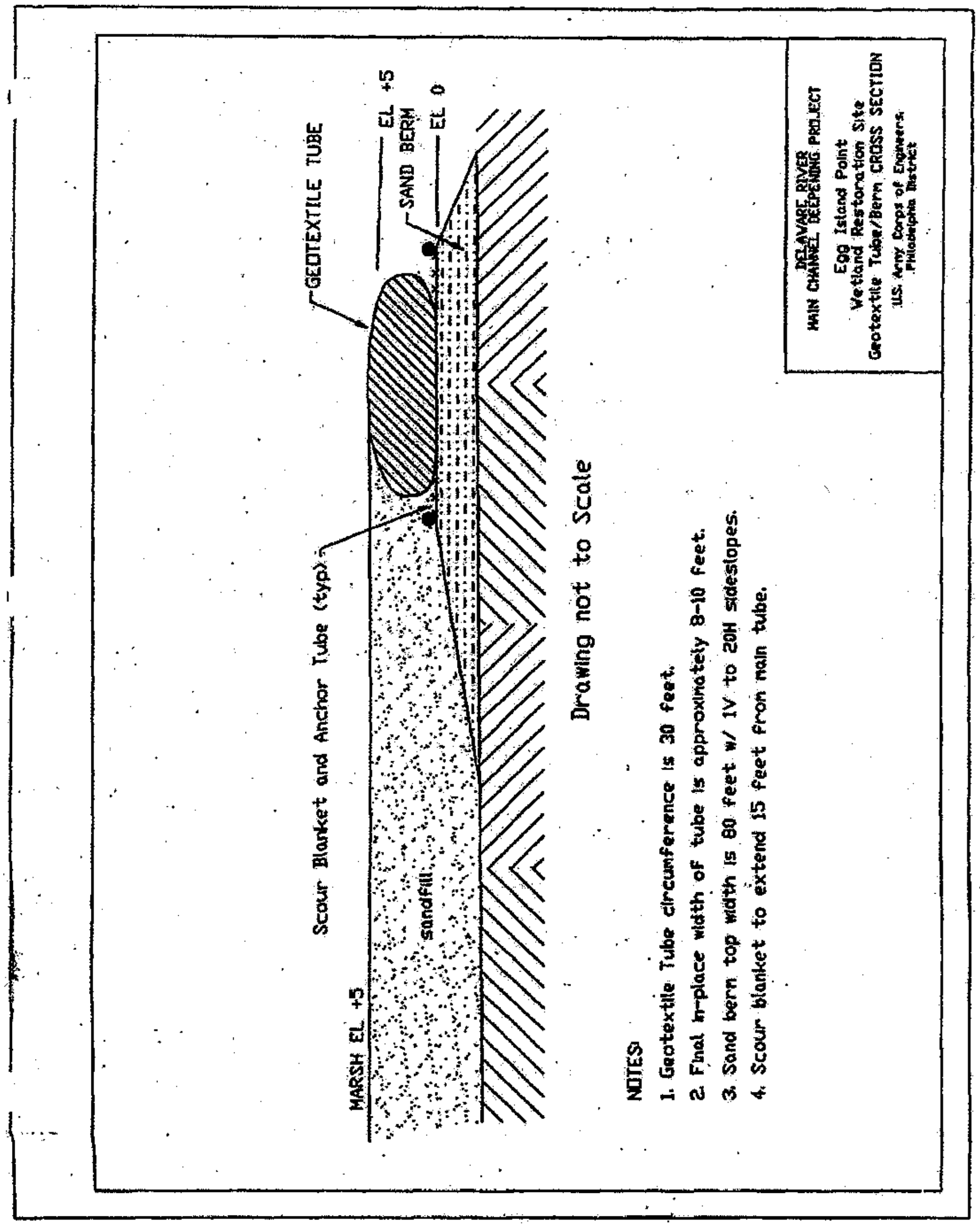


Figure 2-5. Egg Island Point Geotextile Tube/Berm Cross Section.

The southeastern side of the existing marsh at Egg Island Point will be protected by a single geotextile tube structure. The geotextile tube will be placed on top of a dredged material sand foundation built to elevation 0 feet MLW away from the eroding shoreline. The side slopes of the foundation are expected to reach 1:20. The crest elevation for the tube is expected to reach an elevation of +5 feet MLW. The area within the lee of the structure will be filled with sandy dredged material to an elevation of + 5 feet MLW. These elevations will be inundated daily during high tide periods which are expected to reach elevations of +5.5 feet MLW to +6.2 feet MLW (spring high tide). Consequently, waves will often overtop the project. The structure and the fill behind it should attenuate much of the wave energy.

Scour Blanket. Using the design wave height of 6.2 feet and a water depth at the structure of 6 feet, the recommended scour blanket width should be 13 feet. The scour blanket (geotextile fabric) will be anchored along its seaward edge with a factory-stitched anchor tube of one to two feet in diameter below 0 feet MLW, and it will be buried in the substrate.

As an added precaution, the scour blanket and anchor tube will be extended to either side of the tube. It is important to have the scour blanket on the leeward side of the tube to prevent overtopping wave scour from undermining the tube. Overtopping scour problems are more likely at this site than at the Kelly Island site due to the differences in breakwater heights.

Length of Geotextile Tube Segments. Geotextile tubes about 200 feet in length will be used. The use of tubes of this length improves the structures integrity (i.e. should any particular tube be damaged, only a small section of the structure would suffer and could be more easily repaired). Experience has also shown that deploying more than 300 feet of geotextile tube at any one time can be difficult to control or hold in place while filling.

Geotextile Tube Fabric. Fabric needs for Egg Island Point are very similar to Kelly Island. Dredged material filling the tubes will be sandy, and the same wave and wind energies occur at both Egg Island Point and Kelly Island.

The region behind the structure on the southeastern shoreline of Egg Island Point will be filled with sandy dredged material to an elevation of +5 feet MLW. This is equal to the elevation of the geotextile tube crest. The expected occurrence of events are that the area immediately behind the tubes will be scoured somewhat and, in general, material will be moved toward the existing marsh where a small berm or dune may form.

At the Egg Island Point project, as sand behind the breakwater (tubes) is pushed back toward the existing marsh, it may cover over some of the existing marsh. The amount of sand overwash will depend on the amount of wave energy exposure that the site receives before the project is densely colonized by marsh vegetation. The sand overwash may alter the existing marsh locally but should not be considered a long-term detriment.



Waves approaching the tubes obliquely will cause material within the project to move laterally across the project. No technique is available to determine how much transport will occur. However, any dominant wave direction will move the fill material in that direction. At Egg Island Point, waves are limited from the north and east due to land boundaries, but are fully

exposed to waves from the south and west. Hence, the tendency should be for material to move north and east across the project. Initially, the adjustment of sand due to the wave climate may be dramatic, but as the sand achieves a more stable profile across the project area, the amount of sediment movement should diminish and then slow as vegetation colonizes the area.

If sand moves from behind the tube breakwater under the conditions described above, it should behave the same as the sand placed in the structure foundation. Sediment transport impacts are discussed in Section 9.0 of the 1997 Supplemental Environmental Impact Statement.

Since the single row of tubes will be inundated by about 0.5 to 1.0 feet MHW along the entire length of the tube, additional measures are not necessary to ensure tidal flushing. In the event that a second row of tubes is needed, then tidal flushing may be sufficiently accomplished by leaving a few gaps in the second row of tubes. The amount of such openings should be determined after the project is constructed, and natural exchange mechanisms have had time to develop.

Most of the concern for tidal exchange is for the region between the westernmost point of the island, and the marsh point that extends nearly to the breakwater line of tubes near the center of the project. It is assumed that regardless of the structure design, there will be sufficient tidal exchange through the easternmost open end of the tube breakwater (towards the Maurice River Cove).

As stated above, there is only enough sand to construct one of the two wetland restoration sites at this time. Kelly Island was chosen over Egg Island Point for several reasons. The first reason is that the design of Kelly Island was enhanced greatly as a result of coordination with the Bombay Hook refuge and DNREC. The original confinement area was solely constructed of geotubes and did not provide extensive horseshoe crab habitat. In addition there was concern over migrating sand. Ten timber groins were added to the design to mitigate this issue. The risk associated with the success of Egg Island Point was much greater due to its reliance on geotubes as its primary structure. The intent was that they provide temporary protection until the marsh establishes itself. Subsequent study of geotube structures since 1997 reveal a less than positive performance when utilized in open water subject to constant wave attack There were also great concerns over its location with respect to oyster beds in the immediate vicinity of the perimeter dikes at Egg Island Point, whereas at Kelly Island the closest beds are a greater distance from the site. Since the 1997 SEIS the amount of silt required to be confined at Kelly Island has been reduced from 200,000 cubic yards to 55,000 cubic yards. Although this has no effect on the design or performance of the

### 2.6.4 Broadkill Beach

Broadkill Beach was the subject of the Delaware Bay Coastline – Delaware and New Jersey, Broadkill Beach, Delaware Interim Feasibility Study. A final Feasibility Report and Environmental Impact Statement is dated September 1996. That Environmental Impact Statement is incorporated by reference and is referenced herein as USACE (1996). The authorized project for coastal and storm damage reduction along the community of Broadkill

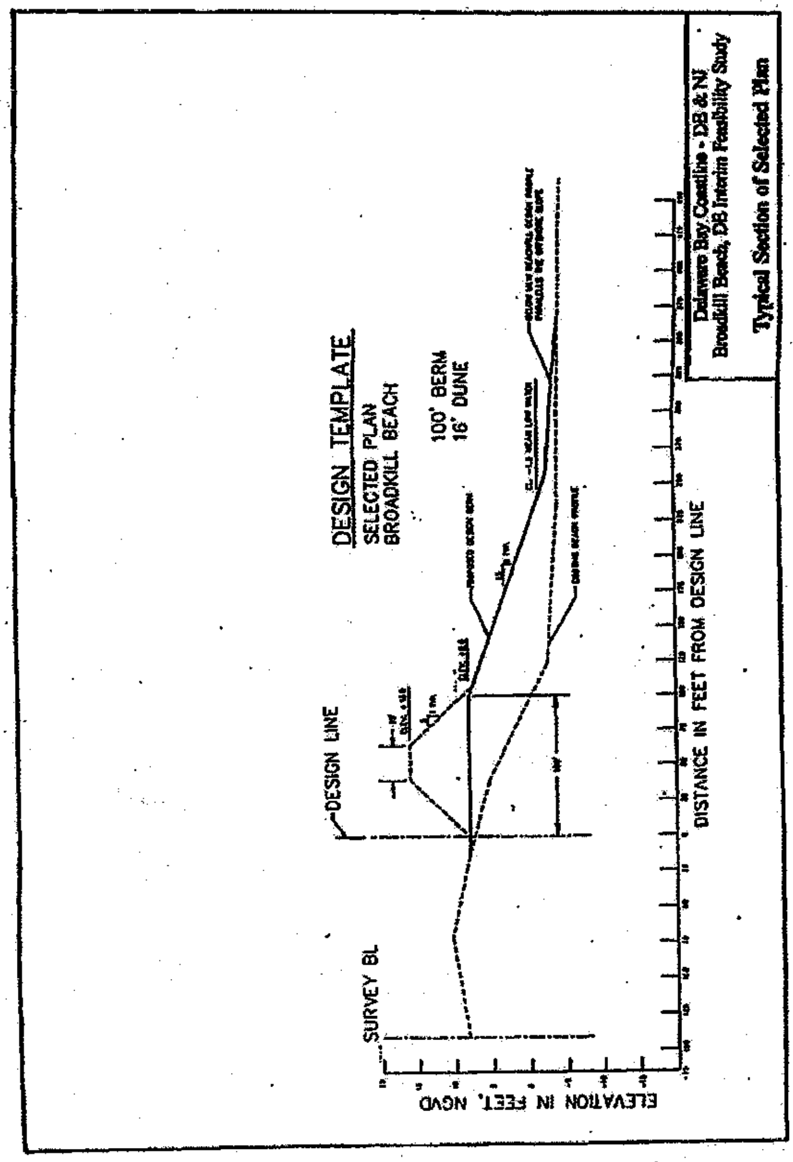


Figure 2-6. Broadkill Beach Design Template.

Beach is shown in Figure 2-6. The NED plan was defined as that plan which maximized beneficial contributions to the Nation while meeting planning objectives. Broadkill Beach was selected, following the 1997 SEIS, as it was one of the State of Delaware's priority placement sites. The material slated for stockpile L-5 was stockpiled offshore of Broadkill Beach due to its proximity to the Brandywine range in the Delaware River channel. The locations that were higher on the State's priority list were Rehoboth, Kitts Hummock, and

Port Mahon. The quality of the sand made it unattractive for placement on Rehoboth Beach, or any oceanside beach due to much more severe wave climate. The Port Mahon and Kitts Hummock beaches did not have the capacity to accept the projected quantities of sand required to be disposed of and the cost of placing the sand at multiple locations was prohibitive.

The Broadkill Beach plan consists of a 100-foot wide berm at an elevation of +8 feet NGVD. The selected plan has the following components:

* A berm extending seaward 100 feet from the design line. The beachfill extends from Alaska Avenue southward for 13,100 linear feet. Tapers of 1,000 feet extending from the northern project limit and 500 feet extending from the southern project limit brings the total project length to 14,600 linear feet.

* On top of the berm lies a dune with a top elevation of +16 ft NGVD and a top width of 25 feet.

* A total initial volume of 1,597,700 cubic yards of sand fill would be placed along the area. This fill volume includes initial design fill requirements and advanced nourishment. Note that the initial volume design quantity will change over time due to natural accretion and erosion.

* Periodic nourishment of 358,400 cubic yards of sand fill would be placed every 5 years.

* Planting of 174,800 square yards of dune grass and 21,800 linear feet of sand fence are included for dune stability.

* Vehicular access to the beach would be provided at Route 16 in the center of Broadkill Beach. Sand fence would be used to create a path 12 feet wide along both sides of the dune at a skewed angle to the dune alignment. This would allow vehicles to climb along the side of the dune at a flatter slope than 5H:1V.

* Pedestrian access paths would be located at each street end in a similar fashion as the vehicular access. However, the access paths would be smaller in width and at a somewhat steeper slope.

Since dredging for deepening in the vicinity of Broadkill Beach will yield high quality sand, there is opportunity to synchronize the deepening project with the Broadkill Beach project and beneficially use the sand as a source for constructing the Broadkill Beach project. This is consistent with the 1997 SEIS. In addition, this activity will involve placement of sand directly

on the beach as requested by resource agencies, instead of stockpiling offshore, as originally proposed.

For protection of the sandbar shark, the following measures will be implemented to allow construction between 1 May and 15 September:

A sand dike, 200 to 300 feet in length, will be constructed above mean high water (MHW) to contain dredged material that is pumped landward of it. The dike will be constructed using existing sand on the beach. The dike will be long enough that most dredged material will drop out on the beach and not return to the bay. As material is deposited the dike may be repositioned seaward to contain the required tilling above MHW for that section of beach. The slurry will still be controlled by the dike along the shoreline. No dredged material will be hydraulically placed below MHW during the restricted period. The dike will be extended down the beach as the area behind the dike is tilled and the dredged pipe is lengthened. The dredged material that has been deposited will be built into dunes. It is expected that little of this material will be re-deposited by wave action during the spring/summer window period since weather is generally mild, except for possible hurricanes. After September 15, some dredged material will be graded into the bay to widen the beach.

The dredge pipe will be placed on pontoons for a minimum of 1000 feet, beginning at approximately elevation -4.7 NGVD, extending offshore to avoid disrupting along shore traveling by the young sandbar sharks. This distance will be determined by the National Marine Fisheries Service. The remainder of the pipeline extending to the beach, and back to the dredge, can rest on the bottom.

2.7 Construction Schedule

Figure 2-7 shows the construction schedule and the type of dredge that would be used for different sections of the river for the Deepening Project. Dredging was scheduled to be in compliance with Delaware River Basin Fish and Wildlife Management Cooperative recommended dredging restrictions for protection of fishery resources in the Delaware River and Bay (Appendix C). Time periods shaded grey are the recommended periods for hopper dredging, cutterhead pipeline dredging, bucket dredging, sand placement and blasting. All windows will be met in Reaches AA, A, B, C, D, and E above River Mile 32. Dredging below River Mile 32 and shoreline work at Kelly Island and Broadkill Beach can not meet the recommended windows. The only period of time that meets all recommended restrictions for these areas is the first half of the month of April. The impact of not meeting the recommendations in these areas is discussed in Section 4 of this document.

2.8 Operation and Maintenance

The required maintenance dredging of the 45-foot channel will increase by 862,000 cubic yards per year (cy/yr) from the current 3,455,000 average cy/yr for the 40-foot channel for a total of 4,317,000 cy/yr. Areas more shallow than 45 feet will be dredged.

2.9 Economic Benefits

National Economic Development (NED) benefits follow the guidelines and procedures established in the Economic and Environmental Principles for Water and Related Land Resources Implementation Studies, February 3, 1983; the Planning Guidance Notebook, ER 1105-2-100, 22 April 2000; and the National Economic Development Procedures Manual – Deep Draft Navigation, IWR–91–R-13, dated November 1991.

The Principles and Guidelines defines NED benefits as follows:

"Contributions to national economic development (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 the rest of the Nation. Contributions to NED include increases in the net value of those goods and services that are marketed, and also of those that may not be marketed."

The NED benefits quantified include the reduced costs of transportation realized through operational efficiencies (reduced lightering and lightloading), and the use of larger more efficient vessels, both resulting from navigation improvements at the harbor. Reduced transportation costs result in reduced production and distribution costs and thereby increase the net value of the national output of goods and services.

Benefits will result from the decrease in the cost per ton for shipping commodities into or out of the Delaware River Port System. The 45 foot channel depth will improve the economic efficiency of ships moving through the Delaware River ports. No induced tonnage (i.e., commodity shifts from other ports) will take place with the proposed project deepening. The largest vessels in the port fleet, crude oil tankers, currently lighter at Big Stone Anchorage in the naturally deep water of the lower Delaware Bay. These vessels will continue to carry the same tonnage from the foreign origin ports but will be able to operate more efficiently in the Delaware River with a deepened channel from reduced lightering. This will also result in a reduction in barge traffic needed to move the lightered crude oil upriver to the refineries. Also, a deeper channel depth will allow current dry bulk and container vessels to carry more cargo as well as allow a fleet shift in the charter dry bulk market. These factors will more efficiently apportion operating costs over a greater amount of tonnage and further reduce total vessel trips through the port. Finally, benefits are claimed for cost reductions resulting from beneficial reuse of dredged material at the authorized Broadkill Beach Project. Benefits have been estimated for liquid bulk, dry bulk, and containerized cargo.

Economic benefits are annualized for the 50-year study period. All project benefits are computed in the Fiscal Year 2009 Price Level and are discounted at the Federal Fiscal Year 2009 discount rate of 4-5/8%.

Categories of Benefits

The categories of benefits include:

Vessel efficiencies;

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WETLANDS

| DELAWARE DEEPENING DREDGING CONTRACTS | River Mile | Duration (Mo) | Estimated Quantity (cy) | Dredge | |
|---|---|---|---|---|---|
| Contract No. 1 (award year 1) | | | | | hyd |
| Reach C- Bulkhead Bar | | | | | HYD |
| 183+000 to 206+201 - Killcohook | 68.3 | 1.65 | 932,600 | 1 | |
| 206+201 to 225+000 - Reedy Pt South | 63.9 | 2.76 | 597,800 | 1 | |
| 225+000 to 242+514 - Killcohook | 60.3 | 1.38 | 972,400 | 1 | |
| Construct Project | | | 2,502,800 | | |
| | | | | | |
| Contract No. 2 (award year 1) | | | | | bla |
| Reach B - Rock Blasting | | 3.17 | | 1 | BLA |
| Reach B - Rock Dredging - Fort Mifflin | | 1.27 | | 1 | MEC |
| Construct Project | | | 77,000 | | |
| | | | | | mec |
| Contract No. 3 (award year 2) | | | | | hyd |
| Reach AA - National Park | | 2.88 | 994,000 | 1 | HYD |
| 19+700 to 32+756 | 99.2 | | | | |
| Reach A - Pedricktown North | | 6.1 | 1,666,600 | 1 | HOP |
| 32+756 to 90+000 | 96.8 | | | | |
| Construct Project | | | 2,660,600 | | |
| | | | | | |
| Contract No. 4 (award year 3) | | | | | hop |
| Reach E - Broadkill Beach - Dredge | | 3 | | 2 | HOP |
| 461+300 to 512+000 | 15.6 | | | | |
| Construct Project | | | 1,598,700 | | |
| | | | | | hyd |
| Contract No. 5 (award year 4) | | | | | hop |
| Reach E - Kelly Island -Dredge | | 4.5 | | 2 | HOP |
| 351+300 to 360+000 | 36.4 | | 345,800 | | |
| 360+000 to 381+000 | 32.1 | | 55,500 | | |
| 381+000 to 461+300 | 30.8 | | 2,081,700 | | |
| Construct Project | | | 2,483,000 | | |
| | | | | | |
| Contract No. 6 (award year 5) | | | | | hop |
| Reach D - | | | | 1 | HOP |
| 249+000 to 270+000 - Reedy Pt. South | 55.8 | 1.13 | 396,300 | | |
| 270+000 to 324+000 - Artificial Island | 51.8 | 4.63 | 1,654,800 | | |
| Construct Project | | | 2,051,100 | | |
| | | | | | |
| Contract No. 7 (award year 6) | | | | | hyd |
| Reach B - Oldmans | | 0.89 | 1,671,400 | 1 | HYD |
| Reach B - Pedricktown North | | 3.51 | 1,050,700 | 1 | HYD |
| Reach B - Pedricktown South | | 3.13 | 1,942,800 | 1 | HYD |
| 90+000 to 176+000 | 0.0 | | | | |
| Construct Project | | | 4,664,900 | | |
| | | | | | |
| | | | | | hop |
| | | 19.21 | 15,961,100 | | |
| UPDATED 9 March 2009 (2:00 a.m.) | | | (No Rock) | | |

| | |
|---|---|
| HOP | HOPPER DREDGE |
| HYD | CUTTER SUCTION DREDGE |
| | LANDSIDE CONSTRUCTION |
| MEC | CLAMSHELL DREDGE |
| BLA | DRILLBOAT (BLASTING) |
| | DREDGING WINDOW |

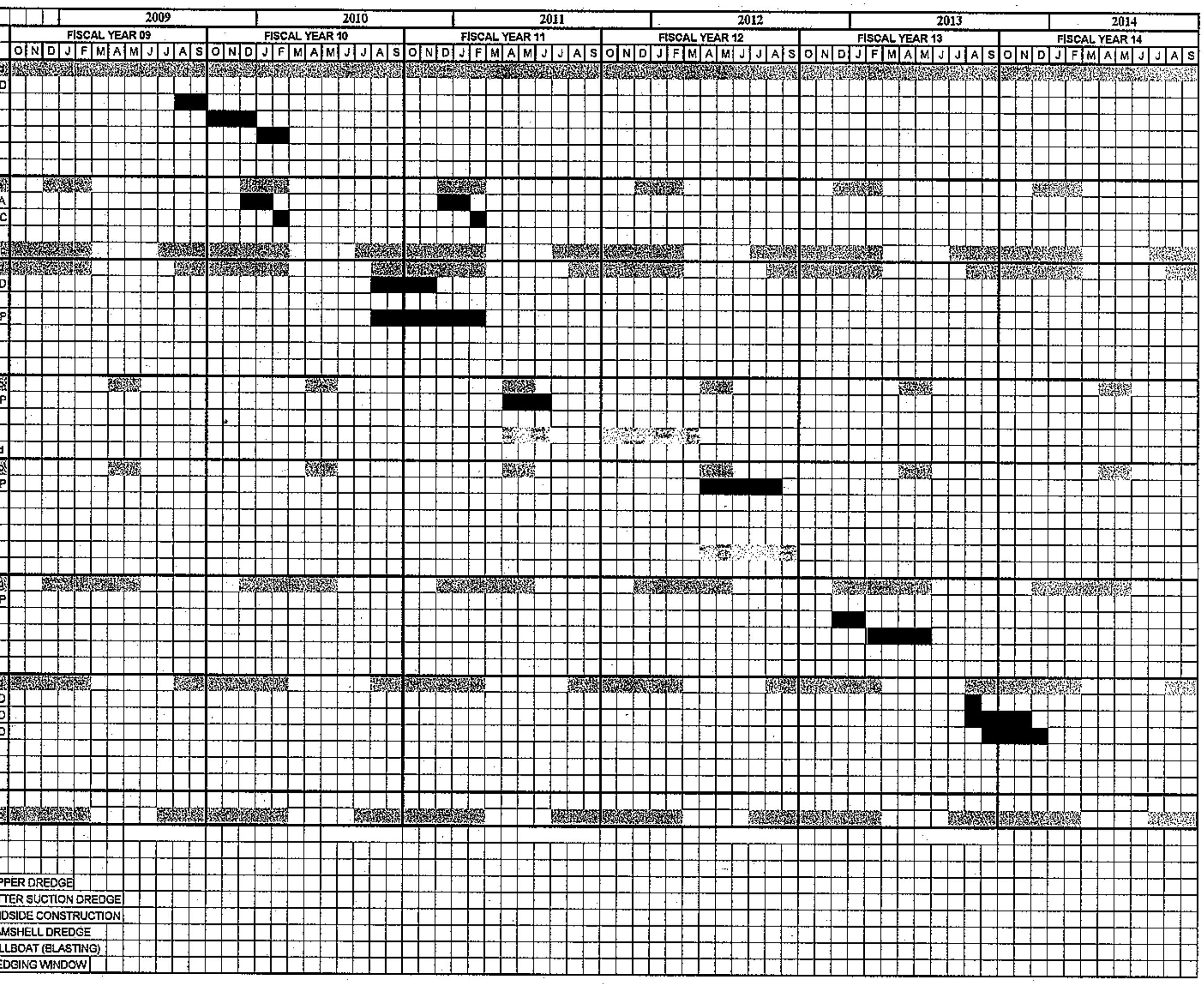



Figure 2-7 Delaware River Main Channel Deepening Project Construction Schedule

Vessel operating cost savings;

Operational efficiencies; and

Beneficial use of dredged material

Vessel Efficiencies

In the category of transportation cost savings resulting from vessel efficiencies, benefits have been identified based on the shift to larger vessels on specific trade routes. Vessel efficiencies have been identified for container ships, liquid bulk and dry bulk vessels.

Operational Efficiencies

Benefits resulting from operational efficiencies have been identified for:

- Reduced liquid bulk (crude oil) lightering: Deeper channels would allow some of the liquid bulk vessels that require lightering to access port facilities with reduced or no lightering. In some cases, this will also result in reduced transit times.
- Reduced lightloading: Deeper channels would allow some vessels that cannot currently load to their design draft to more fully load their vessels, resulting in reduced per unit operating costs. This benefit will accrue to liquid bulk, dry bulk and container vessels.

Beneficial Use of Dredged Material at Broadkill Beach

For the Delaware River Main Channel Deepening project, dredged material in the bay consists of a sand quality suitable for beach restoration at Broadkill Beach. This material would otherwise be placed in an existing federally owned upland confined disposal facility.

Quantified NED Benefits

Background

Economic benefit calculations to the National Economic Development (NED) Account include only the transportation cost savings associated with vessel efficiencies and operational efficiencies, and beach renourishment at Broadkill Beach. Benefits will also likely accrue due to improved safety and beneficial ecosystem uses of dredged material at Kelly Island, but have not been quantified in the project analysis.

Waterborne Commerce

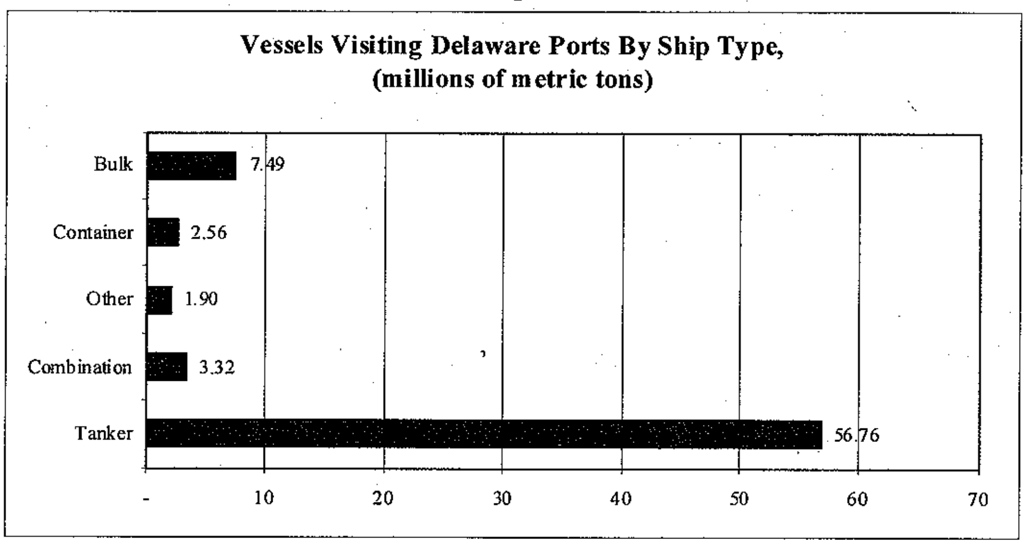
To provide an overall understanding of economic activity and health of the economy related to this project, the following data is provided for the Philadelphia to the Sea Project—Foreign and Domestic Commerce. These are the most recent years available from the Corps' Waterborne Commerce Statistics Center (WCSC):

2002: 124.0 MILLION TONS
2003: 126.8 MILLION TONS
2004: 131.0 MILLION TONS
2005: 132.3 MILLION TONS
2006: 132.0 MILLION TONS

Fleet Composition

As depicted in Figure 2-8, historic data shows that the large majority of the tons of foreign commerce transported to the Delaware River consist of crude oil delivered on tankers, followed, in descending order, by bulk, combination, containerized cargo, and other vessels. Tanker vessels constitute the largest portion of vessel traffic. Nearly 44 percent of total Delaware River port system tonnage was carried on vessels in excess of 100,000 deadweight tons. Over 21 percent of total tonnage was carried on vessels in excess of 140,000 DWT.

Figure 2-8




Crude Oil Benefits

NED benefits for crude oil imports are the reduced cost of transportation realized through operational efficiencies (reduced lightering) and more efficient loading of tankers that will result from navigation improvements at the harbor. Large crude oil vessels that currently lighter in the naturally deep water of the lower Delaware Bay will continue to carry equivalent tonnage into the system, but will be able to travel to the dock more fully laden in a deepened channel, thereby reducing the need for lightering. Reduced lightering costs result in reduced production and distribution costs and thereby increase the net value of the national output of goods and services. The current fleet composition and observed utilization levels have been selected to balance the demands of customer satisfaction with the costs of vessel availability (i.e., that the existing fleet is sized efficiently for the current level of lightering that it performs). Current lightering vessel deployment provides an adequate amount of reserve lightering capacity to handle surges in

demand without causing excessive delays and is considered to be an appropriate allocation of lightering resources.

Vessel utilization is determined by the volume of crude transported and the number of lightering trips, as well as weather delays, time for maintenance and repairs, and external constraints imposed by the refiners.

With-project resource cost savings are calculated as the proportional reduction in the costs of hull replacement, crew, lubes and stores, maintenance and repair, and administration; as well as the reduction in total fuel costs. The reduction in the costs of hull replacement, crew, lubes and stores, maintenance and repair, and administration is based upon the proportion of with-project vessel operating hours to without-project vessel operating hours.



The average annual benefit magnitude for this category is $15,101,600.

Container Benefits

Containership-based benefits were based on operations, including sailing drafts, port rotations, and cargo handling practices. Some of the container lines will benefit from a deepened channel. Other container lines use vessels that do not require a channel in excess of 40 feet. The port rotations, schedules, and vessel characteristics for these services were developed among the slot sharing partners who ship containers on these services. The schedules and port rotations were developed to achieve as many direct service calls as possible, while maintaining service to each port of call. There is an extensive refrigerated warehouse/distribution center infrastructure that has developed in the Philadelphia area. This infrastructure includes many large refrigerated warehouses and USDA inspection facilities. The major cause of the shift in location to the Philadelphia-metro area is that refrigerated warehousing is a very land-intensive operation. Because of the high cost and limited availability of land in competing areas, this industry (which services a broad geographic region), has been relocating to the Philadelphia-metro area.

Average annual containership benefits are estimated at $7,785,400.

Slag Benefits

Blast furnace slag (or clinker), used in the production of cement, is imported. The current fleet is expected to remain the same under the without project condition. Under the with project condition, however, the fleet is expected, through use of the charter market, to shift to larger vessels that can take advantage of the deeper channel depth. Bulk vessels are contracted from the charter market and there are no barriers to fleet replacement. The average annual benefit magnitude for this category is $2,296,400.

Steel Slab Benefits

Steel slabs are imported on a variety of vessels. This existing fleet is expected to remain the same under the without project condition, with the use of similarly sized vessels to handle future

commodity growth. Under with project conditions, it is likely that there will be a shift to larger vessels. These dry bulk vessels will be contracted from the charter market.

The average annual benefit estimate is $4,658,200.

Petroleum Product Benefits

A facility is currently depth-constrained and handles refined petroleum products (#6 fuel oil, diesel, and home heating oil predominantly). A fleet of larger vessels would be employed to take advantage of the deeper channel under the with project condition.

The average annual benefit estimate is $435,900.

Benefits from Beneficial Use Cost Savings at Broadkill Beach

Benefits would be realized due to cost savings resulting from jointly developing the Delaware River and Broadkill Beach projects rather than developing them independently. The Delaware River Main Channel Deepening Project has the capability to provide dredged material for beach nourishment for Broadkill Beach. In doing so, the Delaware River project is assigned the NED cost savings (NED benefits) from beneficial use of the disposal of material. Avoided borrow area sand source costs at Broadkill Beach is a benefit for the material provided by the Delaware River project.

On an average annual basis, this is equal to $642,200 in benefits.

Average Annual Benefits

The average annual NED benefits of the 45-foot deepening plan are presented below at the prevailing FY 2009 federal discount rate of 4-5/8 percent. Table 2-2 displays average annual benefits by individual category, with the total equal to $30,919,800.

## 3.0 Affected Environment

### 3.1 Project Area

#### 3.1.1 Location

The project area encompasses the Delaware River estuary from Philadelphia, Pennsylvania to the mouth of Delaware Bay (Figure2-1). The area extends over 100 river miles, and borders 10 counties in the Commonwealth of Pennsylvania, and the States of New Jersey and Delaware. The upstream portion of the project area includes the cities of Philadelphia, Pennsylvania and Camden, New Jersey, which together form the fifth largest metropolitan area in the United States. In conjunction with the port of Wilmington, Delaware, this area supports the largest freshwater port in the world. The area maintains a high concentration of heavy industry, including the nation's second largest complex of oil refineries and petrochemical plants (DRBC, 1988). Below Wilmington, Delaware, the river broadens into the Delaware Bay. Although

Table 2-2

**Average Annual Benefits by Category**

| Benefit Type | Average Annual Benefits |
|---|---|
| Transportation Cost Savings | |
| Crude Oil | $15,101,600 |
| Petroleum Products | $435,900 |
| Containerized Cargo | $7,785,400 |
| Slag | $2,296,400 |
| Steel Slabs | $4,658,200 |
| Subtotal Transportation Cost Savings | $30,277,600 |
| Beneficial Use Cost Savings at Broadkill Beach | $642,200 |
| Total | $30,919,800 |



many small towns are located along the bay's margins, the surrounding drainage basin is predominantly rural. The bay supports both-commercial and sport fisheries along with other recreational activities, is broad and shallow, and is surrounded by extensive salt marshes and agricultural land.

3.1.2 Socio-economics

The Delaware River Port System hinterland encompasses the domestic origins and destinations for waterborne commodities that pass through the port. These interior origins and destinations are linked to the port through the existing intermodal network, which includes rail, truck, air, pipeline, and water (barges). In general, the extent of the economic hinterlands of the Port is the result of shipping decisions made by individual commercial enterprises in the hinterlands and overseas. Their shipping decisions involve: (1) selection of the port that will be the marine terminus of overseas commerce; and (2) intermodal connections to or from the selected port. These choices are typically made on the basis of shipping costs, delivery schedules, and cargo handling requirements.

Three zones were selected to describe the hinterland of the Delaware River Port System. These zones are a core hinterland, a four-state hinterland, and a 17-state hinterland. As shown in Figure 3-1, the core hinterland is the greater Philadelphia metropolitan area. This area includes 45 counties: 22 counties in eastern Pennsylvania; 20 counties in New Jersey; and the three counties of Delaware.

The second, larger hinterland zone consists of the four states that are near the Delaware River Port System (see Figure 3-2). The 4-state region encompasses all of Pennsylvania, New Jersey, Delaware, Maryland, and the District of Columbia. The third, largest hinterland zone is comprised of the 17-state region (plus the District of Columbia) that extends from Maine to Virginia and west to Illinois. The 17-state region encompasses Pennsylvania, New Jersey, New York, Massachusetts, Rhode Island, New Hampshire, Vermont, Connecticut, Maine, Delaware, Maryland, Ohio, Michigan, Indiana, Illinois, Virginia, West Virginia, and the District of Columbia (see Figure 3-3).

Socio-economic data for the counties in the core hinterland and 4-state hinterland were obtained from the Census data presented by the U.S. Bureau of the Census. Projections to the year 2045 were estimated by applying the U.S. Department of Commerce, Bureau of Economic Analysis (BEA) projected growth rates for the states and income to the Census data.

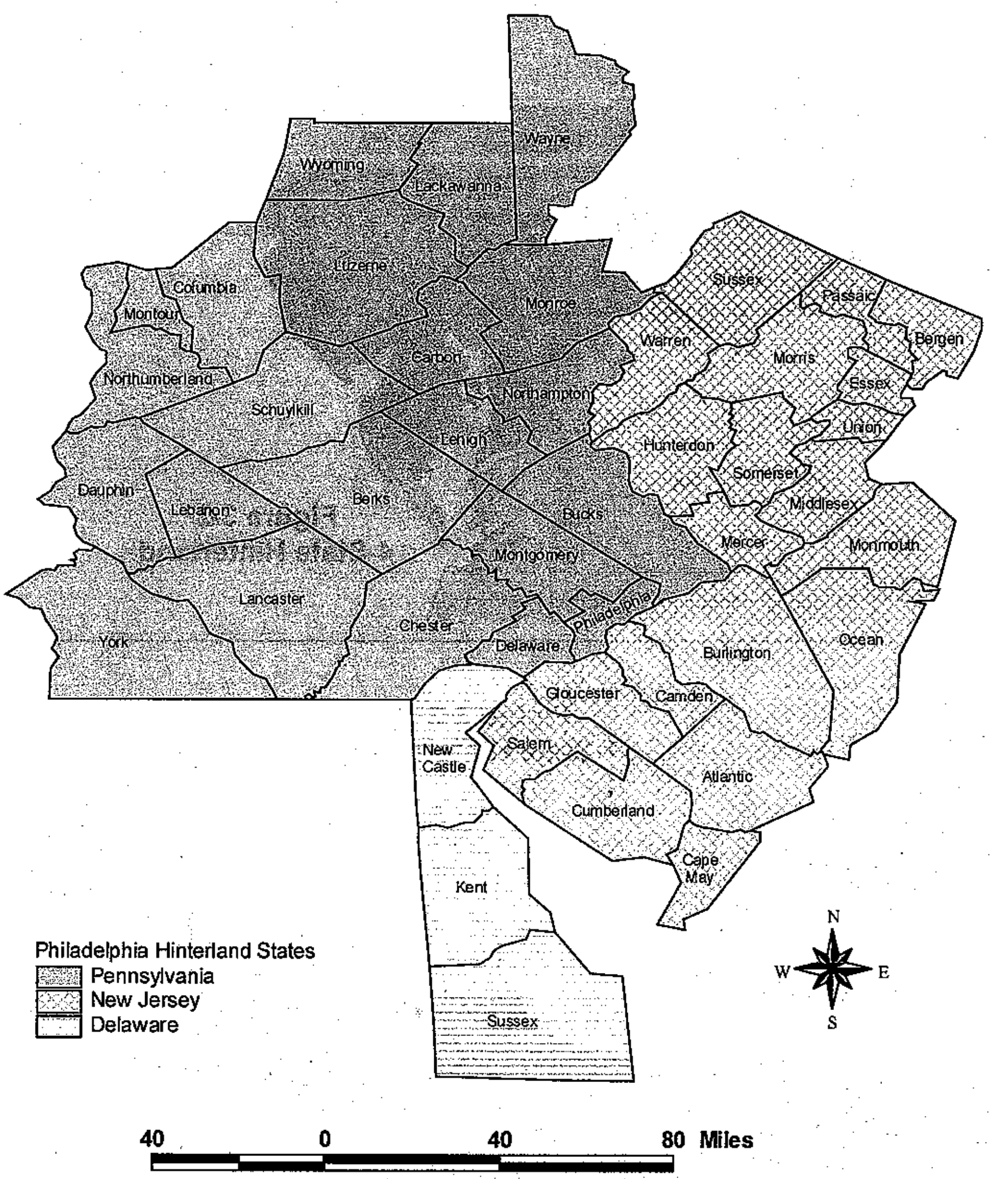
Table 3-1 shows projected population levels for the three hinterland zones. The 17-state hinterland contains almost 40 percent of the population of the continental United States. The populations in the core hinterland and four-state hinterland are expected to grow more slowly than the national average due to the rapid population increases anticipated for the western states.

Income levels in the three hinterland zones suggest their potential to generate imports and exports for the Delaware River Port System, because they imply consumer spending power and serve as broad measures of economic activity. Table 3-2 shows projected per capita and total personal income levels for the hinterland zones. Per capita incomes in the core region, the four-state region, and the 17-state (plus the District of Columbia) region exceed the national average by 16-, 11-, and 8-percent, respectively. Estimates of total personal income indicate that the 17-state (plus the District of Columbia) region accounts for approximately 42 percent of the nation's total personal income.

Table 3-3 shows estimated employment by sector for the core hinterland, the four-state hinterland, and the 17-state hinterland. Industry employment growth rates in the 45-county metropolitan area, in the four-state region and in the 17-state (plus the District of Columbia) region are expected to be slower than projected national growth rates. This is consistent with the expected slower growth in total population for these regions relative to the nation.

## Figure 3-1
## Core Hinterland





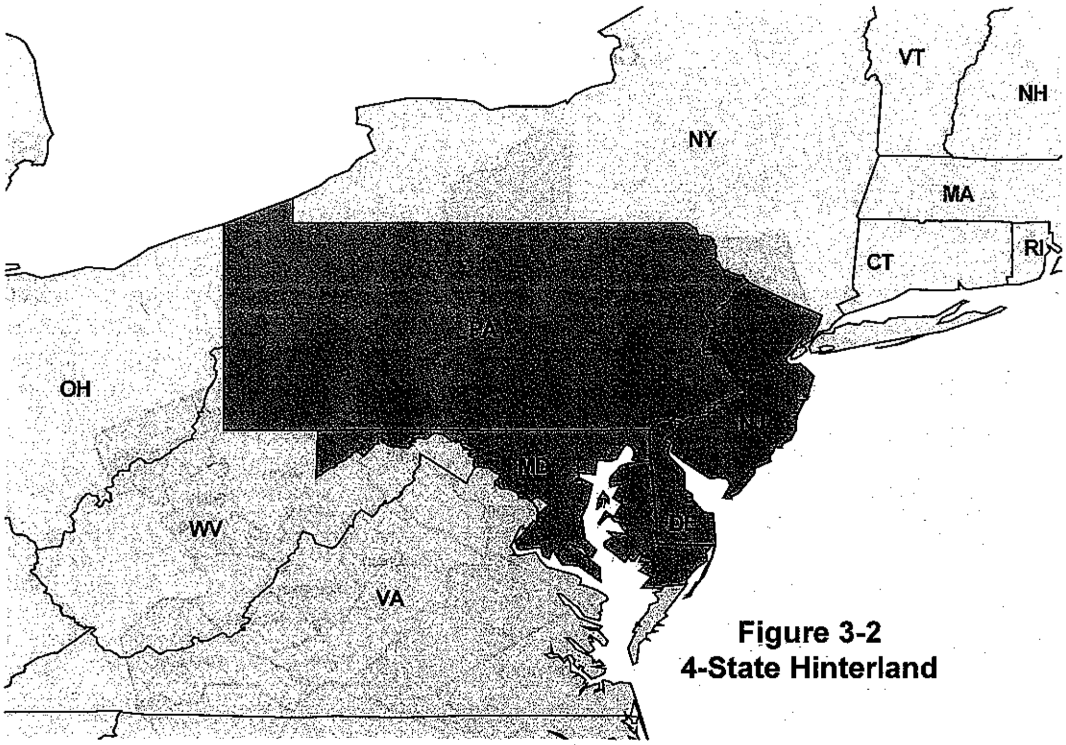
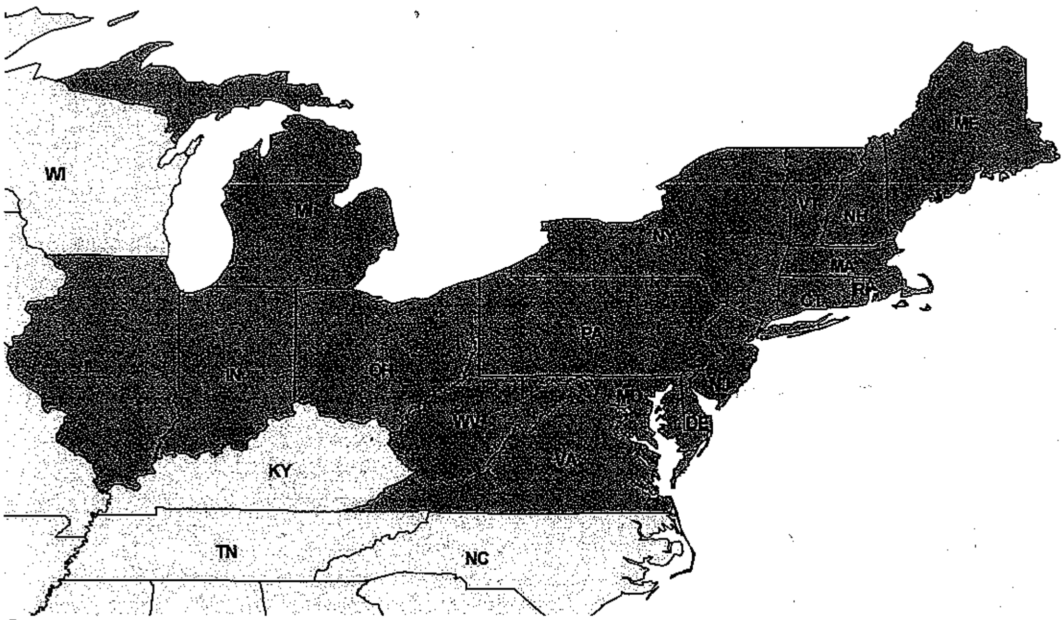



Figure 3-2
4-State Hinterland

Figure 3-3
17-State Hinterland



The sectoral employment forecasts suggest that the three hinterland zones – and the nation as a whole – will continue their current transitions from manufacturing to service economies. For the core hinterland, the four-state hinterland, and the 17-state hinterland, manufacturing employment is expected to decline, while employment in the construction and services sectors is expected to grow.



**Table 3-1**
**Estimated Population of Port Hinterlands (000s)**

| Year | Core Hinterland | 4-State Hinterland* | 17-State Hinterland* | Continental U.S. |
|---|---|---|---|---|
| 2000 | 15,835 | 27,348 | 108,925 | 279,583 |
| 2015 | 17,430 | 30,163 | 118,824 | 310,857 |
| % change 2000-2015 | 10.1% | 10.3% | 9.1% | 11.2% |
| 2045 | 20,755 | 35,990 | 140,557 | 378,986 |
| % change 2015-2045 | 19.1% | 19.3% | 18.3% | 21.9% |

*Sources: U.S. Department of Commerce, Bureau of Economic Analysis & Bureau of the Census*
* includes Washington D.C.

**Table 3-2**
**Estimated Per Capita and Total Income of Port Hinterlands**

| Income Category | Year | Core Hinterland | 4-State Hinterland* | 17-State Region* | Continental U.S.* |
|---|---|---|---|---|---|
| Per Capita Income (dollars) | 2000 | $34,149 | $32,897 | $32,000 | $29,550 |
| | 2015 | $39,135 | $37,728 | $36,896 | $34,880 |
| | % change 2000-2015 | 14.6% | 14.7% | 15.3% | 18.0% |
| | 2045 | $49,069 | $47,437 | $46,763 | $44,474 |
| | % change 2015-2045 | 25.4% | 25.7% | 26.7% | 27.5% |
| Total Income (millions of dollars) | 2000 | $540,769 | $899,639 | $3,485,546 | $8,261,665 |
| | 2015 | $682,117 | $1,137,983 | $4,384,174 | $10,842,821 |
| | % change 2000-2015 | 26.1% | 26.5% | 25.8% | 31.2% |
| | 2045 | $1,018,425 | $1,707,263 | $6,572,872 | $16,854,919 |
| | % change 2015-2045 | 49.3% | 50.0% | 49.9% | 55.4% |

*Sources: U.S. Department of Commerce, Bureau of Economic Analysis and Bureau of the Census*
includes Washington D.C.

**Table 3-3**
**Estimated Employment Characteristics of the Port Hinterlands**
**Thousands of Jobs (percent change from 2000)**

| Employment | Year | Core Hinterland | 4-State Hinterland* | 17-State Region* | Continental U.S.* |
|---|---|---|---|---|---|
| **All-Industry Total** | 2000 | 9,153 | 15,748 | 61,618 | 156,423 |
| | 2015 | 10,271 (12%) | 17,692.1 (12%) | 68,904 (12%) | 180,751 (16%) |
| | 2045 | 11,425 (25%) | 19,757.6 (25%) | 76,950 (25%) | 207,133 (32%) |
| Farm | 2000 | 58.2 | 115.9 | 665.4 | 3,000.3 |
| | 2015 | 53.7 (-8%) | 106.6 (-8%) | 605.2 (-9%) | 2,766.9 (-8%) |
| | 2045 | 46.6 (-20%) | 92.2 (-20%) | 517.6 (-22%) | 2,400.6 (-20%) |
| Mining | 2000 | 6.0 | 30.8 | 151.8 | 816.1 |
| | 2015 | 5.1 (-15%) | 26.2 (-15%) | 129.9 (-14%) | 729.9 (-11%) |
| | 2045 | 4.4 (-27%) | 22.4 (-27%) | 110.1 (-27%) | 632.1 (-23%) |
| Construction | 2000 | 451.0 | 740.5 | 2,827.3 | 7,794.6 |
| | 2015 | 504.4 (12%) | 823.6 (11%) | 3,149.9 (11%) | 9,015.3 (16%) |
| | 2045 | 559.8 (24%) | 910.7 (23%) | 3,511.1 (24%) | 10,338.1 (33%) |
| Manufacturing | 2000 | 1,061.8 | 1,687.2 | 7,790.2 | 18,847.9 |
| | 2015 | 969.3 (-9%) | 1,548.1 (-8%) | 7,358.8 (-6%) | 18,696.9 (-1%) |
| | 2045 | 914.8 (-14%) | 1,469.6 (-13%) | 7,223.4 (-7%) | 19,145.5 (2%) |
| Transportation, Communication, Utilities | 2000 | 488.3 | 774.8 | 2,808.7 | 7,270.4 |
| | 2015 | 533.7 (9%) | 845.0 (9%) | 3,052.1 (9%) | 8,229.8 (13%) |
| | 2045 | 580.6 (19%) | 920.2 (19%) | 3,323.1 (18%) | 9,268.4 (27%) |
| Wholesale & Retail Trade | 2000 | 1,936.2 | 3,271.7 | 12,957.0 | 33,559.7 |
| | 2015 | 2,137.7 (10%) | 3,614.6 (10%) | 14,315.3 (10%) | 38,434.3 (15%) |
| | 2045 | 2,347.7 (21%) | 3,982.4 (22%) | 15,843.2 (22%) | 43,751.7 (30%) |
| Financial, Insurance & Real Estate | 2000 | 845.2 | 1,246.2 | 4,886.4 | 11,392.3 |
| | 2015 | 947.3 (12%) | 1,395.9 (12%) | 5,424.5 (11%) | 13,042.1 (14%) |
| | 2045 | 1,055.5 (25%) | 1,558.1 (25%) | 6,026.2 (23%) | 14,859.1 (30%) |
| Services | 2000 | 3,130.5 | 5,415.6 | 20,310.7 | 49,108.1 |
| | 2015 | 3,872.0 (24%) | 6,705.5 (24%) | 24,970.6 (23%) | 62,435.1 (27%) |
| | 2045 | 4,589.5 (47%) | 7,983.1 (47%) | 29,707.2 (46%) | 76,313.2 (55%) |

*Sources: U.S. Department of Commerce, Bureau of Economic Analysis and Bureau of the Census*
*Includes Washington D.C.

## 3.2 Physical Resources

### 3.2.1 Geology and Groundwater

The study area lies within the coastal plain physiographic province and is underlain by unconsolidated sands and clays of Cretaceous, Tertiary, and Quaternary age. These sediments overlie bedrock which consists of metamorphic and igneous rocks of the upper Precambrian age. The unconsolidated formations dip to the southeast and generally thicken oceanward. The older formations are at or near the surface of the Delaware River and lie progressively deeper toward the Atlantic Ocean. Rock outcrops will be encountered in the vicinity of Marcus Hook, Pennsylvania, during the channel deepening. The unconsolidated sediments consist of permeable and low permeable layers which form a series of aquifers and aquicludes/aquitards.

The primary aquifer units along the Delaware River are the Potomac-Raritan-Magothy aquifers (PRM) and the Cape May and Columbia formations. The PRM aquifers are exposed at various locations at or near the surface in a narrow band along both sides of the Delaware River between Trenton and Pennsville, New Jersey. The Cape May and Columbia formations cover practically all of Delaware and portions of Southern New Jersey.

In many locations in or adjacent to the Delaware River, these aquifer units are mantled by sands and clays of recent alluvial deposits. The upper water bearing zone is usually within the Quaternary age Cape May Formation in New Jersey nomenclature. In Delaware, this formation is known as the Columbia formation. These water table aquifers are often separated from the deeper PRM aquifers by thick sequences of silt and clay layers in the vicinity of the disposal areas.

The municipal water wells in southern New Jersey generally withdrawal their water from the Potomac-Raritan-Magothy formation. The thickness of the Potomac-Raritan-Magothy formations is as much as 500 feet. Many industries and public water companies in the region obtain groundwater from this formation. There are three major aquifers within the formation. In the vicinity of the Killcohook Confined disposal Facility, the uppermost Potomac-Raritan-Magothy aquifer (known in New Jersey as the upper PRM) is approximately 100 to 140 feet below the surface, the middle PRM ranges from 200 to 375 feet below ground surface; the lower PRM aquifer lies 500 feet to 800 feet below ground surface.

### 3.2.2 Hydrology

The study area is situated in the mid-Atlantic temperate zone. In general, the climate is mild with a few brief hot, humid periods in summer as well as cold, windy periods of similar duration and frequency during the winter. However, there are spatial and temporal differences in precipitation and temperature distribution within the region, as the channel deepening study area covers approximately 70 miles in the north-south direction from the mouth of Delaware Bay upstream to Philadelphia. In addition, much of the drainage basin of the Delaware River lies in a zone extending 170 miles north of Philadelphia,

The mean annual precipitation totals at Philadelphia, Wilmington, and Lewes are, respectively, 41.4, 41.4, and 44.3 inches, based on the period of record 1961 to 1990. The corresponding

mean annual temperatures for these sites are 54.3, 54.2, and 55.7 degrees Fahrenheit. Annual precipitation totals in the Delaware Basin above Trenton are somewhat higher, at about 44 inches, than in the Philadelphia metropolitan area. Mean annual temperatures become progressively cooler in the higher latitudes and altitudes of the basin above Trenton, with typical annual means in the range of 45 to 50 degrees F. Within the study area, temperatures of 100 degrees or higher are comparatively rare. Temperatures as high as 90 degrees occur on the average of only 15 days in the summer, normally in two or three periods of excessive heat. Temperatures of zero degrees or below occur one winter in four. Temporary droughts or periods of subnormal rainfall, however, are not uncommon for the area. At Philadelphia, the prevailing wind direction for the summer months is from the southwest, while winds from the northwest prevail during the winter.

The total drainage area tributary to the Delaware River estuary is 12,765 square miles, and includes portions of New York, Pennsylvania, Delaware, and New Jersey. In addition, there are approximately 782 square miles of water surface in the estuary. The total average annual inflow of freshwater, from the head of tide to the bay mouth, is approximately 20,000 cfs. Table 3-4 below presents data showing the geographic distribution of drainage areas and freshwater inflows.

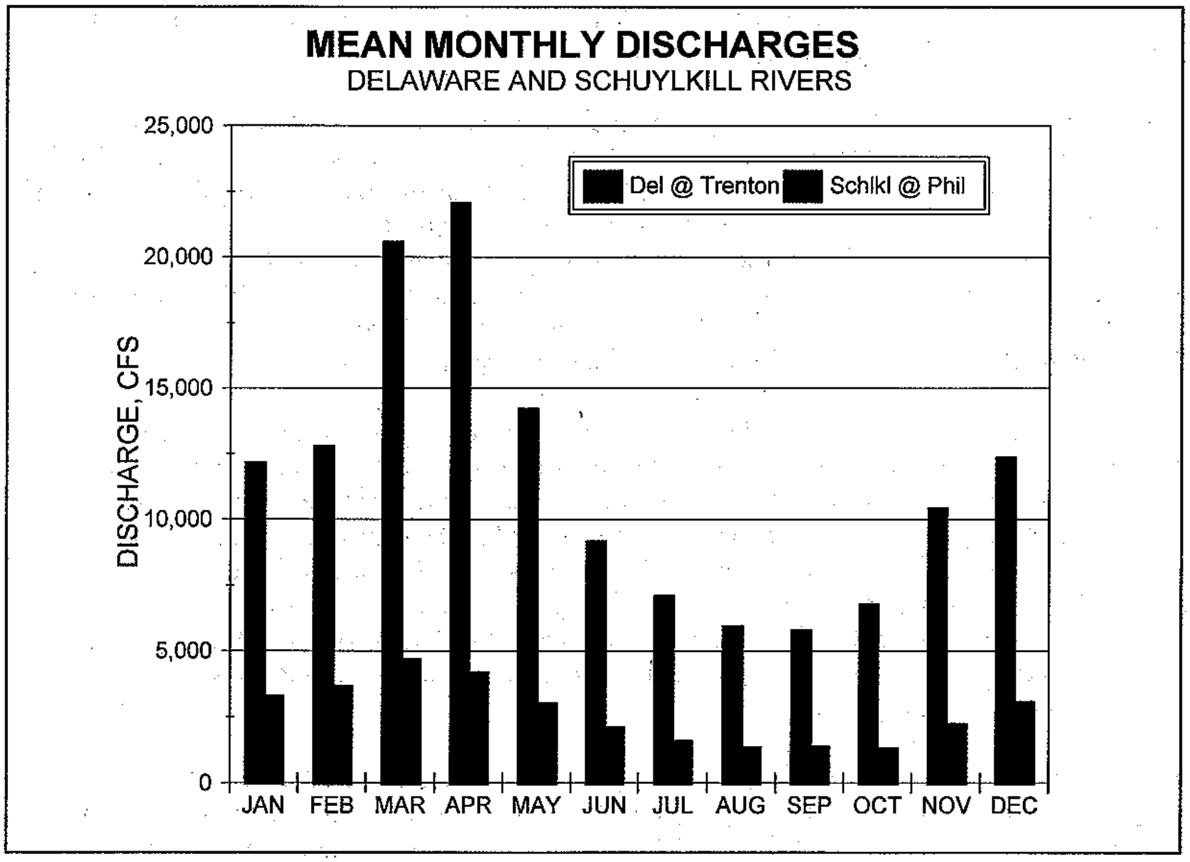
**TABLE 3-4**

**DELAWARE RIVER BASIN**
**DRAINAGE AREAS AND AVERAGE INFLOWS**

| SOURCE OF INFLOW | LOCATION (MILES ABOVE MOUTH) | DRAINAGE AREA | | AVERAGE INFLOW | |
|---|---|---|---|---|---|
| | | SQ MI | % OF TOTAL | CFS | % OF TOTAL |
| Delaware R. at Trenton, NJ | 134 | 6,780 | 53 | 12,000 | 59 |
| Intermediate small tribs (PA, NJ) | n/a | 1,300 | 10 | 1,810 | 9 |
| Schuylkill R. at Philadelphia, PA | 93 | 1,909 | 15 | 2,750 | 14 |
| Intermediate small tribs (PA, NJ, DE) | n/a | 464 | 4 | 650 | 3 |
| Christina-Brandywine at Wilmington, DE | 70 | 569 | 4 | 750 | 4 |
| Intermediate small tribs (NJ, DE) | n/a | 1,743 | 14 | 2,240 | 11 |
| TOTALS AT MOUTH | 0 | 12,765 | 100 | 20,200 | 100 |

The Delaware River is subject to tidal influence up to the head of tide located at RM 134 at Trenton, NJ. Most of the fresh water inflow (89%) enters the estuary in its upper 63 miles, between Trenton and Wilmington. Only an additional 11% of the long-term average flow enters the estuary in its lower 70 miles, between Wilmington and the mouth. There are substantial variations of the mean monthly discharges of all tributaries, with the largest discharges in March and April, due to high precipitation and snow melt, and the smallest discharges between August and October, due to low precipitation and high evapotranspiration. Figure 3-4 displays the mean monthly discharges of the Delaware River at Trenton and the Schuylkill River at Fairmont Dam in Philadelphia, based on periods of record that date to 1913 and 1932, respectively. The combined discharges from these two rivers constitute over 70% of the total freshwater entering the Delaware system.

Figure 3-4.




Above the head of tide, surface water of the Delaware River Basin is found in streams, natural lakes, and in artificial impoundments. Surface impoundments have been constructed in the basin with a total storage capacity of over 1.2 million acre-feet. These impoundments meet a number of water resource needs both within and outside of the basin, including: local water supply (12% of the 1.2 M ac-ft), New York City water supply and flow augmentation (68%), hydroelectric

power (11%), and multi-purpose water supply-flow augmentation (9%). The reservoirs in the last category have an additional capacity of approximately 219,000 acre-feet available for flood control. The Delaware River Basin Commission (DRBC) is charged with the responsibility for overall basin water management, and implements programs addressing basin water quality protection, water supply allocation, regulatory review, conservation initiatives, regional planning, drought management, flood control, and recreation.

Tidal Hydraulics and Salinity. The historic settlement and growth of the Philadelphia region beginning over 300 years ago, as well as the present importance of the Delaware River Main Channel deepening, are both critically dependent on the fact that the Delaware Estuary links the study area to the Atlantic Ocean and thus to ports around the world. The Delaware Estuary is customarily defined as beginning at the imaginary line between Cape Henlopen in Delaware and Cape May in New Jersey. The Atlantic Ocean lies outside this line, and is the source of a number of important physical and chemical influences on the estuary, including tides (the periodic rise and fall of the water surface), tidal currents (the periodic water movements, ebb and flood, induced by the tide), salinity (the dissolved solids present in ocean water), and waves (originating from winds over the ocean surface).

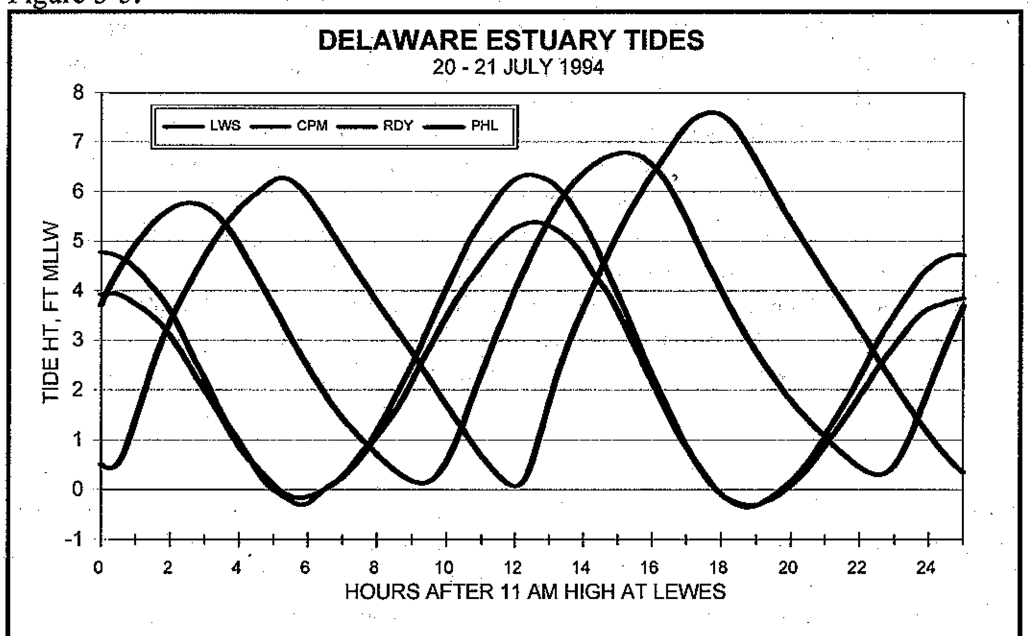
Tides. The upstream limit of the estuary is defined by the head of tide in the Trenton area, where the natural thalweg of the Delaware River rises high enough to be outside of the influence of astronomical tides. Although the influence of tides extends upstream to Trenton, the reach from Trenton to Philadelphia generally is not exposed to salinity derived from the Atlantic Ocean. The actual upstream limit of ocean-derived salt at any given time is determined by the competing influences of freshwater inflow from the Delaware River and its tributaries and from the salinity and tide boundary conditions at the mouth of the estuary. The role of salinity on the study area is discussed in greater detail in the following section of this report.

The water levels and currents of the Delaware Estuary are driven largely, but not exclusively, by the Atlantic Ocean tide wave which enters the Delaware estuary at the 11 mile-wide bay mouth. The ocean tide is driven by the tide producing forces which arise from the combined effects of the lunar and solar gravitational interactions with the earth. The source tide in the Atlantic Ocean is semidiurnal, and consequently the tidal response of the Delaware Estuary is semidiurnal. One tidal period, the time from one high tide to the next, or from one low tide to the next, averages 12.4 hours, hence there are two nearly equal high waters and two nearly equal low waters per lunar day of 24.8 hours. A calendar day of 24 hours thus includes somewhat less than two complete tidal cycles.

The mean tidal range at the mouth of the estuary is about 4.2 feet, with slightly higher tidal ranges experienced on the east (NJ) side of the mouth as compared to the west (DE) side, due to the north-to-south gradient in tide range in the ocean off New Jersey and Delaware. The variation of elevation with time, also referred to as the "tide curve," is approximately sinusoidal at the mouth. As the tidal wave propagates up the estuary, the tide range increases with the distance, such that the mean range at the mouth of the Christina River (RM 70) is 5.6 feet, at the mouth of the Schuylkill River (RM 93), 5.7 feet, at the Benjamin Franklin Bridge in Philadelphia (RM 100), 6.2 feet, and at Trenton (RM 133), 8.2 feet. Spring tide ranges at sites within the Delaware estuary are typically 5 to 20 percent greater than mean tide range. Variations in water level are also dependent on wind speed and direction.

The tidal response of water surface elevations within the Delaware estuary is not instantaneous with respect to the source tide at the mouth. The tidal wave propagates up the estuary with characteristics of a progressive, shallow water wave, such that the time of high (or low) water at any location is dependent on its distance from the mouth. High tide (low tide) occurs at Philadelphia an average of about 5 hours (6.5 hours) later than at the mouth, and at Trenton, about 7 hours (9 hours) later than at the mouth. Figure 3-5 below presents, as an example, observed tide data for two tidal cycles (25 hours) beginning with the time of high tide at Lewes, Delaware, at 1100 hours on 20 July 1994. Tide curves are shown for four locations with tide gages, including Lewes (LWS) and Cape May (CPM) at the bay mouth, Reedy Point (RDY) at RM 58, and Philadelphia (PHL) at RM 100. The plot displays a number of important characteristics of the tidal response of the estuary, including the larger range at Cape May as compared to Lewes, and the increased range and phased arrival time of high and low tide with distance above the mouth. The figure also reveals the change in shape of the tidal curve with distance above the mouth. The nearly sinusoidal tide at the bay mouth becomes progressively distorted with distance above RM 0, approaching a "sawtooth" shape at Philadelphia due to faster travel time of the high tide crest as compared to the low tide trough. The second tide cycle (between hours 12.5 and 25) exhibits a larger range than the first due to the diurnal variation of the tides; when the lunar declination is large, successive high tides differ by a greater amount than when the lunar declination is small, i.e., when the moon is at or near the celestial equator.

Figure 3-5.




Currents. Tidal currents play an important role in transport processes within the estuary and are the principal mechanism by which ocean-derived salinity is transported and distributed with respect to time and space. Currents also play an important role in navigation, as the transit of deep-draft vessels entering the estuary destined for port facilities in the reach from Wilmington to Philadelphia is scheduled to take advantage of flood currents and higher tidal stages, to assure maximum bottom clearance in high shoaling rate areas.

Currents represent the horizontal motion of water in the estuary, as distinct from the vertical motion of the water surface due to the tide. Currents in the Delaware estuary largely result from water surface differentials caused by the tide. Figure 3-5 shows that when the tide is high at the bay mouth, locations upstream, such as Reedy Point and Philadelphia, are experiencing lower tidal water levels. As a result of this head difference, a tidal current is induced in the direction from higher to lower water levels. The current corresponding to high tide at the mouth flows "upstream" and is referred to as the "flood" tidal current. Likewise, the current induced by low tide at the mouth flows downstream, and is referred to as "ebb." Because tidal currents are driven by the tides, the tidal currents also exhibit a semidiurnal periodicity; an average of 12.4 hours is required to go through a full tidal current cycle, from slack before flood, through flood maximum, slack before ebb, and ebb maximum, before returning to slack before flood.

The National Ocean Service (NOS) conducted a comprehensive survey of tides and currents in the Delaware estuary between 1984 and 1985. The results of this measurement program were utilized in a subsequent NOS model investigation to calculate tidal currents over the entire estuary system on a model grid of approximately 0.5 nautical miles, under mean tidal conditions. The model results were synthesized into an NOS report titled "Delaware River and Bay - Tidal Circulation and Water Level Forecast Atlas" (1987.) This report graphically depicts the spatial distribution of currents over the entire estuary at one-hour intervals beginning with the time of high tide at Breakwater Harbor (Lewes.) The results show that the highest velocities typically occur near the longitudinal axis of the estuary where the navigation channel is located, and at locations where significant localized constrictions of the estuary shoreline occur. For mean tide conditions, typical mid-channel peak velocities during the flood phase range from 1 to 1.5 knots, or from about 1.7 to 2.5 feet per second, with comparable values indicated for peak ebb conditions. Locations within the estuary with localized constrictions, such as at the "hook" of Cape Henlopen or adjacent to Artificial Island (RM 63) can experience mean maximum flood or ebb velocities which may exceed 2 knots, or 3.4 feet per second. The typical values cited here can be modified, either increased or decreased, by a number of factors that include: spring (or other astronomic effect) tides; wind speed, direction and duration; and freshwater discharges. Within the study area, from Philadelphia to the bay mouth, there is little or no systematic variation in peak flood or ebb current velocity with distance above the mouth; most of the variation in peak current speed is attributable to the localized geometry of the shoreline and bathymetry.

The tidal discharge across any section of the estuary is a function of the current velocity and the channel cross-sectional area. Table 3-5 summarizes approximate values of tidal discharge at 20-mile intervals above the bay mouth (RM 0). Data are presented for <u>mean</u> discharge over a typical flood or ebb portion of a tidal cycle, and for the <u>total</u> discharge over the same period. On the average, freshwater inflow to the estuary results in a net discharge in the ebb direction at any section in the estuary. However, under most conditions, the freshwater inflow is a small to negligible fraction of the tidal discharge. The values in Table 3-5 demonstrate the dominance of tidal discharge relative to freshwater discharge within the study area. At the bay mouth, for example, the mean tidal discharge of 4,100,000 cfs is approximately 200 times the value the mean freshwater discharge of 20,000 cfs. The Delaware estuary is classified as "well mixed" under most conditions, due to the predominance of tidal influence over freshwater inflow. Tidal "mixing" inhibits the formation of significant vertical salinity stratification. The values

presented in Table 3-5 are derived from the "Long Range Spoil Disposal Study", performed by the Philadelphia District between 1967 and 1973.

**Table 3-5 Delaware River Tidal Discharge**

| MILES ABOVE MOUTH | MEAN FLOOD (EBB) DISCHARGE, CFS | TOTAL FLOOD (EBB) DISCHARGE, CU FT X $10^6$ |
|---|---|---|
| 0 | 4,100,000 | 93,000 |
| 20 | 1,800,000 | 40,000 |
| 40 | 640,000 | 14,000 |
| 60 | 350,000 | 8,000 |
| 80 | 200,000 | 4,200 |
| 100 | 100,000 | 2,000 |

Salinity. Salinity is defined as the concentration of inorganic salts (total dissolved solids, or "TDS") by weight in water, and is commonly expressed in units of "psu" (practical salinity units) or "ppt" (parts per thousand). By example, ocean water with a salinity of 30 ppt contains 30 grams of TDS per 1000 grams of water. The two units of measure, psu and ppt, are effectively equal for practical purposes, and the latter term, ppt, will be utilized throughout this report. The distribution of salinity within the Delaware estuary is important for a number of reasons, including 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.).

The distribution of salinity in the Delaware estuary exhibits significant variability on both spatial and temporal scales, and at any given time reflects the competing influences of freshwater inflow from tributaries (and groundwater) versus saltwater inflow from the Atlantic Ocean. Saltwater inflow from the ocean is in turn dependent on the tidal discharge and the ocean salinity. Salinity at the bay mouth typically ranges from about 28 to 30 ppt. Tributary inflows by definition have "zero" salinity in the sense of ocean-derived salt; however, these inflows contain small but finite concentrations of dissolved salts, typically in the range of 100 to 250 parts per million (ppm) or from 0.10 to 0.25 ppt TDS.

A longitudinal salinity gradient is a permanent feature of salt distribution in the Delaware estuary. That is, salinity is always higher at the mouth and downstream end of the system and decreases in the upstream direction. The upstream limit of ocean-derived salinity is customarily treated as the location of the 0.5 ppt (or 500 ppm) isohaline. For purposes of monitoring water quality in the Philadelphia-Camden area, the DRBC has adopted the 7-day average location of the 250 ppm isochlor as the "salt front". Because chloride ions represent approximately 55% by weight of the total dissolved ions in seawater, a "salt front" defined by a chlorinity of 250 ppm approximates a salinity of 500 ppm.

There is also a lateral salinity gradient present in the bay portion of the estuary, between the mouth and about RM 50, with higher salinities near the axis of the bay, and lower salinities on the east and west sides. Upstream of Artificial Island at RM 50, salinity tends to be nearly uniformly distributed across the channel. Under most conditions in the estuary, there is only a small vertical salinity gradient, due to the dominance of tidal circulation and mixing relative to the normal freshwater inflow. However, under prolonged high-flow conditions, such as during the spring freshet, vertical salinity gradients of as much as 5 ppt can occur in the lower bay, with corresponding smaller vertical gradients at locations further upstream to the limit of the salt front.

At any given point in the estuary between the bay mouth and the location of the salt front, the salinity of the water column will vary directly with the phase of the tidal currents. Maximum salinity at a point occurs around the time of slack after high tide, and minimum salinity occurs at the time of slack after low. This condition reflects the significant role played by tidal currents in advecting higher salinity water in the upstream direction during flood flow, with lower salinity water being advected in the downstream direction during ebb. For periods longer than a single tidal cycle, the salinity at a given location varies in response to other important forcing functions, including the short-term and seasonal changes in freshwater inflow, wind forcing over the estuary and adjacent portions of the continental shelf, and salinity and water level changes at the bay mouth. Over longer periods (years to decades and longer), sea level changes and modifications to the geometry of the estuary also affect the long-term patterns of salinity distribution.

3.2.3 Water Quality

The following was taken from the National Water-Quality Assessment Program, Delaware River Basin Fact Sheet (USGS, 1999).

Advances in the treatment of municipal and industrial waste and changes in manufacturing and processing techniques over the past 25 years have led to improved 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 River Basin can be related to the high human population density in the area and related activities associated with urban, industrial, and agricultural land use. Most concerns are related to human health (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.

Some of the major water-quality issues that are currently being addressed by water-resource managers in the Delaware River Basin include:



- Relation of land use to nonpoint sources of contaminants.
- Effects of natural settings on the distribution, fate, and effects of contaminants in water, sediment, and biota.
- Relations between streamflow and loadings of nutrients, contaminants, and pathogens.

- Effects of nutrients and habitat on algae and macrophytes in streams, lakes, and estuaries.
- Distribution of toxic substances, particularly polychlorinated biphenyls (PCBs), and trace elements in surface water, ground water, and biota.
- Presence of human pathogens and pesticides in drinking-water supplies and recreational waters.
- Effect of dams, impoundments, and diversions on water quality, and on the health of fish and benthic invertebrate communities.
- Development of management strategies for protecting areas of existing high water quality.
- Effects of on-lot septic systems and reduced streamflow caused by ground-water withdrawals on water quality and ecological communities.
- Distribution of natural radioactivity in domestic ground-water supplies.
- Effects of ground-water/surface-water interactions on water quality.
- Effects of coal-mine discharges on water quality and ecological communities.

### 3.2.4 Sediment Quality

Discussions regarding sediment quality within the Delaware River Philadelphia to the Sea navigation channel are provided in Sections 4.2.6 and 5.1.3 of the 1992 Environmental Impact Statement (USACE, 1992) and Section 4 of the 1997 Supplemental Environmental Impact Statement (USACE,1997). Sediment data collected subsequent to the 1997 SEIS are discussed in Section 4.1.4 of this report.

## 3.3 Ecological Resources

The following sections of the Environmental Assessment regard habitats and species that were identified as concerns related to the Delaware River Main Channel Deepening Project. These Environmental Assessment sections discuss habitat and species importance within the estuary. To reduce duplication, only items involving new pertinent information and changes in the plan as previously proposed are addressed here. Items covered in previous National Environmental Policy Act documents for this project are incorporated by reference and are referenced as USACE (1992) and USACE (1997). Impact analyses are presented in section 4.0 of this document.

### 3.3.1 Estuarine Habitats

#### 3.3.1.1 Kelly Island

The following information is provided in the report: Kelly Island Pre-Construction Monitoring Study in Delaware Bay (Versar, 2002a).

Kelly Island is located on the western shore of Delaware Bay in Kent County, Delaware. It is bounded by Delaware Bay to the east, Simons River to the north, and Mahon River to the south and west. The Mahon River is an important port for local commercial and recreational fishermen. The reconstruction project would principally affect the lower eastern shore of the

island, facing the Delaware Bay. Most of the sampling and monitoring activity for a pre-construction evaluation of the Kelly Island area fell within the area bounded by the Kelly Island shoreline to the west, Mahon River mouth to the south, Simons River mouth to the north, and approximately 1.5-miles offshore toward the Delaware River main channel. Additional sampling for juvenile horseshoe crab data comparisons was undertaken along the western shore of Delaware Bay, Kitts Hummock and Broadkill Beach. Shoreline erosion is occurring at an estimated rate of 20 feet per year, mostly from the loss of salt marsh. Depths in Delaware Bay waters adjacent to Kelly Island are shallow and average approximately 9 feet out to the main channel, 5 miles to the east. The beach and access road to the south of the entrance of Port Mahon is severely eroded. Construction to stabilize the shoreline has occurred in the past as evidenced by the rock, sheet bulkheads, and construction rubble placed along the shoreline. The road leading to the State of Delaware dock and ramp facilities is frequently washed out by storm events, and over time, the road has been moved farther back into the salt marsh.

Seasonal sampling was conducted in 2001 to characterize spring, summer, fall, and winter conditions at the Kelly Island beneficial use site. Elements of the pre-construction survey included:

Water Quality Monitoring

Continuous water quality monitoring at four Delaware Bay oyster beds near Kelly Island was conducted from May through November 2001. Oyster beds monitored were Beck's Rock, Delaware Lower Middle, Drum Bed, and Lease Bed 102. Water quality monitoring comprised continuous monitoring of physical/chemical parameters with water quality meters and analytical measures of total suspended solids. Continuous data of physical/chemical parameters were collected by deploying data logging water quality meters (YSI 6600 Sondes). At 30- minute intervals, the meters recorded temperature, specific conductivity, salinity, dissolved oxygen, pH, turbidity, and chlorophyll. Total Suspended Solids (TSS) were measured in the lower water column at the four oyster beds 11 times during the monitoring period. Whole water samples were collected one meter above the oyster beds using a submersible pump. Laboratory methods for the analysis of TSS followed U.S. EPA Method 160.2.

Sediment Sampling

Estimation of sediment accumulation rates on oyster beds using sediment traps were measured in the lower water column at the four oyster beds over nine intervals during the monitoring period. Rates were calculated from the amount of sediment that was deposited over time in sediment traps. Sediment accumulation rates were calculated from sediment trap data. The accumulation rate (g/$cm_2$/yr) is the measured flux of particulate matter into the traps and is composed of net sedimentation plus resuspension.

Oyster Monitoring

Several types of monitoring were conducted. They are summarized below.

<u>Summer Monitoring Of Oyster Spat Settlement.</u> Spat settlement was investigated at five seedbeds and five lease beds in Delaware Bay near Kelly Island during 2001. The seedbeds

included Delaware Lower Middle, Drum Bed, Martin's Rock, Ridge Bed, and Silver Bed. The lease beds (LB) included LB-01, LB-02, LB-05, LB-08, and LB-102. At each bed, a weighted crab pot was deployed fitted with four spat settlement trays. Spat settlement trays comprised 1-ft square sheets of coated wire hardware cloth folded in half and wire-tied at the margins. Each tray held six clean oyster shells placed in alternating positions, and when affixed to a crab pot, was vertical in the water column and immediately above the oyster bed bottom. In total, 24 oyster shells were presented for spat settlement at each bed during each deployment. Spat settlement trays were deployed seven times during the 2001 monitoring period. Deployment dates were July 3, July 17, July 31, August 15, August 28, September 19, and October 12. Soak time, or time deployed at an oyster bed ranged from 13 to 23 days. The last set, deployed on October 12, was retrieved on November 2. After a crab pot was retrieved, the spat settlement trays were removed and labeled for the oyster bed and deployment dates. The crab pot was refitted with new trays and then redeployed. In the laboratory, the oyster shells were inspected under a dissecting microscope. Spat settlement rate was calculated by counting the number of oyster spat that settled onto a measured area of natural oyster shell for a specific period of time.

Seasonal Oyster Bed Dredge Surveys. Oyster dredge surveys were conducted at 12 of the oyster beds near Kelly Island. Five seedbeds were dredged and included Delaware Lower Middle, Drum Bed, Martin's Rock, Ridge Bed, and Silver Bed. Because Ridge Bed and Silver Bed were much larger than the other beds, three portions of these beds were dredged, designated East, West, and Center. In total, 9 locations were dredged within the seedbeds. Seven lease beds (LB) were dredged and included LB-01, LB-02, LB-05, LB-08, LB-09, LB-10, and LB-16. Because LB-02 and LB-05 were proportionally larger than the other lease beds, two portions of these beds were dredged. In total, 9 locations were dredged within the lease beds. Surveys were conducted during early summer and fall. Oyster dredging was conducted off of the Delaware research vessel, *Ringgold Brothers*, using the same crew and gear as used in their annual survey of oyster beds. Oysters were collected with a standard oyster dredge with a 54- inch tooth-bar width and a capacity of 7 bushels. Three dredge hauls were collected at each sampling location and processed as individual replicates. During operation, the dredge was towed at a speed of approximately 2 knots for in most cases 1- minute or less (depending on recovery, dredge time was occasionally longer in some of the less productive lease beds). Location data was recorded at the start and end of each dredge tow with a GPS. The total number of bushels of material collected was recorded for each dredge haul, and one bushel was retained for oyster bed characterization. To characterize the bushel samples, the total number of live oysters present as well as categorizing them into spat (roughly less than 2-cm), small size (from 2 to 7-cm), and market size (7-cm or greater) was recorded. In addition, up to 100 randomly selected oysters in each bushel were measured to the nearest millimeter. To assess recent mortality of oysters, the number of "boxes" or articulated shells present in the bushel sample were counted. In addition, up to 100 randomly selected boxes were measured to the nearest millimeter. To assess predation due to the oyster drill, the number of boxes with oyster drill holes were counted. Additionally the number of oyster drills collected in the bushel sample were counted. Ancillary species collected by the dredge were identified and recorded.

Finfish and Macro-invebrate Survey

A seasonal finfish and macro- invertebrate survey using otter trawl and beach seine was conducted to provide a site-specific characterization. Kelly Island fisheries were characterized

principally by employing a seasonal trawl and seine survey. Trawling and seining surveys were conducted seasonally during 2001. Trawling was conducted in three areas adjacent to Kelly Island in Delaware Bay (South, Central, and North), reference areas were north and south of Kelly Island, and within the Mahon River. Similarly, seining was conducted at three locations along Kelly Island (South, Central, and North) and at the north and south reference locations. Trawling was conducted with a 16-ft otter trawl with ¼-in-mesh cod-end liner towed for 5-minutes parallel to the shoreline in shallow water habitat. Three replicate trawls were completed at each station. Seining was conducted with a 100-foot beach seine with 6-ft depth and ¼-in-mesh. Three replicate seine-hauls were completed at each station. Fish species collected from trawling and seining were identified, counted, and measured in millimeters for total length of 25 specimens. Horseshoe crabs were identified by sex, counted, and measured in millimeters for carapace width and total length. Blue crabs were identified by sex, counted, and measured in millimeters for carapace width. Diamondback terrapins were identified by sex, counted, and measured in millimeters for carapace width and length.

Spring horseshoe crab spawning survey

Adult horseshoe crabs were surveyed on Kelly Island and Port Mahon beaches during the spring spawning of 2001. Spawning adult horseshoe crabs were surveyed by methods instituted by the Delaware National Estuarine Research Reserve (DNERR). Horseshoe crabs were counted along two transects each (South and North) for Port Mahon and Kelly Island beaches. Transects were 50-m in length and followed the "crab-line" or the upper limit of the beach where crabs were laying most intensively. Only crabs within 1-m of the "crab-line" were counted. Along the transect area border, crabs with more than half of their bodies within the area were included in the count. Male and female crabs were counted separately. Two surveyors using mechanical count recorders worked in tandem along each transect, one counting males and the other females. Transect surveys were started 20-minutes after the evening high tide. Start and end times were recorded as well as qualitative assessments of wave height and cloud cover. Port Mahon was surveyed on the new moon of May 22 and full moon of June 5. Kelly Island was surveyed only on 5 June; thunderstorms precluded working on the earlier date.

Summer juvenile horseshoe crab survey

A juvenile horseshoe crab survey was conducted along the Delaware Bay shoreline during September 2001. The survey was designed to characterize juvenile crab use of subtidal habitats adjacent to known spawning beaches. Beaches surveyed included Kelly Island, Kitts Hummock, Broadkill, and in addition adjacent reference areas located 0.5-miles north and south of Kelly Island. The south reference beach was near the Port Mahon spawning beach. Two transects were surveyed at each beach. Each transect constituted twin replicate tows (8 total) of a biological dredge at distances from the mean high tide line of 50, 100, 200, and 300-ft. The dredge was towed for a distance of 30-ft as measured by an incremental tag line. The biological dredge was constructed with a rectangular framed mouth of 10 x 18- in fitted with a ¼-in mesh nylon bag. In operation, the heavy flat bar of the frame scraped along the bottom and dislodged epibenthic fauna into the collection bag. Following a tow, bottom material collected by the dredge was washed, sieved, and sorted; all juvenile horseshoe crabs were counted and measured for carapace width.

Sediment profiling before and after a major storm event

Two sediment profile camera surveys were conducted off Kelly Island, Delaware Bay during 2001. On July 6, Sediment Profile Images (SPI) were successfully collected at 50 stations. The same stations were resampled on October 24 after several storm events. At four stations during the October sampling, rough seas caused the profile camera to pullout of the sediment before any images could be obtained. Stations were arranged in five transects oriented East-West, they were: Reference North (RN), Kelly Island North (KN), Kelly Island Middle (KM), Kelly Island South (KS), and Reference South (RS). At each station a Hulcher Model Minnie sediment profile camera was deployed. The profile camera was set to take two pictures, using Fujichrome 100P slide film, on each deployment at 2 and 12 seconds after bottom contact. Seventy-five pounds of lead were added to the camera frame to improve penetration. Both the 2- and 12-second sediment profile images were analyzed visually by projecting the images and recording all features seen into a preformatted standardized spreadsheet file. The major parameters measured were: prism penetration, surface relief, apparent color redox potential discontinuity (RPD) layer, sediment grain size, surface features, and subsurface features.

A Fall Seasonal Benthic Infaunal Survey

Benthic sampling was conducted off Kelly Island on October 4, 2001. Benthic samples were collected at nine locations that coincided with sediment profile imagery sites. Sampling locations were 2,000, 3,000, and 4,000 feet along the three transects, KI South, KI Central, and KI North, that radiated in an easterly direction from Kelly Island and toward the main channel. At each location, four replicate benthic samples were collected with a Young grab-sampler, which samples an area of 440-cm2 to a depth of 10-cm. A total of 36 benthic samples were collected and processed individually. Each sample was sieved in the field on a 500-μm mesh screen, transferred to a pre-labeled sample container, and preserved with 10% buffered formalin stained with "Rose Bengal". At each sampling location, a fifth sediment grab was taken and a surface subsample was collected for grain-size and organic content analysis. In the laboratory, benthic macroinvertebrates were sorted from the sample material under dissecting microscope, identified, and enumerated. Each organism was sorted and identified to the lowest taxon practicable depending on the maturity or physical condition of the specimen. To calculate biomass, organisms were combined at higher taxonomic levels and processed for Ash-Free Dry Weight (AFDW). AFDW was measured by drying the organisms to a constant weight at 60°C and then ashing them in a muffle furnace at 500°C for four hours. Sediment subsamples were analyzed for grain-size by the standard method ASTM D2487, excepting that the hydrometer portion of the test was not included. The minimum grain size category, or silt, was defined as that passing through U.S. Standard Sieve No. 200 at 63-μm. Total organic carbon (TOC) of sediments was measured by loss on ignition.

Hydroacoustic Survey of Oyster Bed Size

An Acoustic Seabed Classification Survey (ASCS) was conducted in Delaware Bay adjacent to Kelly Island in July and August 2001. The survey grid was located between 39.16297 and 39.23674 degrees N and 75.34837 and 75.38928 degrees W (decimal degrees). The ASCS survey was conducted over four days between July 21-28, 2001. Sixteen principal transects were spaced 200 m apart over the entire extent of the survey. In the northwest corner of the survey,

where oyster seedbeds are located, transect spacing was decreased to 100 m. All transects were oriented north - south. Individual bottom interrogations (pings) were spaced between 6 - 9 m apart, depending on vessel speed over ground. A total of 26.66 $km^2$ of bottom was surveyed. The dataset generated from the ASCS survey was field validated with a tethered video sled on August 1 and 10. After completion of video and physical validation, a number of habitat classes were established which best reflected habitat variability within the population dataset. Once the acoustic classes were validated, the spatial dataset was imported into ArcView GIS to create an "interpolated" polygon representation of the bottom features. Polygons were created with the Spatial Analyst software using iterations of neighborhood statistics on a gridded version of the original ASCS chart.

Findings

Oyster Bed Monitoring. Continuous water quality monitoring on oyster beds off Kelly Island provided an overview of the seasonal patterns for water temperature, specific conductivity, salinity, dissolved oxygen, pH, turbidity, and chlorophyll. Water temperature increased from 17°C in May to a high of 26°C in August, and decreased thereafter to 12°C in November. Specific conductivity increased uniformly over the monitoring period from 23-mS/cm in May to 33-mS/cm in November. Likewise, salinity increased over the same interval from 14 to 21-ppt. Dissolved oxygen, correlating negatively with temperature, decreased from 7.5-mg/L in May to a low of 5- mg/L in August and increased thereafter to 9-mg/L in November. Measures of pH were relatively stable over the monitoring period averaging about 7.7. Turbidity was also consistent at about 100-NTU. Chlorophyll was highest in May averaging about 50-µg/L, and declined thereafter to about 10-µg/L by November. Periodic monitoring of total suspended solids indicated variability over the monitoring period but most measures ranged less than 100-mg/L. Sediment accumulation rates averaged about 250-g/$cm^2$/year over the monitoring period. Spat settlement rates generally ranged less than 0.1-spat/100-$cm^2$/day over the settlement period from July to September, but ranged as high as 0.4-spat/100-$cm^2$/day. The temporal pattern of settlement suggested that oyster spawning might be attuned to a lunar cycle. Seasonal dredge surveys of oyster beds indicated that oysters were relatively abundant on the seedbeds, however, most were small or below market size. In contrast, oysters were infrequent to absent on most lease beds. Oyster mortality, as indicated by empty box shells, appeared to be reflective of the overall population throughout. Predation by oyster drills appeared to affect more of the smaller sized oysters.

Finfish and Macro-invertebrates. Thirty-one species of fish were collected by trawl and seine during seasonal sampling along Kelly Island and in the Mahon River; all species were typical for the nearshore estuarine habitats. In spring, the most abundant fish were spotted hake, striped cusk-eel, and hogchoker. In summer, Kelly Island appeared to offer important nursery habitat for weakfish. Juvenile fish were abundant in the Mahon River and were collected at all sampling locations along the nearshore of Kelly Island. In fall, juvenile Atlantic croaker was the most abundant species with more than 1,000 fish collected at each sampling location. Although to a lesser degree, croaker was most abundant during winter. Also at this time, the abundances of white perch and striped bass peaked, most likely because of the presence of the juvenile croakers on which they prey. Horseshoe crabs were most abundant during spring and were collected incidentally as they attempted to spawn and nest along the shoreline of Kelly Island. Blue crabs were most abundant during fall and for the most part comprised juveniles. Diamondback

terrapins were only occasionally collected during spring sampling, but were commonly observed in nearshore waters. Most likely, terrapins nest on Kelly Island during late spring and early summer.

A survey of spawning adult horseshoe crabs suggested that, relative to Port Mahon Beach, Kelly Island might offer less suitable spawning habitat. However, in comparison with a bay-wide survey run by the United States Geological Service (USGS), both Kelly Island and Port Mahon may be among the most important beach spawning sites along the Delaware shoreline of Delaware Bay. More data needs to be collected for the Kelly Island and Port Mahon beaches using USGS survey methods before their relative importance can be gauged. A survey of juvenile horseshoe crabs in late summer indicated low abundance throughout the study range.

Sediment Profile. For the sediment profile imaging the following summary applies:

- Sediments were predominantly silty-clays. Fine- to medium- sands were the second most predominant sediment type. There was little variation in sediments between July and October with 46 of 50 stations having the same sediment type.
- An oyster bed, whole shell and coarse shell hash, occurred at one station (KM-10) in both July and October.
- Thin flocculent layers of sediments from recent resuspension events occurred at 10 stations. Thicker layers of uniformly colored lighter sediments indicative of major resuspension/deposition events occurred at 13 stations.
- Sediment grain-size layering occurred at 11 stations. Layers were primarily sandy over silty sediments (seven stations), and likely represent lens of coarser sediments transported over finer during storm events. Stations with sandy layer over silt-clay layer may be located near sediment transition areas. At four stations silty overlaid clayey sediments.
- Processes structuring surface sediments appeared to be physical at all stations in October and all but five in July. At these five stations biological processes were dominant in structuring surfical sediment fabric.
- Overall, community succession appeared to be primarily pioneering Stage I with evidence of intermediate Stage II fauna at five stations.

Benthic Organisms. Benthic organisms identified from sediment samples collected offshore Kelly Island were typical for the nearshore estuarine habitats. Overall, the most abundant organisms comprised the oligochaete worms. For the most part, indices of species diversity were similar throughout the study area including mean number of taxa, Shannon-Wiener Index, and Simpson's Diversity Index. Total abundance and total biomass were variable over the study area, but did not appear to be spatially dependent. An invasive species of isopod was found to be pervasive in the study area. Sediment characterization of benthic samples indicated bottom sediments of mostly silt-mud and less than 12% total organic carbon.

Hydroacoustic Survey of Oyster Habitat. Extensive oyster habitat (identified by the presence of exposed shell and related epi-fauna) is present in the region associated with oyster seed beds. Because of generally poor visibility it was difficult to determine quantities of live oysters in these beds. Oyster lease areas to the south did exhibit limited regions of shell bottom, but were generally dominated by non-shell surface habitat. Excluding oyster shell habitat, three other principal habitat types were found in the survey region. Two of these were composed of sand-silt substrate being segregated by the presence or absence of shell bits or pieces in the matrix. The final bottom type was defined by a biogenic component although the bottom character did appear different from the sand-shell types. This bottom type was dominated by epi-fauna/flora, presumably tubeworms.

This study provided a baseline ecological characterization of Kelly Island habitats prior to construction, which will be used to verify and evaluate the ecological benefits of the project by comparing to post-construction monitoring data.

3.3.1.2 Broadkill Beach

Broadkill Beach is located close to the mouth of Delaware Bay. The beach is a continuous band consisting almost entirely of clean sand and small (<2 cm) gravel. The beach is currently protected by a series of groins that extend from high on the beach, out into the water at right angles to the shoreline. Shoreward, the beach is backed by varying widths of sparsely vegetated dunes, and a dense residential area. Broadkill Beach was the subject of the Delaware Bay Coastline – Delaware and New Jersey, Broadkill Beach, Delaware Interim Feasibility Study. A final Feasibility Report and Environmental Impact Statement is dated September 1996. That Environmental Impact Statement is incorporated by reference and is referenced herein as USACE (1996).

3.3.1.3 Egg Island Point

This section of the New Jersey bay shoreline is characterized by eroding salt marsh, with limited areas of sandy beach. Most of the shoreline consists of steep scarps of eroded peat four to six feet tall interfacing directly with open water of Delaware Bay. Some areas, particularly along the southwestern shoreline, have small sandy beaches consisting of thin layers of sand over eroded peat. These areas and the tip of Egg Island Point are the only areas of the site with substantial sandy beaches. Scattered small dunes immediately landward of the shoreline are vegetated primarily by common reed *(Phragmites australis)* and high-tide bush *(Iva frutescens).* The salt marsh in this area is typical of Delaware Bay salt marshes with the dominant vegetation being salt marsh cordgrass. There are also numerous shallow tidal and non-tidal ponds and tidal creeks scattered across the surface of the salt marsh.

Egg Island Point receives moderate to heavy use by horseshoe crabs. However, the shoreline conditions are generally not conducive to high spawning success, except at the tip of Egg Island Point and along the small sandy beach segments on the northwestern shoreline.

Commercially important oyster lease beds are located throughout the offshore area around Egg Island Point. Most of these lease beds are located 500 to 800 feet offshore, but in some cases

lease beds are located within close proximity to the shoreline. Oyster seed beds occur to the northwest of Straight Creek, and this area also supports a commercially important blue crab fishery.

The Egg Island Point area receives heavy use each spring by migratory shorebirds. Shorebirds feed in large numbers along the shoreline and along the sandy deltas at creek mouths. Additionally, the numerous small tidal and non-tidal ponds on the adjacent salt marsh provide valuable shorebird feeding and roosting habitat. The most common species using this area include ruddy turnstone, red knot, and semipalmated sandpiper.

The wetlands and nearshore shallows of Egg Island Point also provide valuable habitat for a large number of migratory waterfowl. Species identified during mid-winter waterfowl surveys conducted between 1985 and 1989 include mallard, American black duck, green-winged teal, scaup, merganser, gadwall, bufflehead, Canada goose, and snow goose.

The Egg Island Point project feature is being deferred because there will not be enough material dredged from Delaware Bay during initial construction.

3.3.2 Confined Disposal Facilities

The following describes the existing, Federally owned confined disposal facilities that are used to maintain the existing Delaware River, Philadelphia to the Sea 40-foot project. See Section 2.5.1 for the location of the project reaches.

Reach A: Approximately 138,000 cubic yards of material are dredged from these channel ranges on an annual basis. This material is dredged for both the Delaware River, Philadelphia to the Sea project, and the Delaware River at Camden project. This material is currently placed in a single upland disposal area located at National Park, Gloucester County, New Jersey. The National Park site has 120 banked acres.

Reach B: Approximately 1,903,000 cubic yards of material are dredged from Reach B on an annual basis. This material is currently placed in three dredged material disposal sites. These sites are the Federally owned Pedricktown North (567 banked acres) and Pedricktown South (522 banked acres) sites, and the adjacent Oldmans (189 banked acres) site which is leased. These three sites are located in Salem County, New Jersey.

Reach C: Approximately 1,160,000 cubic yards of material are dredged from Reach C on an annual basis. This material is currently placed in two Federally owned sites, Penns Neck (325 banked acres) and Killcohook (1229 banked acres). These two sites are located in Salem County, New Jersey.

Reach D: Approximately 162,000 cubic yards of material are dredged from Reach D on an annual basis. This material is currently placed in the Federally owned dredged material disposal site on Artificial Island (305 banked acres). This site is located in Salem County, New Jersey.

In addition to the existing CDFs currently used for maintenance of the existing Delaware River navigation channel, the Federally owned Reedy Point North and Reedy Point South sites would

also be used. These sites are located immediately north and south of the confluence of the Chesapeake and Delaware Canal and the Delaware River in New Castle County, Delaware. The Reedy Point North site contains 122 banked acres. The Reedy Point South site contains 133 banked acres.

### 3.3.3 Benthic and Planktonic Invertebrates

#### 3.3.3.1 Blue Crab

The blue crab supports the most valuable fishery in Delaware, with an average commercial catch of 50,000 bushels of hard shells and peelers per year; the pot fishery accounts for the majority of the total landings. A dredge fishery for blue crabs occurs from December 15 to March 30 in the lower Delaware Bay, targeting fully recruited crabs (carapace width greater than or equal to 120 mm) that overwinter in deeper waters (depth greater than 10 m) with relatively high salinity. Mature females are dominant in these waters, and make up the vast proportion of blue crabs residing in the lower Delaware Bay. At the onset of winter, mature female blue crabs migrate to the mouth of the estuary and burrow into deep-water sediments where they remain until spring. Young-of-year females (carapace width less than 60 mm) and male crabs of all size classes tend to burrow near their foraging habitat in shallow water. If a large portion of the overwintering female blue crab population utilizes the navigation channel, then dredging operations could adversely impact the winter crab dredge fishery and blue crab recruitment in the following year.

#### 3.3.3.2 Horseshoe Crab

The largest population of spawning horseshoe crabs in the world is found in Delaware Bay. The eggs of spawning horseshoe crabs provide a critical food source for the thousands of shorebirds that migrate through Delaware Bay each spring. For some shorebird species migrating to their arctic nesting grounds, the stopover on Delaware Bay beaches to feed on horseshoe crab eggs may represent the most critical part of their annual reproductive cycle. Migrating shorebirds have been shown to make body weight gains of 40%, or more, during their two to three-week stopover on Delaware Bay beaches in May.

Each spring adult horseshoe crabs migrate from deep water in the Delaware Bay and the Atlantic continental shelf to spawn on Delaware Bay Beaches. Spawning generally occurs from April to July, with the peak spawning activity occurring on full moon high tides in May and June. Horseshoe crabs deposit their eggs in the upper portion of the intertidal zone in clusters approximately six to eight inches below the surface. The average cluster contains between 3,000 and 4,000 eggs. Clusters are deposited below the feeding zone of shorebirds. However, many of these clusters become dissociated before the eggs hatch, and their constituent eggs are dispersed through beach sediments, toward the surface.

Optimal spawning beaches may be a limiting factor on the horseshoe crab population. Figure 3-6 depicts the relative importance of Delaware Bay shoreline to spawning horseshoe crabs. Horseshoe crab reproductive success is greatest under the following conditions: 1) the egg clusters are moistened by water with salinity of at least eight parts per thousand; 2) the substrate around the egg clusters is well oxygenated; 3) the beach surface is exposed to direct sunlight to provide sufficient incubation; and 4) the slope of the beach is adequate for larvae to orient and

travel downslope to the water upon hatching. These conditions are found on sandy beaches along the lower portion of Delaware Bay.

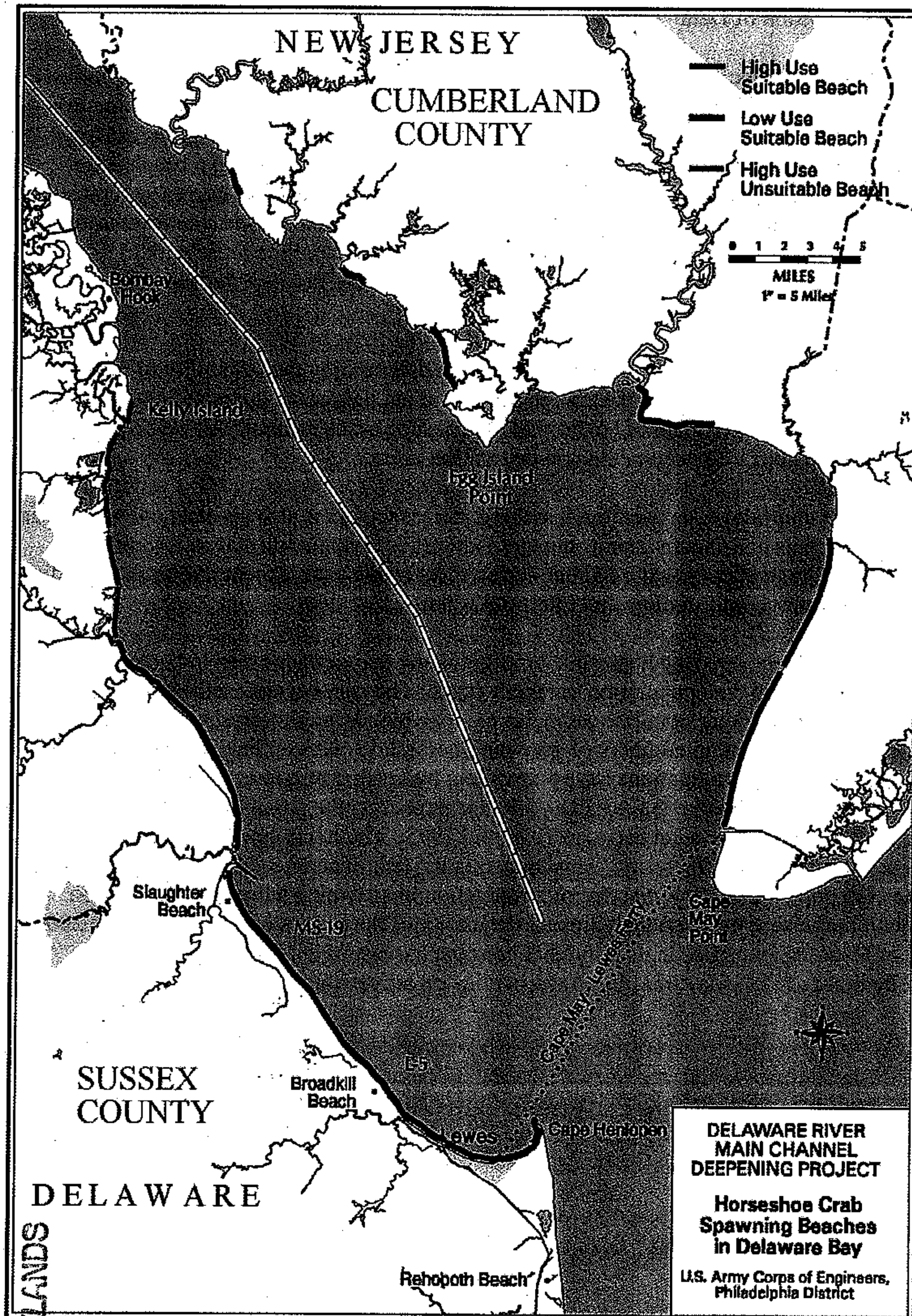
To some extent, horseshoe crabs appear to come ashore wherever they happen to be when full moon high tides occur. Horseshoe crabs can tolerate a wide range of physical and chemical environmental conditions, and will spawn in less suitable habitats if ideal conditions are not encountered. Therefore, the presence of large numbers of horseshoe crabs on a beach is not necessarily an indicator of habitat suitability. However, it also appears that horseshoe crabs can detect hydrogen sulfide, which is produced in the anaerobic conditions of peat substrates, and that horseshoe crabs actively avoid such areas. It is known that shoreline areas with high concentrations of silt or peat are less favorable to horseshoe crabs because the anaerobic conditions reduce egg survivability.

Beach slope is also thought to play an important role in determining the suitability of beaches for horseshoe crab spawning. A slope of between seven and ten degrees at the rack line (mean high water plus wave runup) is thought to be optimal. Horseshoe crabs generally travel dowslope after spawning and appear to become disoriented on flat areas.

In addition to the intertidal zone used for spawning, horseshoe crabs also use shallow water areas such as intertidal flats and shoal water as nursery habitat for juvenile life stages. Adult horseshoe crabs forage in deep water habitat during most of the year, except during the breeding season when they move into shallow and intertidal water.

Annual surveys of Delaware Bay horseshoe crab spawning activity appear to indicate an overall decline in the horseshoe crab population in recent years. The surveys are useful in documenting relative utilization of various shoreline segments by spawning horseshoe crabs. For example, the survey data indicate declining numbers of spawning horseshoe crabs on beaches experiencing the highest erosion. Other investigations have shown that harvesting of horseshoe crabs during their critical reproductive period may have had an adverse impact on the population, resulting in a significant decrease in abundance between 1991 and 1995. The horseshoe crab requires nine to eleven years to reach sexual maturity. This increases the risk of serious adverse impact to the horseshoe crab population due to harvesting. Reduction in spawning habitat due to erosion coupled with harvesting may seriously impact the ability of the population to recover. In 2008, the State of New Jersey passed legislation that bans the harvest of horseshoe crabs in New Jersey. The State of Delaware has placed restrictions on harvesting.

Figure 3-6 Horseshoe Crab Spawning Beaches in Delaware Bay



3.3.3.3 American Oyster

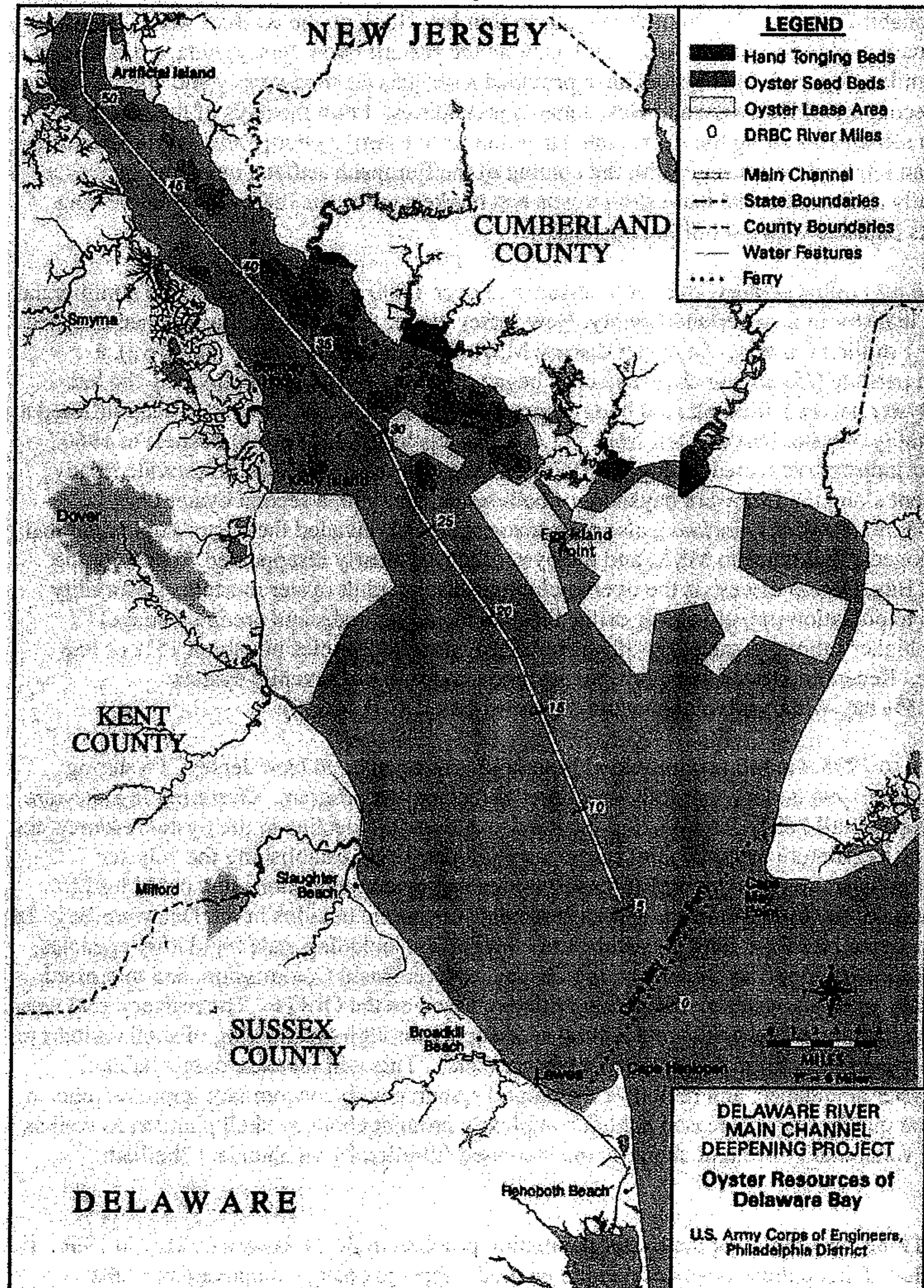
Oysters inhabit Delaware Bay from the mouth to Bombay Hook on the western side (Delaware) of the estuary, and to just below Artificial Island on the eastern (New Jersey) side, a distance of about 50 miles (Figure 3-7). Oysters have provided a sustainable food supply and contributed to the local economy of Delaware and New Jersey for centuries. From the days of the native American settlements along the shores the American (or Eastern) oyster (*Crassostrea virginica*) has been an important resource. With the coming of the European settlers, oystering increased dramatically and commercial harvesting towns and markets grew. In 1880, oyster harvesting reached its pinnacle with 2.4 million bushels.

Before the turn of the century, over 500 vessels and over 4,000 people worked in the commercial oystering industry in Cumberland County, New Jersey alone. By 1950, the harvest had dropped to around 1 million bushels. An oyster disease MSX (multinucleated sphere unknown), a protozoan parasite (*Haplosporidium nelsoni*), began to impact oyster populations by the late 1950s. Oyster harvests from planted beds dropped 90-95% while oysters in seed beds suffered a 50% mortality. Oyster harvests fell from 711,000 bushels in 1956 to 49,000 bushels in 1960. The oyster industry recovered during the 1970s and through the mid-1980s, to provide steady employment along the Delaware bayshore of both states. In 1990, a second oyster disease struck. Dermo (*Perkinus marinus*), also a protozoan parasite, invaded the oyster population that had developed a resistence to MSX, and the oyster industry nearly disappeared. Today in the Delaware Bay, Dermo disease is the overwhelming cause of adult oyster mortality. Mortality attributed to predation (mostly oyster drills, but also including crabs and dredge damage) is high in higher salinity areas (25%-50%) from Egg Island to Bennies but about 15% or less elsewhere. Recent improved estimates put an annual mortality of juvenile oysters at about 25% bay-wide, with higher estimates down-bay (HSRL, 2005).

From 1990 to 1995, the industry provided little in jobs or revenue in New Jersey. Oystering began again in 1996 under a carefully monitored direct market program. Oystering in Delaware did not reopen until 2001. Recognizing the need to address the decline in the oyster resource, the New Jersey Legislature passed a joint resolution (SJR-19, 1996) establishing the "Oyster Industry Revitalization Task Force" (OIRTF) to develop recommendations that could lead to revitalization of the oyster industry and its associated economic benefits in the Delaware Bay. In 2001, representatives from both Delaware and New Jersey, including state regulatory agencies, the Delaware River and Bay Authority, the Delaware River Basin Commission, and interested citizens developed an oyster revitalization initiative based on the OIRTF. The primary goal was to enhance recruitment by enhancing natural seed supply through the planting of shell (cultch) to provide habitat for recruitment of juvenile oysters (spat). This will increase oyster habitat, expand oyster abundance, and revitalize the natural resource with concomitant improvements in Bay habitat quality from increased habitat complexity brought about by shell planting as well as increased water clarity brought about by the increased filtration by an abundant shellfish resource.

The OIRTF began addressing the oyster population problem in the Delaware estuary in 1996. It was concluded that culture practices need to be modernized to change management of the resource (DRBA, 1999). Analysis of long-term time series data suggest that enhanced abundance can stabilize natural mortality (HSRL, 2005). Recent work has shown that low

Figure 3-7 Oyster Resources of Delaware Bay



abundance leads to degradation of the shell bed and eventual loss of the unique habitat of the oyster reef. Thus, a recruitment enhancement program is important for four reasons: 1) recruitment enhancement is needed to stabilize stock abundance imperiled by seven consecutive years of recruitment failure; 2) recruitment enhancement is needed to permit continuation and expansion of the oyster industry; 3) recruitment enhancement leading to increased abundance produces the shell necessary to maintain the bed; and 4) recruitment enhancement is needed to minimize the control of the oyster population dynamics by oyster disease and thereby stabilize stock abundance at a level that will permit the oyster to fulfill its keystone ecological role in the estuary as a filterer.

Since 2001, the condition of the oyster resource has deteriorated despite careful management and a limited controlled fishery, increasing the urgency for augmenting recruitment and providing habitat for oyster spat through a shell planting program. In 2006, Delaware Bay was in its seventh year of below average recruitment (less than 0.5 spat per oyster per year). Seven such consecutive years is unprecedented from the perspective of the 54-year record for which detailed survey data are available (1953-2006). Consistent recruitment failure has resulted in the decline of oyster stocks, endangering the species population dynamics, the continuance of the fishery, and the habitat quality of the oyster beds.

During the 1997-2006 period, through the efforts of the state regulatory agencies, the Shellfish Councils, and the Haskin Shellfish Research Laboratory (HSRL) of Rutgers University, a significant assessment infrastructure has been established that has produced a sustainable industry in Delaware Bay. In New Jersey, this process has been formalized through a stock assessment workshop, a rigorous stock survey, and the development of a coupled shellfisheries-disease model to permit projections of yearly harvest. Through these efforts, a consistent fishery has been established and a stable stock structure has been maintained. The resiliency of Delaware Bay oyster populations was reduced with the advent of Dermo in the 1990s. As a consequence, consecutive years of recruitment failure have significantly endangered the stock. Aside from the decline in adult oyster abundance due to high mortalities resulting from Dermo disease, there are reduced numbers of oyster spat due to relatively poor natural setting that has also contributed significantly to the demise of the Delaware Bay oyster. After two years of shell planting (and a previous small-scale test plant), results of the annual oyster stock assessment released in March 2007 indicate that throughout the New Jersey waters of Delaware Bay, the stock presents a mixture of positive and negative indicators that approximately balance. Abundance continued to be below target levels in all bay regions but above threshold levels on the medium mortality beds and Shell Rock and near, but below, threshold levels on the high mortality beds. The continued shell-planting program is anticipated to increase abundance on downbay beds in 2007. Abundance has increased each year on the high-mortality beds since reaching a post-1988 low in 2004 and abundance has moved in a positive direction for the last several years on Shell Rock. The stock continues to be disproportionately consolidated on the medium-mortality beds, a process that began in the early 2000s with persistent recruitment failure and the influence of Dermo disease downbay (Powell *et al.*, 2007). However, the 2005-2006 shell planting programs have added substantially to bay-wide recruitment and these recruits are expected to underpin increases in oyster abundance in 2007, as was observed in 2006. The Philadelphia District managed the shell planting contracts between 2005 and 2008, and will continue these efforts as funding becomes available.

3.3.3.4 Sandbuilder worm (*Sabellaria vulgaris*)

The sandbuilder worm or "reefworm," *Sabellaria vulgaris* is a tube-building, annelid polychaete worm common on the Mid-Atlantic coastline of the United States. This species ranges from Cape Cod to Georgia, occurring from low in the intertidal zone to shallow subtidal in waters with salinity above 15 ‰ (parts per thousand). Their life cycle includes a planktonic larval stage, and the larvae settle gregariously on a wide variety of substrata, including rocks and cobbles, clamshells, oyster bars, horseshoe crab carapaces, other worm tubes and pilings.

Sandbuilder worm tubes are built of sand grains cemented together into a hard encrustation or rock-like structure. For feeding and tube construction, the worms protrude their crown of tentacles from the tube openings. Worm tubes may be found singly or in small clusters attached to various substrata. In Delaware Bay, sandbuilder worms are also found in dense aggregations where the tubes grow in straight, parallel, spaghetti-like bundles that completely cover the substratum. These bundles may extend 20 cm or more above the substratum and be firm enough to walk on, often forming worm reef. The surface of the reef is of brown, honeycomb-like tube openings, each representing an individual sandbuilder worm. Reef development appears to be a unique characteristic of Delaware Bay populations, although masses were described on a shipwreck in North Carolina that closely resemble Delaware reefs in consistency, morphology and tidal elevation. Sandbuilder reefs form a habitat that is far more physically stable and ecologically diverse than would otherwise be found on bare rock or sand substratum. Thus, their reef structure and associated invertebrates are likely to provide food for fish and therefore represent a productive nearshore marine habitat.

3.3.4 Finfish

3.3.4.1 Sandbar Shark

The sandbar shark (*Carcharhinus plumbeus*) inhabits coastal waters of the Atlantic from Massachusetts to southern Brazil. The sandbar shark is an important component of shark fisheries, and it has been severely overfished in the north Atlantic. A management plan for the sandbar shark, involving catch quotas and size restrictions, was implemented in U.S. waters in 1993. Since that time the north Atlantic population has ceased declining and is beginning to show signs of recovery. The Delaware Deepening Project contains areas designated as "Habitat Areas of Particular Concern" (HAPC) for the sandbar shark. HAPC are areas of Essential Fish Habitat (EFH) that are judged to be particularly important to the long-term productivity of populations of one or more managed species, or to be particularly vulnerable to degradation (NOAA, 1999a).

Sandbar sharks use the shallows of Delaware Bay as an important seasonal nursery ground. The juvenile sharks (1 to 6 yr. old) return to the Bay from wintering grounds in the Carolinas, in mid May. Adult females visit the Bay to pup (deliver live-born young) in the first weeks of June. This has not been directly observed yet, many young caught in June bear fresh umbilical cord remnants and all have open umbilical scars indicating very recent birth. Newborns weigh about 1.5 pounds and are about 1.5 feet in length. Tag returns show that they stay in the bay feeding throughout the summer and depart for their winter (secondary) nurseries when the waters turn

cool in mid October. Most newborns are found on the shallow flats in the Southwestern Bay although they seem to radiate out and use more of the Bay during the summer, as they get larger. Telemetry studies show that juveniles cross the bay mainly on the bottom. They are bottom feeders, preying on fish, particularly flat fish, crabs (blue crabs and spider crabs) and other benthic organisms. The sharks' main nursery areas on the East Coast are in Delaware and Chesapeake bays. They formerly used Great South Bay, Long Island, N. Y. but surveys show that they have not used it recently, possibly due to anthropogenic or geological (morphological) changes (Pratt, 1999).

Pup and juvenile sharks use submerged flats for residence and feeding in water depths of from 1 to 4 meters. On the Delaware coast they extend from Roosevelt Inlet at the southern terminus of Broadkill Beach, to Port Mahon in the north. The greatest concentrations of young sharks occur off Broadkill and Primehook beaches, Delaware. They also are found in great numbers on submerged flats off the New Jersey shore (1-4 m) between Villas and Reed's Beach and shoal areas throughout the Bay such as Deadman and Hawksnest Shoal. They are limited by salinity to areas south of the latitude of Fortescue, NJ. Juveniles and pups may be caught almost anywhere in the bay, but the southwest coastal areas have the greatest consistent numbers as reflected in Catch per Unit Effort (CPUE) data (Pratt, 1999).

3.3.4.2 Winter Flounder

Most of the material presented here is taken from the source document for winter flounder (NOAA, 1999 b) and a table titled "Summary of Essential Fish Habitat (EFH) and General Habitat Parameters for Federally Managed Species" compiled by the NMFS, Northeast Regional Office, Habitat Conservation Division. The winter flounder (*Pleuronectes americanus*) in Delaware Bay are part of the Mid-Atlantic population that migrate inshore in the fall and early winter and spawn in late winter and early spring. In Delaware Bay, spawning takes place January, February and March, with early life stages being present in April and May (Riportella, 2001). Trawl surveys by the Delaware Department of Natural Resources and Environmental Control indicate that they are not abundant and that they occur in the lower portion of Delaware Bay where there are higher salinity levels (Michels, 2000). Generally the concern for winter flounder extends from the mouth of Delaware Bay to River Mile 35.

The eggs of winter flounder are demersal, adhesive, and stick together in clusters. They range in size from 0.74-0.85 mm in diameter. The eggs are laid when temperatures are greater than 10 degrees Celsius, in salinity levels from 10 to 30 ppt, and in depths less than 5 meters, from January through March. The habitat consists of substrates of sand, muddy sand, mud and gravel. On Georges Bank, eggs have been found in depths up to 90 meters. In New York Harbor, winter flounder used the 45 feet deep navigation channel for spawning; however, they did so in smaller numbers as compared to shallow areas adjacent to the channel (Gallo, 2000). With the exception of Georges Bank and Nantucket Shoals, winter flounder eggs are generally collected from very shallow waters (less than about 5 m), at water temperatures of 10 C or less, and salinities ranging from 10 to 30 ppt. These shallow water, nearshore habitats are of critical importance because they are most likely to be impacted by human activities. The type of substrate where eggs are found varies, having been reported as sand, muddy sand, mud and gravel, although sand seems to be the most common. Trawl surveys in Delaware Bay indicate that the winter flounder populations are smaller there than in more northern parts of their range (Michels, 2001, Scarlett

2001). Since winter flounder become less common along the New Jersey coast from north to south (Scarlett, 2001), it is therefore less likely that they would be found along the Delaware Atlantic coast.

As mentioned above, early life stage larvae are found in April and May in Delaware Bay. They occur in temperatures that are less than 15 degrees Celsius, in salinity from 4 to 30 ppt., and in depths less than 6 meters expect in Georges Bank where they have been found to depths up to 90 meters. Their preferred habitat is pelagic and bottom waters. Juveniles are generally found in water temperatures of less than 25 degrees Celsius, in salinity of from 10 to 30 ppt, and in depths from 1 to 50 meters. Their preferred habitats are substrates of mud or fine-grained sand. Their main prey species are amphipods, copepods, polychaetes, and bivalve siphons.

Adults are generally found in water temperatures of less than 25 degrees Celsius, in salinity of from 15 to 30 ppt, and in depths of from 1 to 100 meters. They prefer bottom habitats, including estuaries, with substrate of mud, sand, or gravel. Their main prey species are amphipods, polychaetes, bivalve siphons, and crustaceans. Spawning adults are generally found in water temperatures of less than 15 degrees Celsius, in salinity of from 5.5 to 36 ppt, and in depths less than 6 meters, except in Georges Bank where they spawn in depths up to 90 meters. They prefer bottom habitats, including estuaries, with substrate of mud, sand, or gravel.

3.3.4.3 Anadromous Species

Anadromous defines species of fish that use freshwater rivers for spawning and marine environments for growth and migration. Spawning is triggered by increased water temperatures in spring. Anadromous species of commercial and recreational importance in the Delaware River include striped bass (*Morone saxatilis*), American shad (*Alosa sapidissima*), alewife (*Alosa pseudoharenqus*), blueback herring (*Alosa aestivalis*), and hickory shad (*Alosa mediocris*). The Delaware River Basin Fish and Wildlife Management Cooperative has recommended time of year dredging restrictions for the protection of these species. These restrictions are mostly designed to protect the spring spawning run.

Along with the Chesapeake Bay and Hudson River, the Delaware River is one of the major striped bass spawning areas along the Atlantic coast. The main spawning grounds are located between Wilmington, DE and Marcus Hook, PA. Spawning also occurs above Marcus Hook and in the Chesapeake and Delaware Canal. Striped bass support valuable commercial and recreational fisheries. Due to pollution levels in the Delaware River, the striped bass population was reduced to practically nothing in the late 20th century. During the last decade, the spawning bass population and the number of striped bass eggs, larvae, and juveniles in the Delaware River has steadily increased.

The American shad is the largest member of the herring family. Adults commonly reach four to eight pounds. Like the striped bass, the American shad population in the Delaware River has benefited from water pollution control programs. American shad spawning in the Delaware River extends from Lambertville, New Jersey upstream into the east and west branches of the Delaware River in New York. Annual shad festivals are held each spring in places like Lambertville and Easton, Pennsylvania to celebrate the return of the shad. To date there has been great variability in population estimates from year to year. Estimates in the range of

800,000 were reported in the late 1980's to mid 1990's at the Route 202 bridge in Lambertville. Recent estimates have ranged from around 100,000 to 400,000. This decrease may not reflect a decline in the environmental condition of the river. Other possible explanations are that shad are now spawning in lower portions of the river, in tributaries of the Delaware, or in other river systems. The increased striped bass population may also be impacting shad through increased predation.

River herring is a term that applies to both alewife and blueback herring. The river herring fishery is one of the oldest fisheries in North America. River herring are commercially important; they are used for human consumption, crab bait, fish meal for animal food manufacturing, and fish oil. Recreational fishing is minimal. Until the late 1960's the fishery was exclusively an inshore fishery. At that time fleets began fishing for river herring off the mid-Atlantic coast. Over the last ten years the Atlantic coast population of river herring, including the Delaware River population, has sharply declined. Contributing factors include decreased access to spawning areas from dams and other impediments, habitat degradation, over fishing, and increased predation by striped bass. In response to this decline the National Marine Fisheries Service has listed both the alewife and blueback herring as species of concern. Species of concern are defined as species which the National Marine Fisheries Service has concerns regarding status and threats, but for which insufficient information is available to indicate a need for listing under the Endangered Species Act.

Hickory shad was once thought to be a rare species in the Delaware River. Today, they are being caught in good numbers between Trenton and Lambertville by American shad anglers. Hickory shad are listed as an endangered species by both the States of New Jersey and Pennsylvania. The State of Delaware lists hickory shad as a species of conservation concern. There is a year round closed season on hickory shad in the Delaware River. Any fish caught must be released back to the river.

### 3.3.5 Wildlife

#### 3.3.5.1 Shorebirds

Delaware Bay is recognized as one of the most critical stopovers worldwide for shorebirds migrating from their wintering grounds in Central and South America to their Arctic and Sub-Arctic breeding grounds. Each spring shorebirds arrive by the hundreds of thousands on their staging grounds along the Delaware Bay to fuel up for the last leg of their northward journey. Their stopover coincides with the peak of horseshoe crab spawning. The millions of horseshoe crab eggs laid in the sand along bay shore beaches comprise an important food source for the migrants. There are six species of migratory shorebirds that rely on horseshoe crab eggs and whose populations have declined on Delaware Bay in recent years. These species include: red knot (*Calidris canutus*), ruddy turnstone (*Arenaria intepres*), sanderling (*Calidris alba*), dunlin (*Calidris alpine*), semipalmated sandpiper (*Calidris pusilla*), and short-billed dowitcher (*Limnodromus griseus*). Both the States of Delaware and New Jersey have annual programs to monitor the health and status of shorebird populations. These are species of special concern in both States. The red knot is a New Jersey State-listed threatened species and a candidate species for Federal listing.

3.3.5.2 Pea Patch Island Heronry

Pea Patch Island is located in the middle of the Delaware River approximately ½ mile east of Delaware City, Delaware. The island measures 1 ½ miles in length (north-south) by ½ mile at its widest point. Pea Patch Island contains the largest multi-species nesting colony of wading birds found along the eastern seaboard north of Florida. Total nest pairs ranged from 12,251 in 1993 to 3,886 in 2000 (DNREC, 2001). The following nine species of wading birds have nested annually on the northern upland section of the island: great blue heron (*Ardea Herodias*), great egret (*Casmerodius albus*), snowy egret (*Egretta thula*), little blue heron (*Egretta caerulea*), tricolored heron (*Egretta tricolor*), cattle egret (*Bubulcus ibis*), black-crowned night heron (*Nycticorax nycticorax*), yellow-crowned night heron (*Nyctanassa violacea*), and glossy ibis (*Plegadis falcinellus*). All nine species are classified rare by the Delaware Natural Heritage Program (DNHP). The DNHP ranks all species S1, except the great blue heron, which is ranked S2. The S1 ranking means that the species is extremely rare; typically five or fewer occurrences in the State; or only a few remaining individuals and may be especially vulnerable to extirpation. S2 is very rare; typically between six and 20 known occurrences and may be susceptible to becoming extirpated. The global ranking for all nine species is G5, which means demonstrably secure globally, though it may be quite rare in parts of its range, especially at the periphery. The critical periods for different nesting species of herons vary, time frames generally follow this pattern: March: herons arrive; April: courtship; May-early July: young in nest. Although the decibel levels of noise that disturb nesting herons is not known, it is believed that loud intermittent noises are more disturbing than constant background noises. A cannon is periodically fired at Fort Delaware, which is located on Pea Patch Island. Cannon fire appears to have no adverse impact on nesting herons and is allowed by the Delaware Department of Natural Resources and Environmental Control (DNREC). However, there may be concern that noise generated from dredging activities could impact herons during their critical courtship and nesting periods.

3.3.6 Threatened and Endangered Species and Other Species of Special Concern

Endangered species are those whose prospects for survival are in immediate danger because of a loss or change of habitat, over-exploitation, predation, competition or disease. Threatened species are those that may become endangered if conditions surrounding the species begin or continue to deteriorate. Species may be classified on a Federal or State basis. The Delaware estuary is within the historic range of 12 Federally listed threatened or endangered species, including six species of whales, five turtles and one fish. Most of these are transient in the area.

3.3.6.1 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 project area. All five species of sea turtles are listed in the State of New Jersey. All but the hawksbill turtle are listed in the State of Delaware.

3.3.6.2 Whales

There are six species of endangered whales that have been observed along the Atlantic coast, and occasionally within 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 right whale (*Balaena glacialis*). These are migratory animals that travel north and south along the Atlantic coast. All six species of whales are listed in the State of New Jersey. None are listed in the State of Delaware.

3.3.6.3 Shortnose Sturgeon

The shortnose sturgeon (*Acipenser brevirostrum*) is the only Federally endangered species of fish within the Delaware estuary. The shortnose sturgeon is listed in the States of New Jersey and Pennsylvania, but not in Delaware. The shortnose sturgeon is an anadromous species that inhabits marine and estuarine waters, but spawns in freshwater. Shortnose sturgeon occur throughout the Delaware River estuary and may occur in the nearshore ocean (Brundage and Meadows, 1982). The abundance of adults is greatest in the tidal river from Trenton, New Jersey to Philadelphia, Pennsylvania (Hastings et al., 1987). Spawning occurs primarily in the lower non-tidal Delaware River during April (Brundage, 1986). After spawning, adult shortnose sturgeon disperse and spend the summer and early fall foraging throughout the tidal river, with some fish moving into Delaware Bay (Brundage and Meadows, 1982; O'Herron et al., 1993; ERC, unpublished data). Adult shortnose sturgeon are known to overwinter in dense aggregations in the Bordentown, New Jersey to Trenton reach of the river (O'Herron et al., 1993). It is believed that some shortnose sturgeon overwinter in the lower tidal Delaware River, although areas of aggregation have not been identified.

Little is known regarding the occurrence and distribution of juvenile shortnose sturgeon in the Delaware River. In other rivers, juveniles are known to occur upstream of the freshwater-saltwater interface during summer. Depending on river discharge, this zone can variably occur from Wilmington, Delaware to Philadelphia.

3.3.6.4 Atlantic Sturgeon

In the October 17, 2006 Federal Register the National Marine Fisheries Service (NMFS) provided notice that it was adding the Atlantic sturgeon (*Acipenser oxyrinchus*) as a candidate species for the Federal Endangered Species list. NMFS initiated a status review of the Atlantic sturgeon in 2005. That review was completed in February 2007. The status review team identified three distinct population segments (DPSs) that were likely to become endangered in the foreseeable future. The three DPSs were named Carolina, Chesapeake Bay and New York Bite. The Delaware Estuary is within the New York Bite DPS. The status review team recommended that the three DPSs be listed as threatened under the Endangered Species Act. NMFS will use the status review report to determine if listing Atlantic sturgeon or distinct population segments is warranted. Candidate species receive no statutory protection under the Endangered Species Act. Atlantic sturgeon is a State-listed species in Pennsylvania and Delaware. Atlantic sturgeon has been recommended for endangered status listing in New Jersey.

The Atlantic sturgeon is an anadromous species variously utilizing oceanic, estuarine, and riverine habitats depending on its life stage. The location of spawning grounds in the Delaware River are not known, but based on information from other estuary systems, they would occur in the middle estuary, probably north of Wilmington, Delaware, but may extend from Bombay Hook, Delaware to Chester Pennsylvania. Spawning occurs from late April to early June in moving water over hard bottom substrate. After spawning, the adults move seaward over the course of the summer and fall. Juveniles utilize the estuary year-round for several years after hatching, and may migrate annually to the lower estuary and immediate oceanic waters during fall and winter (O'Herron et al., 1995). Atlantic sturgeon spawn in deep water and are likely to use the navigation channel for this purpose, although no gravid adults have been recently collected. The critical reach of river for spawning is believed to be from Artificial Island, New Jersey to Chester, Pennsylvania, from early April to mid-June. Although the Federal government does not presently list this species as endangered, in 1998 the Atlantic States Marine Fisheries Commission (ASMFC) adopted Amendment 1 to the Atlantic sturgeon fisheries management plan. The ASMFC plan recommended that a coast-wide moratorium on Atlantic sturgeon landings be implemented by all member States. This recommendation has been adopted and the moratorium is expected to last a minimum of 40 years. NMFS followed this with a similar moratorium for Federal waters.

3.3.6.5 Bald Eagle

The bald eagle (*Haliaeetus leucocephalus*) was listed as an endangered or threatened species throughout the United States in 1978; the Chesapeake Bay Region (CBR) bald eagle population was determined to be threatened in 1995. The bald eagles in the project area are included as part of the Chesapeake Bay Region.

The CBR bald eagle occupies shoreline habitat of the Chesapeake and Delaware Bays and their tributaries. The eagle requires large blocks of undisturbed mature forested habitat in proximity to aquatic foraging areas. The principal threat to its continued recovery is habitat loss due to shoreline development and other land use changes. The CBR eagle is also threatened by acute toxicity caused by continued use of certain contaminants, shooting, accidents, and natural environmental events (USFWS, 1990).

Bald eagles have been documented to be sensitive to human activity and disturbance, particularly during the breeding season, although sensitivity varies greatly between individuals (Mathisen, 1968; Stalmaster and Newman, 1978; USFWS, 1990; Grubb and King, 1991). The breeding cycle of CBR bald eagles can generally be divided into four phases with each phase having an associated level of sensitivity to human disturbance (Cline; 1990). Eagles are most sensitive early in the nesting cycle when nest selection, nest building, incubation and brooding occur (Mathisen, 1968). Bald eagles are moderately sensitive to disturbance when young are older and preparing to fledge. After young are fledged and before nest selection begins, the bald eagles are least sensitive to disturbance. Most bald eagle nests are located in large wooded areas associated with marshes and other water bodies. Sometimes nests are built in isolated trees located in marshes, farmland or clear cuts. Nest sites are typically remote from areas of intense human activity, although some have been observed near railroad tracks, highways, airfield runways and human residences (USFWS, 1990). Primary factors contributing to breeding habitat suitability

are distance from human activity, availability of suitable nest trees, and an adequate forage base (USFWS, 1986).

Based on improvements in bald eagle population figures for the contiguous United States, the U.S. Fish and Wildlife Service removed the bald eagle from the Endangered Species list in June 2007. The New Jersey Department of Environmental Protection reported that there were 154 wintering eagles along the Delaware Bay shore and Atlantic coast in 2006. This was a record year since annual counts have been taken beginning in 1978. In the State of the Delaware Estuary 2008, the Partnership for the Delaware Estuary listed the bald eagle population in good condition. The estuary bald eagle population was rated above average with the trend moving in a positive direction. They reported over 35 nesting pairs of bald eagles in the State of Delaware in 2004.

Although the bald eagle has been removed from the Endangered Species list, the bird is still protected by the Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act. These laws prohibit killing, selling or otherwise harming eagles, their nests, or eggs. The bald eagle remains a state-listed species in New Jersey, Pennsylvania and Delaware.

3.3.6.6 Peregrine Falcon

Pergrine falcons (*Falco peregrinus*) were placed on the Endangered Species list as endangered in 1984. In the early 1960s the number of peregrine falcons nesting in the United States declined rapidly, with extensive use of organochlorine pesticides considered to be the primary cause. High levels of organochlorines, particularly the widely used insecticide DDT, proved lethal to birds, and sublethal doses induced reproductive failure. DDE, a metabolite of DDT, disrupted calcium metabolism so that peregrine falcons accumulating sufficient DDE residues produced abnormally thinshelled eggs, which often broke before hatching. Eggshell thinning in combination with other effects of organochlorines upon reproduction greatly reduced the nesting success of peregrine falcons, and the recruitment rate of young peregrine falcons fell below the number necessary to replace natural and pesticide-caused mortalities. Subsequently, peregrine falcon numbers dwindled to the point where, by the mid-1960s, the breeding population of the peregrine falcon in the eastern United States was extirpated. Due to successful efforts to captively breed and reintroduce peregrine falcons into areas where they once bred, as well as new areas, the peregrine again breeds in many regions of the Northeast, and have steadily increased in numbers (Steidl et. al. 1991).

The peregrine falcon nests on high cliffs, tall buildings, and bridges. It requires an uncontaminated avian prey base and undisturbed nest sties. The primary threats to the eastern population at the present time are disturbance of habitat by humans at existing sites and predation by great horned owls, which may limit population expansion in the southern Appalachians, Great Lakes, and southern New England/Central Appalachians recovery regions, except at urban sites.

Prey for the peregrine consists primarily of common passerine bird species such as bluejays, flickers, meadowlarks and pigeons. During migration and on the wintering grounds, passerines, shorebirds and waterfowl are taken while starlings, other passerine, and pigeons serve as the principal source of food for falcons occupying metropolitan areas.

The peregrine falcon was removed from the Endangered Species list in August 1999. The bird continues to be protected by the Migratory Bird Treaty Act, which prohibits the taking, killing, possession, transportation, and importation of migratory birds, their eggs, parts, and nests except when specifically authorized by the Interior Department. The peregrine falcon remains a state-listed species in New Jersey and Pennsylvania.

Within the project area, peregrine falcons have nested on Delaware River bridges including the Betsy Ross, Ben Franklin, Walt Whitman, Commodore Barry and Delaware Memorial. They have also nested at the Heislerville Wildlife Management Area and near Egg Island Point, both in Cumberland County, NJ. The New Jersey Department of Environmental Protection's 2007 peregrine falcon in New Jersey report stated that both the Betsy Ross and Walt Whitman Bridges produced four chicks each. All fledged successfully at the Walt Whitman nest, while three from the Betsy Ross nest were transported to a southern Virginia hack site where they all flew successfully. In addition, a nesting pair fledged two at the Ben Franklin Bridge and a nest on Philadelphia's Girard Point Bridge produced three young. The Heislerville Wildlife Management Area site fledged three. The Egg Island nest was occupied in 2007, but unsuccessful. Overall the report concluded that peregrines had excellent nest success in 2007.

3.3.6.7 Red Knot

The following information was taken from the New Jersey Department of Environmental Protection (http://www.nj.gov/dep/dsr/trends2005/pdfs/wildlife-redknot.pdf). The red knot (*Calidris canutus*) travels from the southern tip of South America to arrive on Delaware Bay in May, which coincides with the horseshoe crab spawning season. The majority of the western hemisphere's red knot population uses Delaware Bay as a spring migratory stopover. While on Delaware Bay, horseshoe crab eggs account for more than 90 percent of the red knot diet. In general, by the end of May red knots need to double their arrival weight to reach their Arctic nesting grounds in adequate breeding condition. It is believed that there is a link between the loss of horseshoe crab resources on Delaware Bay over the last 10 years and the decline in the red knot population. In general numbers, the New Jersey Department of Environmental Protection reports that both horseshoe crabs and red knots have declined by over 75 percent since the early 1990's.

The U.S. Fish and Wildlife Service designated the red knot as a candidate for Endangered Species Act protection in September 2006. In response to the declining population size, the Service has concluded that threats to red knot are imminent.

3.4 Cultural Resources

3.4.1 Pea Patch Island

During the Supplemental Environmental Impact Statement process, the Corps evaluated the potential for increased shoreline erosion on Pea Patch Island as a result of the deepening project. It was ultimately determined that the deepening of the Delaware River main channel to a depth of 45 feet would have an adverse effect upon historic Fort Delaware on Pea Patch Island. Both the fort and the island are properties listed in the National Register of Historic Places. Pea Patch

Island is located in the middle of the Delaware River, approximately ½ mile east of Delaware City, and measures 1½ miles in length (north-south) by ½ mile at its widest point. Fort Delaware State Park encompasses a 50-acre tract located on the southern half of the island. The park hosts about 30,000 visitors per year. Visitors arrive by ferryboat from Delaware City and can tour the historic fort, hike a loop trail, watch wildlife, and picnic. There is also an active living history program sponsored by the Delaware Division of Parks and Recreation. Visitors can witness firsthand cannon fire, cooking demonstrations, the laundry, officers' quarters, and military drills.

Pursuant to Section 106 of the National Historic Preservation Act of 1966, as amended, the Philadelphia District Engineer signed a memorandum of agreement in 1999 with the Delaware State Historic Preservation Officer (SHPO) and the Advisory Council on Historic Preservation in which the Corps committed to the installation of extensive shoreline erosion control measures. These measures included the reconstruction of a breakwater, filling behind the breakwater, reconstructing a parapet wall, installing drainage ditches behind the breakwater, and reestablishing site surface contours. These erosion control measures were developed in close consultation with the Delaware SHPO and the Delaware Department of Natural Resources and Environmental Control (DNREC) and took into account the unique historic and engineering features of historic Fort Delaware. Acting in consultation with DESHPO and DNREC the MOA was amended in 2000 to extend the shoreline erosion control measures north of the sluiceway, and to restore the sluiceway at Fort Delaware on Pea Patch Island. In 2003 a second amendment to the MOA was signed to extend the shoreline erosion control measures north of and immediately adjacent to the original 1999 project area. As part of the new work the District, again in consultation with the Delaware SHPO and DNREC, committed to Historic American Building Survey (HABS)/Historic American Engineering Record (HAER) recordation prior to the rehabilitation of the existing seawall.

Since the signing of the initial MOA in 1999 the Philadelphia District has completed extensive shoreline protection and historic restoration measures. Work to rebuild the historic seawall, which protects Fort Delaware, began in fiscal year 1999. A contract was awarded to place a stone breakwater along the most heavily damaged portion of the seawall. This new breakwater is approximately 1050 feet long, 40 feet wide, and 12 feet high, and consists of approximately 10,074 cubic yards of rip-rap. Construction carried into fiscal year 2000 with additional work to complete the southern portion of the seawall and to remove silt and debris from the historic sluiceway and to rebuild the main sluice gate to enhance the historic aspects of the project. In fiscal year 2001, the northern portion of the seawall was constructed. The northern portion of the breakwater is approximately 650 feet long, 40 feet wide, and 12 feet high, and consists of approximately 6,300 cubic yards of rip-rap. The sluiceway, which measures 315 feet long, 25 feet wide, and 4.6 feet deep, was restored by excavating the silt down to approximately 1 foot above mean low water. Approximately 900 CY was excavated down to one foot above mean low water for the entire length. The existing stone breakwater was extended across the sluiceway to prevent trash from entering the sluiceway and to minimize the silt buildup within the sluiceway. A reinforced concrete pipe was constructed through the stone breakwater to allow water flow in and out of the sluiceway. The sluice gate and winch for the drainage ditch on the East Side of the sluiceway was reconstructed to agree with the historical documents. However, the sluice gate would not be used and the tidal flow in and out of the sluiceway and drainage ditch would be unimpeded. In fiscal year 2002, contracts were let to purchase the granite needed to replace the cut stonewall, backfill the area behind the newly placed seawall, rebuild

the smaller sluice gates to allow flow to and from the drainage ditches and install the granite stone wall. In fiscal year 2004 construction of the northernmost portion of breakwater was constructed.

As a result of these shoreline protection measures it is concluded that deepening the navigation channel to 45 feet will not increase shoreline erosion on Pea Patch Island, and consequently, will not impact significant cultural resources along the shoreline.

### 3.5 Air Quality

The U.S. Environmental Protection Agency's (EPA) Office of Air Quality Planning and Standards has set National Ambient Air Quality Standards (NAAQS) for six principal pollutants, called "criteria" pollutants. They are carbon monoxide (CO), ozone [which is composed of nitrogen oxides (NOx) and volatile organic compounds (VOCs)], lead (Pb), particulates (PM2.5 and PM10), and sulfur oxides (SOx). The 1990 Federal Clean Air Act Amendments directed EPA to develop two federal conformity rules. Those rules (promulgated as 40 CFR Parts 51 and 93) are designed to ensure that federal actions do not cause or contribute to air quality violations in areas that do not meet the NAAQS. The rules include transportation conformity, which applies to transportation plans, programs, and projects; and general conformity, which applies to all other projects, which includes the Delaware River Main Channel Deepening Project. The Delaware River Project Area is within the Philadelphia-Wilmington-Atlantic City, PA-NJ-MD-DE Area. In 2004 the project area was classified as severe non-attainment for ozone (composed of NOx and VOCs). It was also classified as a maintenance area for CO.

The U.S. Army Corps of Engineers (USACE) performed an emissions analysis and mitigation study (*Delaware River Main Channel Deepening Project General Conformity Analysis and Mitigation Report*, Moffatt & Nichol, 2004) to determine if construction activities associated with the deepening project would generate pollutant concentrations that exceed de minimis threshold limits that have been set and, if so, how to mitigate so that the Project could reach conformity. This analysis is summarized in Section 4.4 of this Environmental Assessment.

Due to the reduction in dredging quantities and associated changes to the dredged material disposal plan for the Delaware River and beneficial use of dredged material in Delaware Bay, the emissions generated from construction of the deepening project will be less than estimated in 2004. USACE is in the process of updating the emissions analysis. While emissions will be less, it is anticipated that some annual de minimis threshold limits will be exceeded, thus requiring mitigation. The updated analysis will re-evaluate mitigation alternatives to determine the most cost effective plan.

## 4.0 Environmental Effects

### 4.1 Physical Resources

#### 4.1.1 Groundwater

4.1.1.1 Infiltration and Contamination of Groundwater Aquifers Beneath CDFs

The confined disposal facilities (CDFs), previously discussed, will be utilized to provide capacity for the 45 foot project in Reaches A through D. All of the sites other than Reedy Island North and South, are located in New Jersey. The sites are all situated near the Delaware River shore, have similar subsurface conditions, contain varied amounts of fine grained dredged material, and overlie the PRM aquifer.

The existing 40-foot navigation project has historically been maintained through the use of annual maintenance dredging. The material dredged from the existing 40-foot channel has been deposited in CDFs in New Jersey for long-term storage. As part of the proposed 45-foot deepening project, the existing CDFs will receive additional material from native sediments slated to be removed from the base of the channel.

Several concerns have been raised in regard to the use of these CDF sites. The main concern involves the potential impact to drinking water aquifers from leachate generated by the disposal operations. It is hypothesized that water could percolate through the dredged material, leach out potential contaminants such as Volatile Organic compounds (VOCs) Semi-volatile Organic Compounds (SVOCs), Poly Chlorinated Biphenyls (PCBs), or heavy metals, and carry them to the groundwater resulting in impacts to drinking water aquifers.

Several studies were performed to ensure that deepening the main channel by 5 feet would not impact drinking water aquifers. Initially, sediment testing of the Delaware River channel and channel bends was conducted. Sediment quality testing, discussed in Section 4.1.4, concludes that the materials are sufficiently clean to meet NJDEP soil criteria. As a supplement to the sediment testing efforts, the United States Geological Survey was tasked with performing an evaluation of potential contaminant travel times from the proposed project disposal sites to nearby drinking water and industrial production wells. The report entitled, Evaluation of Groundwater Flow from Dredged Material Disposal Sites in Gloucester and Salem Counties, New Jersey" (USGS, 1995), determined that the disposal sites would not impact local wells as the sites provide a very small percentage of well recharge and potential contaminant travel times were on the order of fifty to one hundred years.

Oldmans disposal area is centrally located among the CDFs. This site has been used over 40 years by the Corps of Engineers for disposal of maintenance material from the existing Delaware River 40 foot project. A detailed groundwater investigation of the Oldmans disposal area has been completed by the Corps of Engineers. It is important to consider all of the contributing factors when evaluating the potential negative impact of the travel times from all disposal areas. First, the existence of 20-40 feet of fine grained material from past dredging within the disposal areas greatly impedes the flow of water from the areas and increases the travel times substantially. In addition, the new dredged sediments from the 45-foot project contains no harmful levels of contamination; so in the event that the water were to reach the aquifer from the disposal area, it would have no impact on water quality. The aforementioned conditions with respect to travel time, recharge, contamination levels, and conclusions from the recent groundwater investigation conducted by the Corps of Engineers at Oldmans disposal area indicate that possible risk of groundwater impacts at the dredged material disposal sites is negligible.

The USACE voluntarily instituted a groundwater monitoring program for the New Jersey Federally-owned Main Channel Disposal Areas. In 2002 groundwater sampling began in National Park, Oldmans, Pedricktown North, Pedricktown South, Killcohook, Artificial Island and Penn's Neck

disposal areas. Wells were installed in all areas to ensure that major drinking water aquifers were not impacted by CDF activities. In all the CDFs except Artificial Island, the first major drinking water aquifer is either the upper, middle or lower PRM. At Artificial Island, the first major drinking water aquifer is the Mt. Laurel/Wenonah aquifer.

From 2002 to the present, 8 rounds of groundwater sampling were performed. Samples were collected for up to 18 different analytical parameters from more than 30 wells. A total of approximately 3,800 groundwater samples have been collected to date during the course of this program. One of the parameters, the high resolution PCB analyses were capable of detecting PCBs in parts per quadrillion (ppq). These analyses showed no confidently detected hits of PCBs, so PCBs were then sampled with a detection of parts per trillion. These analyses showed no confidentially detected hits of PCBs so PCB analyses were eventually ceased.

Concerns have been raised about contamination from oil or petroleum spills migrating into dredged material from the bottom of the shipping channel. The concern is that this could end up contaminating the groundwater under the disposal sites. This would happen if all of the following were true;

- A petroleum spill occurred which resulted in chemicals that were heavier than water
- Oil or other petroleum products migrated to the bottom of the shipping channel. The channel only represents a very small fraction of the river channel.
- Oil or other petroleum products were then pumped up onto a disposal area
- Groundwater from the disposal area would have to penetrate the base of the disposal area. This groundwater would have to pass through thick sequences of silts and clays between the disposal areas and the PRM or in the case of Artificial Island the Mt. Laurel/Wenonah aquifer.
- Contaminated groundwater entering the PRM or Mt. Laurel/Wenonah would have to be of sufficient mass to impact the aquifer.

Spills from refineries or oil tankers would contain VOCs and/or SVOCs. Eight rounds of samples including VOCs and SVOCs were taken from the CDFs.

The results of the CDF groundwater monitoring show that;

- No confidently detected VOCs were found in any of the wells sampled.
- No confidently detected SVOCs were found in any of the wells sampled.
- No confidently detected PCBs were found in any of the wells sampled.

The phrase "no confidently detected VOCs" means that only compounds found above detection limits were reported as hits. Some common laboratory contaminants such as methylene chloride (used in analytical laboratories) were occasionally found in low levels in samples and trip blanks. These laboratory contaminants were not considered hits of contamination.

Metals in Groundwater

Unlike VOCs and SVOCs, metals are endemic to groundwater. The concentration of dissolved metals is related to the particular soil and groundwater geochemistry. The purpose of sampling groundwater for dissolved metals is to determine whether the CDFs are impacting groundwater in drinking water aquifers.

This is accomplished by comparing metals concentrations underneath the site with upgradient or known background conditions. These comparisons can often be difficult to make. For example, the Pedricktown CDFs are adjacent to the National Lead (NL) superfund site. At NL ground water, surface water, and soils have been extensively contaminated with various heavy metals. NL has performed remediation at the Pedricktown CDF. Elevated arsenic levels in Oldman's Creek and other nearby watersheds are currently being studied by the USGS.

The USACE is currently studying metals in groundwater at the Federally-owned main channel disposal areas in New Jersey. Commonly occurring metals such as Fe, Al, and Mn were detected in most samples. Less abundant metals such as As, Sb, and Be were found in some groundwater samples. The USACE is currently installing additional monitoring wells at the Pedricktown CDF to help study dissolved metals found in groundwater. In addition, the USACE is currently preparing summary reports for all of the groundwater samples taken from 2002 to the present. These reports will include discussions of dissolved metals analyses. These summary reports will be completed in the Spring of 2009.

4.1.1.2 Increasing River Connection to Groundwater Aquifers and Contamination Through Direct Recharge

The Delaware River is currently a major source of drinking water for millions of people in the Philadelphia area and Southern NJ. Purveyors and municipalities that use river water simply pipe water from the river, remove solids and add trace amounts of chlorine. Drinking water from the Delaware must by law pass strict Federal Water Quality Standards. This same water is an important source of recharge for the PRM aquifers which is also used by millions of people. Deepening the shipping channel by 5 feet will not alter the recharge of these aquifers in any measurable way.

Groundwater flow is generally toward the main river in a typical river basin. However, the groundwater regime in the project area, has been disturbed by industrialization and urbanization. Prior to 1900 the PRM aquifers discharged groundwater to the Delaware River. Between 1900 and 1930 overpumping of the PRM aquifers reversed this flow, and since the 1930s the Delaware River has been recharging the PRM aquifers. Recharge from the Delaware River into the PRM aquifers continues to be a major source of PRM water. This information has been documented in numerous reports.

The U.S.G.S. Atlas HA-697 dated 1986 estimates a leakage of 70 million gallons per day (MGD) from the Delaware River into the Potomac-Raritan-Magothy aquifer system in the project area. This is due to the fact that permeable sand and gravel in the river are in direct contact with the sediments which comprise the Potomac-Raritan-Magothy system. According to the USGS, "Generally, upstream of Little Tinicum Island (near Paulsboro, NJ), the sands of the Potomac-Raritan-Magothy aquifer system are exposed in the river bottom."

Although a large volume of river water is presently infiltrating the aquifer from the river, no contamination or salinity problems have been reported. Since the amount of aquifer recharge from the river is controlled by the pumping rate of private and public wells, any deepening of the channel will not increase the amount of intrusion.

There are areas in the downstream portion of the project that have aquicludes/aquitards between the river bottom and the PRM aquifers. According to the USGS, "downstream of Little Tinicum Island, clay, thicker than the proposed depth of dredging predominates in the river-bottom material." This is why deepening the channel by 5 feet will not impact aquifers in the downstream portion of the project.

### 4.1.2 Salinity/Hydrology/Sediments

#### 4.1.2.1 Salinity Distribution

Salinity is the concentration of inorganic salts (total dissolved solids, or "TDS") by weight in water, and is commonly expressed in units of "psu" (practical salinity units) or "ppt" (parts per thousand). By example, ocean water with a salinity of 30 ppt contains ~30 grams of salt per 1000 grams of water. The two units of measure, psu and ppt, are effectively equal for practical purposes, and the latter term, ppt, will be utilized throughout this report. The distribution of salinity within the Delaware estuary is important for a number of reasons, including 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.).

The distribution of salinity in the Delaware estuary exhibits significant variability on both spatial and temporal scales, and at any given time reflects the opposing influences of freshwater inflow from tributaries (and groundwater) versus saltwater inflow from the Atlantic Ocean. Saltwater inflow from the ocean is in turn dependent on the tidal discharge and the ocean salinity. Salinity at the bay mouth typically ranges from about 28 to 32 ppt. Tributary inflows by definition have "zero" salinity in the sense of ocean-derived salt; however, these inflows contain small but finite concentrations of dissolved salts, typically in the range of 100 to 250 parts per million (ppm) or from 0.1 to 0.25 ppt TDS.

A longitudinal salinity gradient is a permanent feature of salt distribution in the Delaware estuary. That is, salinity is always higher at the mouth and downstream end of the system and decreases in the upstream direction. The upstream limit of ocean-derived salinity is customarily treated as the location of the 0.5 ppt (or 500 ppm) isohaline. For purposes of monitoring water quality in the Philadelphia-Camden area, the DRBC has adopted the 7-day average location of the 250 ppm isochlor as the "salt line". Because chloride ions represent approximately 55% by weight of the total dissolved ions in seawater, a "salt line" defined by a chlorinity of 250 ppm approximates a salinity of 450 ppm, or 0.45 ppt.

There is also a lateral salinity gradient present in the bay portion of the estuary, between the mouth and about RM 50, with higher salinities near the axis of the bay, and lower salinities on the east and west sides. Upstream of Artificial Island at RM 50, salinity tends to be more uniformly distributed across the channel. Under most conditions in the estuary, there is only a small vertical salinity gradient, due to the dominance of tidal circulation and mixing relative to the normal freshwater inflow. However, under prolonged high-flow conditions, such as during the spring freshet, vertical salinity gradients of as much as 5 ppt can occur in the lower bay, with corresponding smaller vertical gradients at locations further upstream to the limit of the salt line.

At any given point in the estuary between the bay mouth and the location of the salt line, the salinity of the water column will vary directly with the phase of the tidal currents. Maximum salinity at a point occurs around the time of slack water after high tide, and minimum salinity occurs at the time of slack after low. This condition reflects the significant role played by tidal currents in advecting higher salinity water in the upstream direction during flood flow, with lower salinity water being advected in the downstream direction during ebb. For periods longer than a single tidal cycle, the salinity at a given location varies in response to other important forcing functions, including the short-term and seasonal changes in freshwater inflow, wind forcing over the estuary and adjacent portions of the continental shelf, and salinity and water level changes at the bay mouth. Over longer periods (years to decades and longer), sea level changes and modifications to the geometry of the estuary also affect the long-term patterns of salinity distribution.

To illustrate the variability of salt distribution in the estuary over time, Figure 4-1 presents a plot of the "salt line" location within Delaware estuary, along with average daily inflow at Trenton, for the period 1 January 1998 through 30 November 2008 (10.9 years). The term "salt line" refers to the 7-day average location of the 250 mg/l (ppm) isochlor, and is used as an approximate indicator of the upstream penetration of ocean-derived salinity. In the ~11-year period shown, the salt line has been as far north as RM 90 in late summer 2005, and at or below RM 40 during multiple high-flow periods in 2006, a range that exceeds 50 miles along the axis of the estuary for a period just over a decade.

Figure 4-2 is a histogram of the daily salt line location for the same January 1998 to November 2008 period, and shows that the average location over this period is about RM 71, upstream of the Delaware Memorial Bridge and near the mouth of the Christina River in Wilmington, Delaware. Based on monthly averages, the salt line maximum penetration occurs in October (RM 81) with the minimum in April (RM 61), reflecting the typical seasonal pattern of freshwater discharge to the estuary. A general observation is that the salt line location varies directly with the volume of freshwater inflow, and is located in the twenty-mile long zone between RM 61 and RM 81 during an "average" year.

Figure 4-1. Salt Line Location and Trenton Inflows from 1998 to 2008.

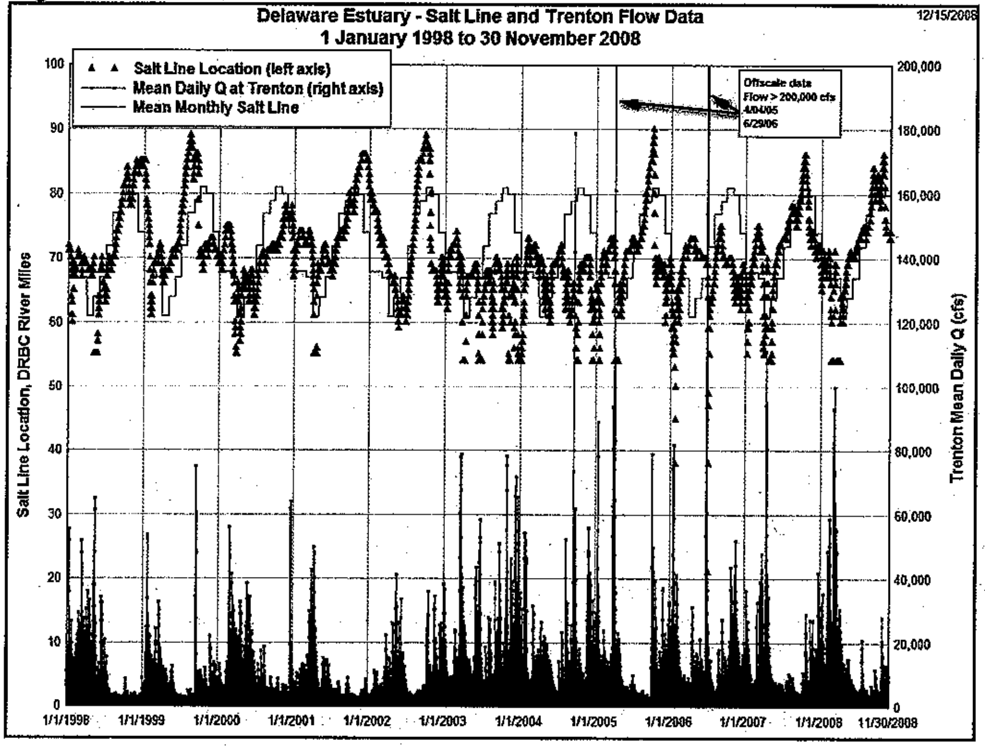
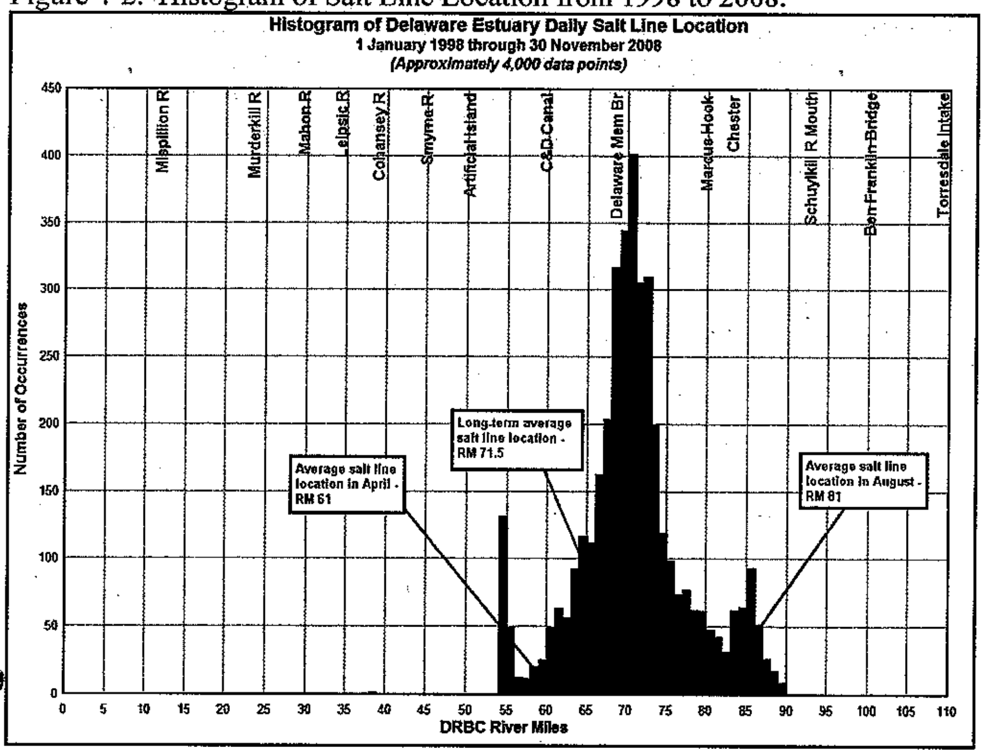



Figure 4-2. Histogram of Salt Line Location from 1998 to 2008.



The spatial and temporal distribution of salinity within the Delaware Estuary is an important water quality issue for a number of reasons. In the tidal region from Trenton downstream to Wilmington, Delaware River water is utilized for a number of industrial and municipal water supply purposes. The City of Philadelphia obtains its municipal water supply by withdrawal of river water at Torresdale (RM 110). Many industrial users obtain both process and cooling water from the river in the Trenton to Wilmington reach. Above RM 98, the river provides a portion of the recharge to aquifers that supply groundwater in the Camden Metropolitan area in New Jersey. This heavily urbanized area of the river is thus sensitive to increases in salinity that might affect industrial and municipal water uses, particularly under drought conditions.

The four longitudinal salinity zones within the Delaware Estuary, starting at the downstream end, are referred to as: ***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) from Marcus Hook to Trenton. 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.

Salinity is also a key factor regulating the distribution of fauna and flora in the estuarine environment. Vegetation, aquatic organisms, and to a lesser degree, wildlife distribute themselves within the estuary based on their salinity tolerances. Freshwater organisms that can not tolerate high salinity are restricted to the freshwater portion of the estuary generally located above Wilmington. Marine organisms that require high salinities are restricted to the lower bay. Organisms that can function over a broad range of salinity inhabit the portion of the estuary that is within their salinity tolerance range. It should be noted that salinity is only one environmental factor that affects the distribution of organisms within the estuary, and it is necessary to consider a variety of other factors to precisely define the spatial limits of a particular species.

The U.S. Fish and Wildlife Service prepared a planning aid report in support of the Philadelphia District's Delaware Estuary Salinity Intrusion Study (USFWS, 1981). That report provides a discussion of how various components of the Delaware Estuarine ecosystem relate to salinity, and require specific salinity patterns to carry out portions of their life cycle. The following excerpt from the report characterizes the influence of salinity on the oligohaline-mesohaline portion of the estuary:

> "The information we have reviewed shows that salinity exerts strong influence on the Delaware estuarine ecosystem. Briefly, it influences the distribution of marsh plants, benthic invertebrates, fishes and certain wildlife. Relatively few aquatic species are tolerant of the entire salinity gradient from fresh water to salt water. Most species occupy portions of the gradient beyond which survival is threatened. Salinity affects seed germination and growth of marsh plants; oyster drill predation and probably MSX disease in the oyster seed beds; movement of blue crab larvae; location of blue crab spawning, nursery and mating grounds; movement of fish eggs and larvae; location of spawning,

nursery and feeding grounds of fishes; muskrat production; and, waterfowl feeding and resting grounds. The overall effect of the salinity gradient is to create numerous niches, fostering wide ecologic diversity and high productivity. Literally hundreds of plant and animal species, some with populations numbering in the many thousands, utilize the Delaware estuary."

4.1.2.2 Salinity Modeling

In order to estimate the potential for the proposed channel deepening to affect salinity distribution, the Army Corps of Engineers applied the 3-D numerical hydrodynamic model "CH3D-WES" (Curvilinear Hydrodynamics in Three Dimensions) to develop data on the movement of the salt line and the 5, 10, and 15 ppt isohalines that cover various locations in the estuary and correspond to salinities significant to various components of the estuarine ecosystem.

CH3D-WES includes as input data ("boundary conditions") the most important physical factors affecting circulation and salinity within the modeled domain. As its name implies, CH3D-WES makes computations on a curvilinear, or boundary fitted, planform grid. Physical processes affecting baywide hydrodynamics that are modeled include tides, wind, density effects (salinity and temperature), freshwater inflows, turbulence, and the effect of the earth's rotation. The representation of vertical turbulence is crucial to a successful simulation of stratification in the bay. The boundary fitted coordinates feature of the model provides enhancement to fit the scale of the navigation channel and irregular shoreline of the bay and permits adoption of an accurate and economical grid schematization. The vertical dimension is Cartesian which allows for modeling stratification on relatively coarse horizontal grids.

The principal goal of the modeling effort was to identify and quantify any impacts of the proposed 5-foot channel deepening on spatial and temporal salinity distribution. A number of modeling scenarios were developed to represent a range of boundary and forcing conditions of potential importance to both human and non-human resources of the Delaware Estuary.

Several scenarios were identified and selected for application in the 3-D model to address the impact of channel deepening on salinity distribution and subtidal circulation in the Delaware Estuary. The selection of these sets of conditions was based on coordination accomplished through interagency workshops. The selected scenarios include:

1. The June-November 1965 drought of record, with Delaware River discharges adjusted to reflect the existing reservoir regulation plan and corresponding flows ("Regulated 1965");

2. Long-term monthly-averaged inflows with June-November 1965 wind and tide forcings; and

3. A high-flow transition period, represented by the April-May 1993 prototype data set.

Each of these periods was simulated first with the existing 40 foot navigation channel, and then with the proposed 45 foot channel in place. A detailed presentation of the findings of the salinity modeling is presented in Section 5 of the July 1997 Supplemental Environmental Impact

Statement (SEIS), and is not presented here. Instead, the concluding paragraphs of Section 5 are quoted.

> "A fundamental conclusion from the study is that deepening the existing navigation channel from 40 feet to 45 feet will result in salinity (chlorinity) increases in the Philadelphia area during a recurrence of the drought of record. However, the increases will not have an adverse impact on water supply. The present DRBC drought management plan, including reservoir storage added since the drought of record, prevents the intrusion of ocean salinity into the Philadelphia area in excess of existing standards [maximum 30-day average of 180 ppm of chlorides and 100 ppm of sodium at River Mile 98]. With the deepened channel and a recurrence of the drought of record, the maximum 30-day average chlorinity at RM 98 is about 150 ppm.
>
> Historic groundwater withdrawals from the Potomac-Raritan-Magothy (PRM) aquifer in Camden County, New Jersey, have depressed the potentiometric surface of the aquifer system to a level as much as 100 feet below sea level in the central portion of the county. This has led to a condition in which a portion of the total recharge to the (PRM) aquifer system in Camden County is derived from Delaware River water. The present Delaware River Basin Commission drought management standard for RM 98 chlorinity is a maximum 30-day average of 180 ppm. This standard was adopted in order to limit the recharge by river water with elevated chlorinity into the PRM aquifers exposed at the bed of the Delaware River above RM 98 under low flow conditions.
>
> Investigations of Camden County groundwater resources by the US Geological Survey (Navoy, 1996) have indicated that the rate of aquifer recharge from the river is principally controlled by groundwater withdrawals. Deepening of the Delaware River navigation channel will have a negligible effect on the recharge characteristics of the aquifer. Although the proposed channel deepening is predicted by the salinity model to increase RM 98 chlorinity with a recurrence of the drought of record, the resulting 30-day average chlorinity will still be below the present standard of 180 ppm. Transient increases in chlorinity of the river water recharging the aquifer under drought conditions will cause no loss of potability in the groundwater resource. Thus, it is concluded that the proposed channel deepening will not have a significant adverse impact on the hydrogeology or groundwater resources of Camden County, New Jersey. Increases in salinity attributable to channel deepening that could occur during a recurrence of the 1961-65 drought are unlikely to cause any additional adverse effect to environmental resources; freshwater aquatic vegetation will experience temporary decreases in distribution and productivity in the vicinity of RM 69, during a recurrence of the drought of record, but is expected to recover when the drought is over.
>
> During normal to high flow periods with the deepened channel, oyster bed areas in the lower bay will experience increases in salinity due to steeper longitudinal salinity gradients which accompany high flow conditions. The impact of those increases on oyster production is viewed as negligible. Changes in the subtidal circulation over the oyster beds due to channel deepening will also be minimal, e.g., less than 1 cm/sec. Impacts that may occur to other environmental resources are also considered to be insignificant."

4.1.2.3 Post-SEIS Salinity Modeling

In 2003, DRBC requested additional information regarding the potential for factors other than the proposed deepening to impact salinity in the Delaware Estuary system. DRBC asked whether increased consumptive use of Delaware River water, and potential future increase in sea level, would amplify the impacts of deepening on salinity. To address these questions, the Army Corps of Engineers conducted additional simulations with the CH3D model between 2004 and 2007.

The model was applied to assess the impact on salinity of three independent scenarios, namely:

1. Delaware Bay and River channel deepening from 40 ft to 45 ft
2. Projected increased consumptive use of fresh water between 1996 and 2040
3. Projected sea level change from 1996 to 2040

The model was executed for the entire year of 1965. The year 1965 was selected because it includes the period of lowest flows and highest observed chlorinity in the vicinity of Philadelphia during the 1962-65 drought of record, which is the worst-case hydrologic regime adopted by DRBC for water resources planning in the Delaware Basin. Suitable prototype data sets for tide and salinity/chlorinity exist to allow meaningful comparison of observed 1965 data with model computed values. Minor model adjustments (bottom friction and horizontal diffusion coefficients) were made that improved the model's ability to reproduce observed salinity/chlorinity measurements made during the drought of record in the portion of the estuary from Philadelphia downstream to the Delaware Memorial Bridge.

The projected 2040 consumptive use input files were generated by DRBC, and a sea level rise value of 1.27 per century was adopted based on measurements at NOS tide gauges during the $20^{th}$ century along the coasts of New Jersey and Delaware. Model results were saved at the Delaware Memorial Bridge, Chester, and RM 100 (Ben Franklin Bridge). Although the estuary south of the Delaware Memorial Bridge was included in the modeling, data were not saved in this reach.

The three scenarios were first modeled individually, and then all three scenarios were modeled together. The modeling demonstrated that all three system changes – channel deepening, increased consumptive use, and sea level rise – individually cause small but finite increases in salinity in the reach between Philadelphia and Wilmington during a recurrence of the drought of record. Of the three changes modeled individually, the smallest impact resulted from the projected consumptive use, and the largest impact was from projected sea level rise. Table 4-1 presents the peak 7-day-average change resulting from each scenario, compared with the background range of salinity/chlorinity during the 1965 simulation period. The last row in Table 4-1 presents the results of the model run with all three scenarios imposed – channel deepening, 2040 consumptive use and sea level projected to 2040.

It is noted that 7-day-averages of salinity and chlorinity were computed for this modeling effort, rather than 30-day-averages as is stated in the DRBC River Mile 98 standard. A peak 7-day-

average results in a slightly higher predicted value of salinity or chlorinity than would have resulted from computing 30-day averages. Nevertheless, the 7-day averages demonstrate that even if the drought of record were to recur with (a) projected 2040 sea level rise, (b) the channel deepened to 45 ft and (c) 2040 depletive uses, the RM 98 chlorinity standard is not exceeded. The peak 7-day average with all three changes imposed is a 20 ppm chlorinity increase, equivalent to a peak 7-day average chlorinity of 160 ppm at RM 98.

Table 4-1. Salinity Model Results

| **MODEL SCENARIO** | **Location** | | | | | |
|---|---|---|---|---|---|---|
| | **Delaware Memorial Bridge (RM 69)** | | **Chester (RM 83)** | | **Ben Franklin Bridge (RM 100)** | |
| | Peak 7-Day-Avg Change, Salinity ppt | Background Range, 1965, Salinity ppt | Peak 7-Day-Avg Change, Salinity ppt | Background Range, 1965, Salinity ppt | Peak 7-Day-Avg Change, Salinity, Chlorides ppm | Background Range, 1965, Chlorides ppm |
| Deepen Channel to 45 ft | 0.17 | 0 to 6 | 0.07 | 0 to 1.8 | 6 | 0 to 140 |
| Consumptive Use in 2040 | 0.18 | | 0.07 | | 4 | |
| Sea Level Rise in 2040 | 0.5 | | 0.18 | | 12 | |
| Three Scenarios Combined | 0.9 | | 0.3 | | 20 | |

As a sensitivity test, the model results were applied to estimate the amount of sea level rise that would be required to elevate the peak 7-day-average chlorinity at RM 98 to the DRBC standard of 180 ppm (a 30-day average) for the existing 40-ft channel. The 2040 sea level rise used in the modeling was 0.56 ft and resulted in a peak change of 12 ppm in the 7-day-average chlorinity. Extrapolating this relationship suggests that a sea level rise in excess of 3 feet would be required to raise the chlorinity at RM 98 to approximately the existing DRBC standard of 180 ppm.

Model results show that each of the system changes individually increase the intrusion of salt into Delaware Bay and River. The increase due to sea level rise is larger than increases due to either the deepening or projected depletive use acting alone. The impact of all three systems changes coincident with a recurrence of the worst-case basin hydrology (drought of record, 1965) results in predicted salinity/chlorinity changes in the Delaware River as shown in Table 4-1.

4.1.2.4 Sea Level Rise

Global mean sea level (GMSL) is recognized as rising at the majority of tide gage locations around the world, although local mean sea level is falling in some areas where local tectonic effects cause the land to rise faster than GMSL (coastal Alaska, for example). Implications of sea level rise include increased shoreline erosion and coastal flooding, changes in extent and

distribution of wetlands, and salinity intrusion into upper portions of estuaries and into groundwater systems.

The principal international effort to evaluate risks associated with climate change and sea level rise is the Intergovernmental Panel on Climate Change (IPCC). The most recent report issued by the IPCC, "Climate Change 2007: Impacts, Adaptation and Vulnerability", adopts a present rate of GMSL rise of 1.7 mm/yr (~ 0.6 ft/century). Although there is substantial regional variability, relative mean sea level has risen at a rate of about 1 ft/century (or approximately 3 mm/yr) over the past century along the East Coast of the United States.

NOAA/NOS tide gages representative of conditions in Delaware Estuary include those at Philadelphia, PA, Reedy Point and Lewes, DE. For the adjacent region in the Atlantic Ocean, the tide gage at Atlantic City, NJ is appropriate. The measured period-of-record change in mean monthly sea level at all four tide gage locations is illustrated in Figures 4-3a through 4-3d below. Notwithstanding the significant recent attention to the issue of potential *accelerated* rate of sea level rise, none of these tide gage sites provides evidence that such acceleration has in fact occurred in the Delaware estuary over the past century. Nevertheless, the Philadelphia District is performing additional runs with the Delaware Estuary hydrodynamic-salinity model to investigate potential sea level rise at rates greater than were adopted in the work described above in Section 4.1.2.3. That effort utilized a projected linear rate of sea level rise (1.27 ft/century) to the year 2040, which coincided with the date of DRBC projections for increased depletive uses of Delaware Basin water.

4.1.2.5 Sea Level Rise, Climate Change and Impact to Wetlands

Tidal wetlands within the Delaware River and Bay have experienced progressive loss over the preceding several centuries since the earliest European settlers arrived. A portion of the wetland loss has been directly or indirectly attributed to human activities (e.g., diking, farming, filling, bulkheading, dredging, changes in watershed sediment management, etc.) and a portion of the loss has been attributed to largely "natural" causes (e.g., sea level rise, wave action, overfeeding by geese, etc). Wetlands have been lost both along the fringes of Delaware Bay and River, as well as in interior wetland areas that do not front on open water. The relative importance of the numerous human-induced and natural factors contributing to wetland loss is at best poorly understood at present. However, future sea level rise is one factor that has been identified, widely publicized, and is frequently cited as a significant threat to the existing stock of tidal wetlands in the estuary.

Tide gage records in Delaware River and Bay and adjacent areas of the Atlantic coast have been operated for as long as 150 years, and clearly demonstrate a regional rate of relative sea level rise of about one foot over the past century. Locally within the Delaware Estuary area the rate at any given site may be slightly higher or lower than the value cited above, but to a first approximation, one foot per century is the regional rate of mean sea level rise.

From a geological perspective, it is recognized that at the peak of the last North American continental glaciation about 18,000 years ago, mean sea level was on the order of 100 meters (330 feet) lower than it is today. Despite a rise of sea level of that magnitude in the period since ~18,000 BP, a large and diverse stock of wetlands evolved as a dominant feature of the Delaware

Estuary. Geologic evidence indicates that wetlands have been a stable part of the estuary landscape, migrating up and landward as sea level has risen even during significant post-glacial climate change. Thus sea level rise alone can not be uniquely identified as the principal cause of wetland loss experienced over the past several centuries.

The potential for significant climate change, in particular global warming and accelerated sea level rise, has been widely publicized as a likely occurrence during the 21st century and beyond. However, the proposed channel deepening of the Delaware River navigation channel will not affect the regional rate of relative sea level rise, nor will it directly have an adverse impact on estuary wetland resources. In fact, the dredged material disposal plan for the project includes wetland restoration features for Kelly Island, Delaware, where historic shoreline erosion has caused retreat of more than 15 feet per year over the past century along more than a mile of tidal wetland shoreline. Hence the deepening project, regardless of the actual course of sea level rise in the coming decades, will have a net positive impact on wetland resources in the estuary.

Figure 4-3a. Sea Level Trend at Philadelphia, PA.

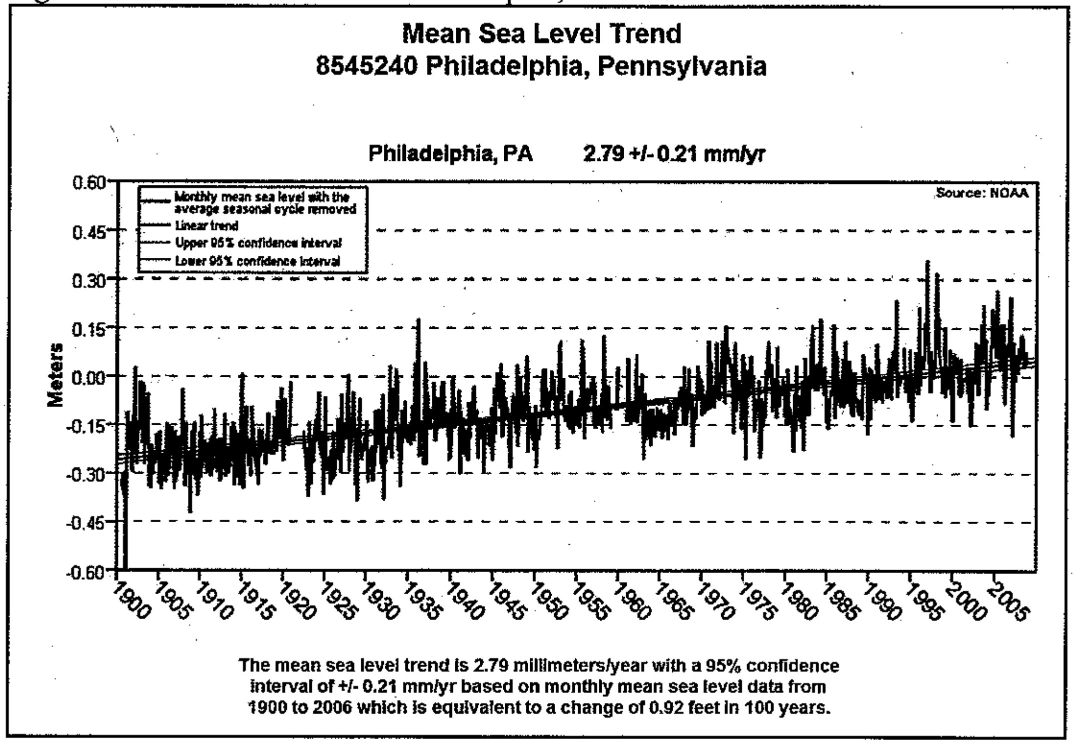



Figure 4-3b. Sea Level Trend at Reedy Point, DE.

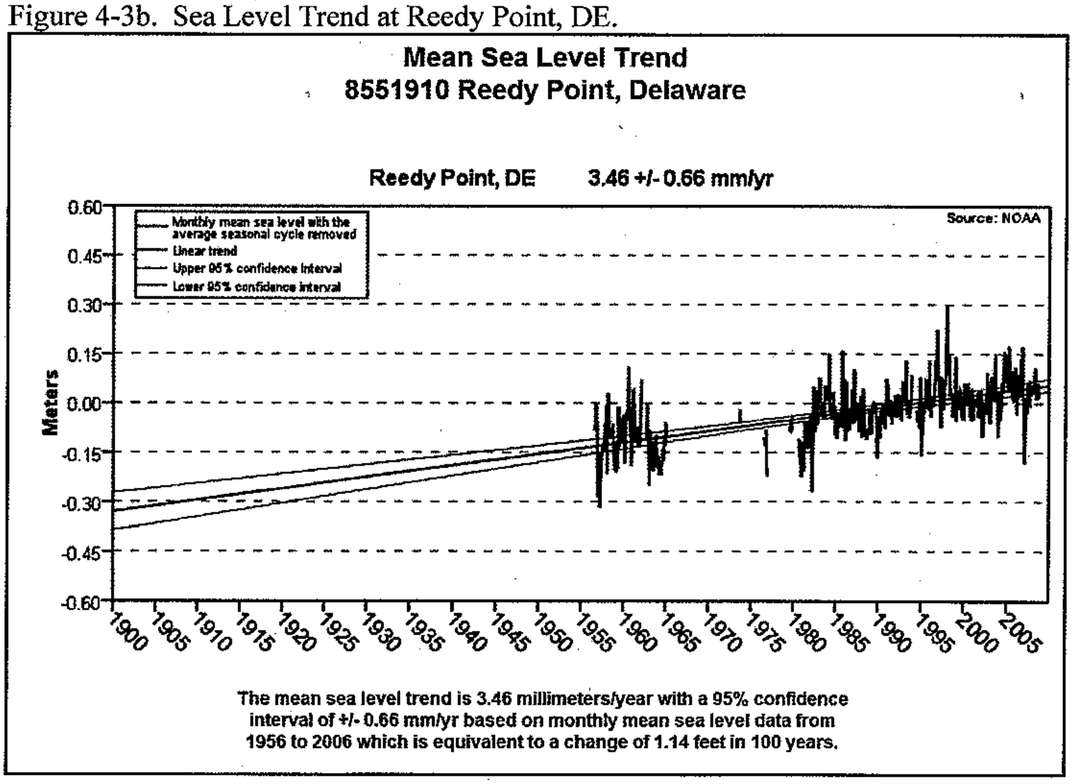
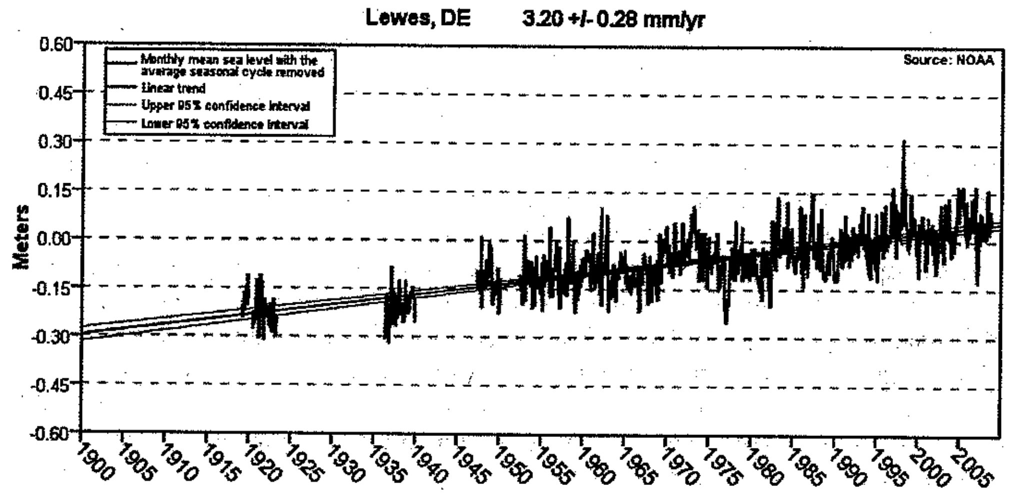


Figure 4-3c. Sea Level Trend at Lewes, DE.

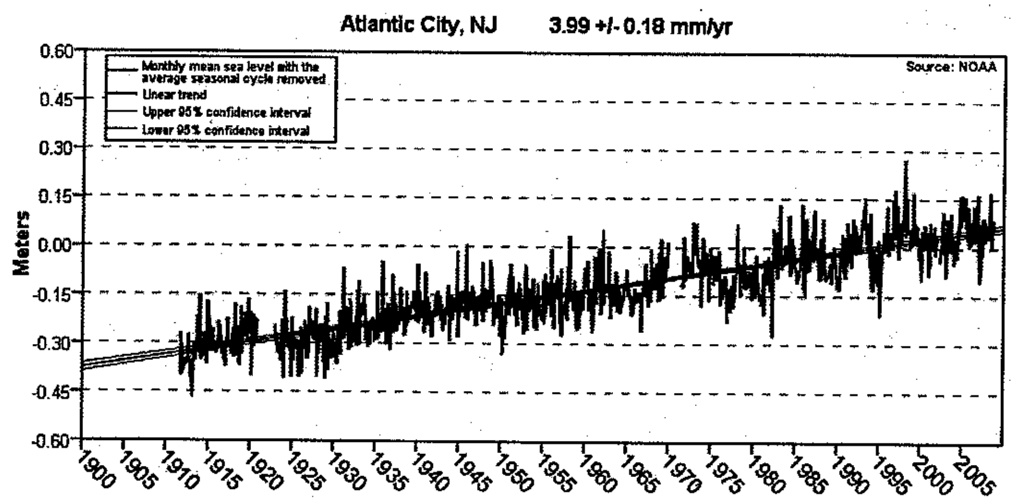
**Mean Sea Level Trend**
**8557380 Lewes, Delaware**




The mean sea level trend is 3.20 millimeters/year with a 95% confidence interval of +/- 0.28 mm/yr based on monthly mean sea level data from 1919 to 2006 which is equivalent to a change of 1.05 feet in 100 years.

Figure 4-3d. Sea Level Trend at Atlantic City, NJ.

**Mean Sea Level Trend**
**8534720 Atlantic City, New Jersey**




The mean sea level trend is 3.99 millimeters/year with a 95% confidence interval of +/- 0.18 mm/yr based on monthly mean sea level data from 1911 to 2006 which is equivalent to a change of 1.31 feet in 100 years.

4.1.2.6 Dredging, Sediment Budget and Impact to Wetlands.

Within the past several years, some members of the Delaware estuary scientific community have hypothesized a possible relationship between loss of tidal wetlands and the sediment budget of the estuary, especially in regard to maintenance dredging and dredged material disposal practice.

There is a well-documented historic loss of fringing wetlands on both the NJ and DE sides of the Bay extending back to at least 1900. There are also interior areas of formerly robust tidal wetlands that have reverted to shallow open water. To the present, no consensus has emerged as to the most important factor(s) causing or contributing to these losses. At a minimum, the observed rise in mean sea level over the past century is believed to have contributed to the loss, if only from the standpoint of sea level rise occurring more rapidly than vertical accumulation of sediment has occurred, leading to more frequent or permanent inundation of wetlands. A number of other potential contributing factors have been identified as potential contributors to wetland loss including: excessive nutrient loading of estuarine waters, reduced suspended sediment supply (including reduction in watershed contribution of sediment through land use management), alteration of wetland hydrology, marsh sediment auto-compaction, atmospheric deposition of pollutants, waves including vessel wakes, etc.

Disposal of dredged material in the Delaware River and Bay over the past five decades has involved placement of the vast majority of the dredged sediment in confined upland disposal sites, which effectively sequesters this sediment from the estuarine system. One attempt to quantify the sediment budget for the entire estuary was performed by the Philadelphia District as part of "Long Range Spoil Disposal Study" in the 1970's. This effort identified and quantified sources and sinks of sediment in the estuary. The investigation concluded that the proximate source of fine-grained sediments that shoal in the navigation channel is the bed of the estuary outside the limits of the channel. The ultimate source of the fine-grained sediments was attributed principally to the watershed of the estuary above the head of tide.

The most recent contributions to quantifying the estuary sediment budget consist of work done by Dr. Christopher Sommerfield and David Walsh at the University of Delaware (Walsh, 2004). Sommerfield and Walsh recognize the complexity of understanding the sediment transport and deposition/erosion regime of the estuary. Nevertheless, they estimate an estuary sediment mass balance with sources contributing $4.7 \times 10^9 \pm 1.1 \times 10^9$ kg/yr, and sinks removing $5.4 \times 10^9 \pm 7.4 \times 10^8$ kg/yr. Walsh concludes "The estimates are not statistically different from one another when the confidence limits are considered. Overall, the budget balances within about 13 %, suggesting that any other source or sink terms are minor. As elaborated later, the erosional sediment mass outweighs that supplied by rivers, a condition recognized in previous work."

The apparent overall estuary sediment deficit identified by Sommerfield and Walsh was calculated from mass balance estimates of sediment sources and measured accumulation rates. However, it is not possible at present to link the estuary sediment mass balance with the problem of wetland loss in a conclusive manner. Further, it is not apparent that existing maintenance dredging and disposal practices, which sequester dredged sediment in upland disposal sites, are a significant factor in estuary wetland loss, or that maintenance dredging anticipated for the project deepened to 45 feet will exacerbate the wetland loss problem.

4.1.3 Water Quality

The existing 40-foot Federal navigation channel from Philadelphia to the Sea is routinely maintained by the Corps of Engineers. Approximately 3,455,000 cubic yards are dredged annually to maintain the 40-foot depth. This maintenance dredging is reviewed by NJDEP as part of the water quality certification process. Data on sediment quality and placement area(s) discharges are analyzed as part of this process. The method of dredging, the location of the samples taken and the monitoring are all within the proposed 45-foot channel deepening project area. This data provides further verification, to some degree, of the analysis done for that project.

In accordance with NJDEP water quality certification for maintenance of the existing Delaware River Philadelphia to the sea project, the quality of water discharged from confined disposal facilities (CDFs) during maintenance dredging operations has been monitored on an annual basis from 1998 through 2006. Inlet slurry samples, a mixture of dredged sediment and water from the Delaware River that is pumped through pipes into the CDF, and water samples from the weir, discharge plume, and background locations were analyzed for inorganics, volatile organic compounds, semi-volatile organic compounds, pesticides, and high resolution or arochlor PCBs. Water samples were compared to DRBC water quality criteria for the protection of aquatic life.

Water quality criteria for inorganic elements defined by the DRBC are intended for comparison to dissolved metals concentrations. Dissolved inorganics are biologically available to aquatic organisms, whereas particulate inorganics are not likely to be taken up. Since dredged material disposal operations are short-term events, comparison of sample data to acute water quality criteria is more relevant than chronic. Some of the water quality criteria are hardness based. To calculate these criteria the average hardness was determined over all sampling events and divided in half to be conservative. The lower the hardness the lower the criteria. A total of 71 water samples have been collected at the point of CDF discharge and analyzed over the last nine years. Of these 71 samples, none exceeded DRBC freshwater acute water quality criteria for arsenic, cadmium, lead, mercury, nickel, selenium or silver. Three samples exceeded the acute criterion for aluminum, four samples exceeded the acute criterion for copper and 17 samples exceeded the acute criterion for zinc. A total of 70 samples have been collected within approximately 100 yards of where the CDF discharges back to the adjacent water body. These samples represent water quality with some initial mixing. After initial mixing, three samples exceeded the acute criterion for aluminum, two samples exceeded the acute criterion for copper and eight samples exceeded the acute criterion for zinc. Based on these minimal exceedences, the impact of CDF operation on water quality is considered small.

Water samples collected at the point of CDF discharge have also been analyzed for a variety of organic contaminants. Only one sample had a concentration of an organic contaminant (endrin ketone) above an acute freshwater quality criterion (0.15 parts per billion compared to the criterion of 0.09 parts per billion).

Water quality impacts associated with operation of upland confined disposal facilities for construction of the channel deepening project would be minimal. This data has been recently reviewed by the NJDEP and a new water quality certificate for continued maintenance of the existing channel was issued in September 2007.

### 4.1.3.1 Water Quality Impacts at the Point of Dredging

In 2001, the Delaware Department of Natural Resources and Environmental Control requested that the Corps evaluate the near-field concentrations of metals and PCBs released during dredging operations (Versar, 2001a). The purpose of this evaluation was to ensure that potential sediment contaminants that may be released during dredging were not likely to exceed applicable water quality criteria. These evaluations were conducted for cutterhead hydraulic dredging in the shipping channel and for a bucket dredge in berthing areas. In addition, a separate analysis was conducted to assess impacts to human health criteria. That analysis was conducted as is discussed under the heading of "*PCB Mobilization During Dredging Operations and Seqestration by Upland Confined Disposal Facilities*".

The model selected for the water quality evaluation was the DREDGE model, developed for the Corps of Engineers for a near-field (i.e., within a 200-foot mixing zone) evaluation of dredging operations. DREDGE was developed to assist in making a-priori assessments of environmental impacts from proposed dredging operations. DREDGE estimates the mass rate at which bottom sediments become suspended into the water column as the result of hydraulic and mechanical dredging operations and the resulting suspended sediment concentrations. These are combined with information about site conditions to simulate the size and extent of the resulting suspended sediment plume. DREDGE also estimates particulate and dissolved contaminant concentrations in the water column based upon sediment contaminant concentrations and equilibrium partitioning theory.

Bulk sediment contaminant data previously collected from the Marcus Hook Range of the Delaware River navigation channel and the Sun Marcus Hook Berth were used to represent the expected level of contamination in the sediment to be dredged. These locations are in the immediate vicinity of the State of Delaware line.

The results of the DREDGE model indicated the following, using environmentally conservative assumptions. Neither dissolved metals nor total dissolved PCBs released during cutterhead hydraulic dredging would exceed acute or chronic water quality criteria outside of the mixing zone, using the model. Even using a more conservative estimation approach, none of the metals would exceed water quality criteria at the edge of a 60-meter mixing zone except mercury and then only within 0.1 meters of the bottom. Given the conservative nature of these predictions, actual contaminant concentrations are expected to be considerably lower than predicted.

None of the dissolved metal or total PCB concentrations predicted to be released to the water column as a result of bucket dredging were above the Delaware River Basin Commission acute or chronic water quality criteria, even using the maximum sediment metal concentration measured in the area to be dredged. Even with a more conservative metals partitioning estimation approach, no metals with measurable sediment concentrations would exceed chronic or acute water quality criteria.

Metals and PCBs would not exceed Delaware River Basin Commission water quality criteria in the vicinity of a working cutterhead hydraulic dredge or a bucket dredge during construction of the deepening project.

PCB Mobilization During Dredging Operations and Seqestration by Upland Confined Disposal Facilities

Based on PCB contamination concerns in the Delaware estuary, the Corps reviewed data and conducted various studies to understand how PCBs are distributed in the estuary and how dredging and dredged material disposal activities might affect the movement of PCBs. Work efforts included testing channel sediments for PCBs using high resolution congener specific techniques, reviewing similar data from a study conducted in shoal areas of the Delaware River, and developing mass balance analyses for PCBs entering and leaving active CDFs during dredging operations (Versar, 2001d). Four conclusions were drawn from this work: (1) PCB concentrations tend to be higher in shallow areas outside of the navigation channel; (2) PCB concentrations are lower in Delaware Bay than in the Delaware River; (3) the vast majority of PCBs present in dredged sediments are retained in upland confined disposal facilities (CDFs); and (4) PCB concentrations in CDF weir discharges are not vastly greater than background river PCB concentrations. To evaluate potential PCB impacts associated with the deepening project, previously collected data was used to (1) conduct a mass balance analysis for the entire deepening project and (2) determine the potential for exceeding the human health water quality criteria established for the Delaware River (0.0448 ng/L for freshwater and 0.0079 ng/L for marine waters) as a result of dredging and dredged material disposal activities.

To conduct a PCB mass balance analysis for the entire deepening project, previously collected PCB sediment data collected from various reaches of the channel were matched with up-to-date estimates of the volume of material to be removed from each reach. The previously collected PCB data was obtained from sediment cores collected in the channel. In that study, the top three inches of the core was tested and the bottom 57 inches of the core was tested. For this analysis, weighted PCB concentrations were calculated for each core. Average weighted concentrations for areas that had more than one core were calculated to provide one estimate of total PCB concentration per dredging reach. The total volume of material to be dredged was converted to total grams of material assuming the density of the material was 1.33 gm/cc. Average reach PCB concentration was then multiplied by the total grams in the reach to estimate the total kg of PCBs that may be removed from the channel for the entire deepening project. Based on efficiency studies conducted at the Pedricktown North, Killcohook and Oldmans CDFs, the total kg of PCBs returned to the river through the weir was estimated assuming an efficiency of 99.9%.

A mathematical equation was developed to estimate PCB concentrations in the Delaware River resulting from construction of the deepening project. The equation combined a sediment source strength factor (the quantity of sediment placed in the water column per unit of time by the working dredge) and the average PCB sediment concentration to calculate a PCB release rate. The dissolved fraction of PCBs in the water column was estimated by selection of a reasonable partition coefficient for PCBs. The dredging production rate combined with the volume of material to be removed provided an estimate of the time over which the dredging operation would occur. The total and dissolved PCB release rate combined with the time required for completing the excavation provided an estimate of the mass of total and dissolved PCBs that may be released into the water column during the dredging project. Human health criteria were applied under a complete-mix condition, which is defined as the material released per unit of time into the mean harmonic flows in the different reaches. These were extrapolated from the mean harmonic flow at Trenton, NJ. The water column concentrations of total and dissolved PCBs were calculated and compared with PCB human health criteria for the Delaware River.

Nearly 423 kilogram ( kg) of total PCBs would be removed during dredging operations in the Delaware River navigation channel for the deepening project; this amount represents about 1.5% of the total PCBs in the Delaware estuary. This material would be placed in upland confined disposal facilities where at least 99.9% would be retained, resulting in a release back to the estuary of only about 0.42 kg of PCBs. During the dredging process itself, between 0.07 and 0.23 kg of total PCBs could be released to the water column, using environmentally conservative or worst-case estimates of physical and chemical processes, which occur during dredging. The dissolved fraction of PCBs, which might be released during dredging, is estimated to be between 0.036 and 0.117 kg, again using worst-case assumptions. In the most contaminated reach of the estuary, this dissolved fraction could result in water column concentrations that are between 13 and 43% of the PCB human health criteria using these worst-case assumptions.

Human health criteria established for PCBs in the Delaware River would not be exceeded.

4.1.3.2 Water Quality Impacts at Confined Disposal Facilities

The existing Corps placement site at Reedy Point South is one of the placement sites that will be used to store dredged material from the deepening project. This site is located on the south side of the Chesapeake and Delaware Canal at its confluence with the Delaware River, in the State of Delaware. Material would be dredged from the Reedy Island Range of the Delaware River navigation channel and placed in Reedy Point South. At the request of the Delaware Department of Natural Resources and Environmental Control, water quality was modeled to determine the potential levels of exposure for aquatic organisms to contaminants mobilized into the water column by dredging activities in this area (Versar, 2001). Mobilization of contaminants into the water column can occur at two points of exposure, the point of dredging and the point of weir discharge from an upland placement site. Unlike particulate substances bound to sediment, dissolved substances are available for potential uptake by aquatic organisms.

The equilibrium partitioning model was used to predict levels of contaminants that may become dissolved in the water column at the point of dredging. Equilibrium partitioning theory is a simple mathematical method of estimating the proportion of a chemical sorbed to sediment to the chemical dissolved in water. With a known concentration of chemical per unit weight of sediment, and a known weight of total sediment, this method can be used to determine the concentration of the chemical in the water. Assuming linear relationships between sediment concentration, fraction of organic carbon, and the octanol/water partition coefficient, the concentration of a chemical in sediment can be multiplied by a factor to yield a concentration of that chemical in the water column. Bulk sediment contaminant data previously collected from the Reedy Island Range were used to represent the expected level of contamination in the sediment to be dredged. Because of a lack of organic contaminants in this area, modeling was limited to inorganic heavy metal parameters (arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver and zinc).

The Cornell Mixing Zone Model (CORMIX) was used to predict dissipation of contaminants discharged from the weir at Reedy Point South. CORMIX is used to predict how contaminants dissolved in the water column will behave as mixing and tidal action disperses them from their source. CORMIX is intended as a first-order screening/design model. It does not carry out detailed hydrodynamic calculations using the exact geometry of the discharge location, nor does

it explicitly handle dynamic ambient currents (i.e., tides). It uses a simplified representation of the physical conditions at the discharge location to approximate the fundamental behavior of the plume. Dissolved contaminant concentrations in the Reedy Point South weir discharge were conservatively assumed to be equal to dissolved contaminant concentrations predicted by the equilibrium partitioning model at the point of dredging. This assumption is considered to be conservative because this is the maximum dissolved contaminant concentration that would occur, and does not account for processes that may reduce the aqueous contaminant load within the placement site.

The results of the equilibrium partitioning model indicate that four contaminants, copper, lead, mercury, and nickel may exceed water quality criteria near the point of dredging and at the weir discharge. These results are based on the assumptions of the model, including the conservative assumption that 80% of the sediment-bound contaminants will dissolve into the water column and that TSS concentrations would be 250 mg/l. A June 2001 study of the Corps Oldmans placement site indicated that the equilibrium partitioning model may overestimate dissolved metals concentrations. This study also showed that it is likely that TSS concentrations will be lower than 250 mg/l, resulting in no exceedances of water quality criteria.

Even given the conservative nature of the equilibrium partitioning model and the TSS concentration of 250 mg/l, only copper may exceed acute water quality criteria, which range from 2.4 ug/l for the New Jersey Department of Environmental Protection to 5.3 ug/l for the Delaware River Basin Commission. None of the other contaminants were projected to exceed acute water quality criteria near the point of dredging or at the weir discharge. Once mixing is considered at the weir, it was determined that at flood and ebb tides, all water quality criteria would be met within 2 meters of the weir. While water quality during slack tide may exceed chronic criteria for lead, mercury, and nickel, and acute criteria for copper, to a distance of nearly 44 meters, slack tide only lasts for a half hour and the plume is located within 0.2 meters of the surface. At the point when the tide begins to flood or ebb, the slack tide plume will dissipate in a short period of time, likely less than an hour. This limited affected area would not substantially impact water quality.

Water quality impacts at the point of dredging and in the vicinity of the weir of the Reedy Point South confined disposal facility would be minimal during construction of the deepening project.

4.1.3.3 Water Quality Monitoring During Construction

Two types of water quality monitoring are planned during construction to evaluate potential water quality impacts.

Monitoring will be conducted to evaluate the chemical quality of dredged material and water flowing into and out of confined disposal facilities during construction of the Delaware River Main Channel Deepening Project. Samples will be collected concurrent with dredging operations. Sampling will include material flowing into the disposal facility (influent), water and associated suspended sediment discharging from the facility (effluent), water samples collected in the Delaware River in the vicinity of the discharge point (representing the discharge plume), and water samples collected in the Delaware River at a location that can provide background water quality data. Samples will be collected and appropriately preserved in the field, and delivered to a laboratory for various chemical and geotechnical analyses. Instrumentation will be

installed at the discharge pipe to collect daily readings of the volume of water being discharged from the disposal site and the concentration of suspended sediment associated with the discharge. Data will be compared to Delaware River water quality criteria for the protection of aquatic life.

An evaluation of the chemical quality of Delaware River water immediately downstream of a working, hydraulic cutterhead dredge during initial construction of the Delaware River Main Channel Deepening Project will also be conducted. Specifically, the same parcel of water will be sampled before and after it passes the point of dredging to identify changes in total suspended sediment and contaminant concentrations. Discrete water samples will be collected at the surface, mid-point and bottom of the water column. Downstream samples (ie. after the parcel of water has passed the point of dredging) will be collected at a distance of 200 feet from the point of dredging. In addition, composite samples of bottom sediment in the area of dredging will be collected and analyzed to characterize the total contaminant loading of the dredged material. Samples will be collected and appropriately preserved in the field, and delivered to a laboratory for various chemical and geotechnical analyses. Contaminant data will be compared to Delaware River water quality criteria for protection of aquatic life. Total suspended sediment concentrations will be compared to a criterion established by the Delaware Department of Natural Resources and Environmental Control for protection of water quality, 250 mg/L. Composite sediment sample data will be used to estimate the release of contaminants to the water column using equilibrium partitioning theory. These data will be compared to actual concentrations measured in the water column downstream of the cutterhead dredge.

4.1.4 Sediment Quality

A review of sediment quality concerns associated with the Delaware River Philadelphia to the Sea navigation channel was provided in Section 4 of the 1997 Final Supplemental Environmental Impact Statement. That information is incorporated here by reference. The review included bulk sediment analyses, elutriate sediment analyses, Toxicity Characteristic Leaching Procedure (TCLP) analyses, biological effects based sediment testing, and high resolution PCB congener analyses. Based on this review the U.S. Environmental Protection Agency commented: "These tests showed no toxicity or bioaccumulation of any significance; therefore, EPA continues to believe that there will be no adverse impacts associated with the disposal of sediments generated by the project." (USEPA, 1997). In addition, in a letter from the U.S. Fish and Wildlife Service regarding Endangered Species Act consultation for the deepening project the Service commented: "Results of chemical analyses provided within the BA indicate that contaminant loads in the sediments tested are low. 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. Additionally, no demonstrable acute toxicity or bioaccumulation of sediment-associated contaminants were demonstrated in laboratory tests." (USFWS, 1996).

Since 1997, two additional sets of bulk sediment data have been collected from the channel (Versar, 2003 and 2005b). 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. The results were compared to updated Residential Direct

Contact criteria developed by the State of New Jersey, and used by the State to evaluate the quality of dredged material.

In general, the post-1997 data are similar to data presented in the 1997 SEIS. The most common parameters detected in sediments are 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. Overall, the relatively small number of exceedences is an indication that channel sediments are not contaminated with inorganic metals.

Organic parameters were less frequently detected in channel sediments. Only one sample had a pesticide concentration above New Jersey Residential criteria. A sample collected just below the Walt Whitman Bridge had a concentration of heptachlor epoxide of 0.074 ppm, which is slightly above the New Jersey residential criterion of 0.070 ppm. This sample and a second in the vicinity of the Walt Whitman Bridge were the only samples to exceed the PCB residential criterion of 0.2 ppm. Total PCB concentrations (sum of detected arochlors) in these two samples were 0.28 and 2.52 ppm.

The most frequently detected organic parameters were polycyclic aromatic hydrocarbons (PAHs). This was also true of previous sampling efforts. PAHs are primarily formed through combustion of fossil fuels and are expected to be found in highly industrialized and populated regions. Five PAHs were detected in sediment samples above New Jersey residential criteria. These PAHs are benzo(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene, dibenzo(ah)anthracene and ideno(123-cd)pyrene. In 2003, one sediment sample collected in the Marcus Hook range had concentrations of all five PAHs above the New Jersey residential criteria. Two other sediment samples had concentrations of benzo(a)pyrene (0.23 and 0.26 ppm) above the New Jersey criterion of 0.2 ppm. In 2005, three samples in the vicinity of the Walt Whitman Bridge or upstream of the bridge had concentrations of benzo(a)pyrene and benzo (b)fluoranthene above criteria. Two of the samples also had concentrations of benzo(a)anthracene (1.2 and 1.0 ppm) above the criterion of 0.6 ppm. Two additional samples collected in the vicinity of Wilmington, DE also had concentrations of benzo(a)pyrene (0.39 and 0.34 ppm) above the New Jersey criterion of 0.2 ppm. Overall, regarding organic contaminants, the relatively few detections above New Jersey criteria and the magnitude of the exceedences are indications that channel sediments are not a contaminant concern.. The 2003 and 2005 data sets support the findings presented in the 1997 Supplemental Environmental Impact Statement. This data was reviewed by the New Jersey Department of Environmental Protection and used to support issuance of a water quality certificate for continued maintenance of the existing channel in September 2007.

In November 2004, the M/T ATHOS struck a submerged anchor while docking at the Citgo Asphalt Refinery in Paulsboro, NJ and discharged nearly 265,000 gallons of crude oil into the Delaware River and nearby tributaries (Aquatic TWG, 2007). As part of its responsibilites under the Oil Pollution Act, NOAA conducted an assessment of natural resource losses associated with the Athos oil spill. One of the elements of this assessment was an "Aquatic Injury Assessment"

prepared by the Aquatic Technical Working Group (Aquatic TWG). This group issued a Final Report on June 21 2007. By comparing sediment chemistry and toxicity data from sediment samples taken 1, 3, and 10 months after the oil spill with similar data from pre-spill samples the Aquatic TWG reached the conclusion that, although there was a substantial impact on productivity in the months immediately following the spill, baseline conditions (i.e., no spill associated service losses) were reached 14 months after the oil spill (see, Aquatic TWG Final Report, page 17, and NOAA's Draft Damage Assessment and Restoration Plan and Environmental Assessment, January 2009, page 38). Thus, based on NOAA's conclusion that baseline conditions were reached in 14 months ( February 2005) there is no basis to conclude that adverse environmental impacts associated with the Athos Oil Spill in 2004 will contribute to any adverse impact resulting from Delaware River Dredging performed at least 4 and1/2 years beyond the date that baseline conditions were reached.

It should also be noted that the extensive sediment sampling taken 10 months after the oil spill as part of the Aquatic TWG Assessment do not conflict with the sediment samples collected by the Corps in 2003 and 2005. Of the 162 sediment samples taken in September 2005 only 5 of those samples were taken from within the Delaware River Main Channel. None of these 5 samples were evaluated beyond the initial Ultraviolet Fluorescence screening for PAH concentrations. As noted in the Sediment Collection Field Data Report (December 6, 2005) the results derived from the initial screening significantly overstated PAH concentrations and, thus, are only useful to compare the 162 samples in relative terms. The screening results for the five channel samples (0.8, 6.1, 22.7, 10.9, and 7.0 ppm) are all well below what the Field Data Report characterized, even if just in relative terms, as "very high [PAH] concentrations (above 100 ppm).

In accordance with the Federal Oil Pollution Act, a natural resource damage assessment has been conducted and a plan has been formed to restore natural resources injured by the M/T ATHOS spill (NOAA, 2009). The plan includes the following components:

*"Freshwater tidal wetlands restoration at John Heinz National Wildlife Refuge (Pa.)*
Restore 7.0 acres of freshwater tidal wetland to benefit 56 acres within John Heinz National Wildlife Refuge to compensate for tributary losses. This project would restore tidal exchange to the proposed site through tidal channels, shallow pools, and scrub/shrub wetland habitat.

*Create oyster reefs (N.J., Del.)*
Create roughly 78 acres of oyster reef in the Delaware River to compensate for injuries to aquatic resources, diving birds, and gulls. Oyster reefs enhance benthic communities, increase aquatic food for fish and birds, and improve water quality by filtering out sediments and pollutants from the water column.

*Darby Creek dam removal and habitat restoration (Pa.)*
Remove three dams and a remnant bridge pier from Darby Creek in southeastern Pennsylvania to open up an additional 2.6 miles of habitat to anadromous fish, and restore about 10 acres of riparian habitat along the creek edges. Dam removal and riparian habitat projects would compensate for tributary losses.

*Habitat restoration at Mad Horse Creek (N.J.)*
Restore 62.5 acres of degraded wetland and create 35 acres of wet meadow and 100 acres of grassland at state-owned property on Mad Horse Creek (N.J.). The proposed wetland restoration would compensate for non-tributary shoreline losses and a portion of the bird loss. The increase in upland vegetation (wet meadow and grassland habitat) would serve as food sources that can reasonably be expected to enhance bird biomass, thereby compensating for a portion of the total bird loss.

*Shoreline restoration at Lardner's Point (Pa.)*
Restore shoreline through the demolition of existing structures, import of fill material, grading of a 0.9 acre site to restore tidal inundation, and creation of intertidal marsh and wet meadow habitat. This shoreline restoration project would have multiple benefits in the urban part of the river that was heavily impacted by the spill.

*Blackbird Reserve Wildlife Area Pond and Pasture Enhancement (Del.)*
Excavate two shallow wetland ponds in former agricultural areas, convert 16 acres of agricultural lands to cool-season grass pasture, and establish approximately 24 acres of food plots by modifying existing agricultural practices. Conversion of existing agricultural land to pond and pasture habitat and modification of existing agricultural practices would provide resting and foraging areas targeted to migratory geese.

*Improve recreational opportunities (Pa., N.J., Del.)*
Implement three projects to address the estimated 41,709 river trips that were affected by the spill:

Improve the Stow Creek (N.J.) boat ramp;
Construct an additional breakwater at Augustine Boat Ramp (Del.) to address ongoing shoaling immediately offshore of the boat ramp; and
Enhance the recreational trail on Little Tinicum Island (Pa.)

The Delaware River deepening project would not impact the success of any of these plan components. Except for possibly oyster reefs, none of these locations are immediately adjacent to the navigation channel or dredged material placement sites. A discussion of potential impacts to oyster beds is provided in Section 4.2.3.3.

4.2 Ecological Resources

4.2.1 Delaware Bay Beneficial Use Sites

Environmental impacts associated with the Kelly Island and Egg Island Point wetland restoration sites are presented in Section 9.1 of the 1997 Supplemental Environmental Impact Statement (USACE, 1997) and are incorporated here by reference.

Environmental impacts associated with the Broadkill Beach, beach nourishment site are presented in Delaware Bay Coastline- Delaware and New Jersey, Broadkill Beach, Delaware Interim Feasibility Study, Final Feasibility Report and Environmental Impact Statement (USACE, 1996) and are incorporated here by reference. Placement of channel sand directly on

to Broadkill Beach eliminates the impacts of sand stockpiling as noted in the 1998 Record of Decision for the 1997 Final Supplemental Environmental Impact Statement.

4.2.2 Confined Disposal Facilities

Since preparation of the 1997 Supplemental Environmental Impact Statement initial construction quantities and subsequent maintenance quantities have significantly decreased, which reduces dredging requirements and dredged material disposal capacity needs. As such, the dredged material disposal capacity that would have been gained from the four new sites (17-G, 15-D, 15-G and Raccoon Island) is no longer needed. Constructing and maintaining the 45-foot project for a period of 50 years utilizing existing Federal disposal sites only is both feasible and cost-effective. At the same time, it will eliminate all environmental impacts associated with construction and utilization of new disposal sites and substantially reduce the overall environmental impact of the project. The current dredged material disposal plan for the riverine portion of the project will only utilize the existing Federal sites (National Park, Oldmans, Pedricktown North, Pedricktown South, Killcohook, Reedy Point South, and Artificial Island). These sites have long been dedicated for the disposal of dredged material and no additional environmental impacts are anticipated as a result of their continued use. The sites will continue to provide the existing level of wildlife habitat benefits.

Development of sites 17-G, 15-D, 15-G and Raccoon Island, as presented in the 1997 SEIS, was projected to impact a total of 396 acres of various wetland types. The SEIS included a management plan for the new dredged material disposal sites so that higher quality wetlands (from existing conditions) would be established on a temporary and cyclical basis between dredging cycles. The proposed site management would have resulted in the projected establishment of 615 acres of temporary and cyclical palustrine emergent wetlands. While this wetland gain will not be realized under the current plan, the management plan was not mitigation for the project and is not required.

4.2.3 Benthic and Planktonic Invertebrates

4.2.3.1 Blue Crab

Concerns have been raised that dredging in the lower Delaware Bay (from the mouth to River Mile 32) during the winter could impact the over-wintering population of female blue crabs. The Delaware River Basin Fish and Wildlife Management Cooperative recommends a dredging restriction from December 1 through March 31 to protect over-wintering blue crabs (Appendix C). Stratified random blue crab surveys were conducted in January 2001 and February 2002 to provide information on crab density, abundance and population characteristics for the lower Delaware Bay that could be used to assess the relative importance of the navigation channel as habitat for over-wintering blue crabs (Verasr, 2001c and Versar, 2002).

The first year survey was conducted in lower Delaware Bay (including the Federal navigation channel) in an area extending from river mile 0 to the N 39 degree 20' parallel, excluding tributaries and shallow waters (less than 5 m). The survey area was divided into six primary geographic strata: (1) deep water at the mouth of Delaware Bay; (2) lower bay on the State of New Jersey side; (3) lower bay on the State of Delaware side; (4) upper bay on the State of New

Jersey side; (5) upper bay on the State of Delaware side; and (6) the Federal navigation channel. The navigation channel was divided into four segments based on range (Liston, Crossledge, Miah Maull, and Brandywine). Sampling in the channel covered three distinct dredging categories: (1) areas previously dredged within the last 15 years for maintenance of the Delaware Bay 40-foot project; (2) areas not previously dredged but would be dredged for construction of the Delaware Bay 45-foot project; and (3) areas not previously dredged and not required to be dredged for construction of the Delaware Bay 45-foot project.

A stratified random dredge survey was conducted during January 2001 to estimate density, abundance, and size/sex composition of the blue crab population. The survey was designed to obtain separate estimates of density and abundance by sex for the Federal navigation channel, the channel bank, and the remaining areas of Delaware Bay with depths greater than 1.5 m. A total of 105 stations were sampled in the standard stratified random survey, with 30 stations allocated to the channel, and 15 stations to each of the other strata. In addition, 30 stations were sampled as a test for differences in density between the bottom of the channel and the channel bank. Sampling was conducted from a commercial fishing vessel equipped with a dredge (4.3 m wide) widely used in the Delaware winter blue crab fishery. The dredge was generally hauled for 2 minutes along the bottom at a speed of 3 knots. The towing distance (in meters) for all hauls was measured by GPS, and depth was recorded from acoustic readings. The area swept for each haul was estimated as the towing distance multiplied by the width of the dredge. For each haul, the number of blue crabs was recorded, and information on carapace width to the nearest mm, sex, maturity stage, and overall condition was collected for each specimen. Live crabs and dead crabs were tallied separately by sex to provide information on winter mortality. The Catch-Per-Unit-Effort (CPUE) for each haul was standardized to number of crabs per 1,000 square meter area swept. A bottom sediment sample was collected at each station to determine grain size.

On average, it was estimated that 22% of the crabs present in the path of the survey dredge were caught. After statistically adjusting for the dredge catching efficiency, the density of blue crabs in the Federal navigation channel was estimated at 62.0 live crabs per 1,000 square meters (251 crabs per acre), as compared to 51.4 live crabs per 1,000 square meters (208 crabs per acre) for the entire study area. There was no significant difference between these two density estimates. The winter mortality appeared to be substantial, with dead crabs constituting about 20% of the total. The total winter population was estimated at 71.46 million live crabs for the entire study area, and 1.1 million for the section of the Federal navigation channel included in the survey. Only a small fraction (1.6% or less) of the blue crab population in lower Delaware Bay resided in the navigation channel during the survey. The absolute abundance of fully recruited crabs (120 mm and greater carapace width) in the study area was 60.2 million crabs, and 1.05 million for the navigation channel (1.7% of the total). A significant number of age 0 crabs and adult males (age 1+) are likely to over-winter in the upper Delaware Bay and its tributaries, and were not sampled effectively in this survey. This portion of the stock is unlikely to be affected by the deepening project, and therefore was not a target for the survey.

Blue crab sampling in the Federal navigation channel covered bottom habitats that have previously been subject to Corps of Engineers regular maintenance dredging, as well as areas that have not previously been dredged. Although not statistically significant, the estimated mean absolute density in previously dredged areas (2.7 crabs per 1,000 square meters) was substantially lower than the mean density in areas that have never been dredged (65.9 crabs per

1000 square meters). This suggests that frequent dredging may result in less suitable habitat for over-wintering blue crabs.

For a section of Miah Maull Range that could be dredged during the winter (3.7 km in length and 1.13 square km in area), the estimated abundance of live crabs across size and sex groups was 70,038 crabs based on the mean density in the entire channel. The number of crabs in the impacted area constituted,about 6% of the live crabs in the channel and 0.1% of the crabs in the entire lower Delaware Bay survey area (based on the overall mean density of crabs in the channel). Sampling stations in the Miah Maull Range alone gave an estimate of 2.3 live crabs per 1,000 square meters or a total of 2,594 live crabs in the impacted area.

The second year survey was conducted in the same portion of Delaware Bay as the first year. The survey area was divided into the same six primary geographic strata: (1) deep water at the mouth of Delaware Bay; (2) lower bay on the State of New Jersey side; (3) lower bay on the State of Delaware side; (4) upper bay on the State of New Jersey side; (5) upper bay on the State of Delaware side; and (6) the Federal navigation channel. The sampling intensity in the navigation channel was enhanced relative to the first survey; taking into account more detailed and spatially referenced information about previous and planned channel dredging. Again, sampling in the channel covered three distinct dredging categories: (1) areas previously dredged within the last 15 years for maintenance of the Delaware Bay 40-foot project; (2) areas not previously dredged but would be dredged for construction of the Delaware Bay 45-foot project; and (3) areas not previously dredged and not required to be dredged for construction of the Delaware Bay 45-foot project. The previously dredged category was further divided into three categories: (1) dredged between 1991 and 1995, (2) dredged in 1996, and (3) dredged between 1999 and 2001. These three sub-categories of the previously dredged area were of approximately equal size. In total, 25 previously dredged plots were defined for the Brandywine, Miah Maull, Crossledge and Liston navigation ranges. Survey methodologies were the same as the first year.

Again, it was estimated that 22% of the crabs present in the path of the dredge were caught. After statistically adjusting for the dredge catch efficiency, the density of blue crabs in the Federal navigation channel was estimated at 3.60 live crabs per 1,000 square meters, which was a significantly lower density than the estimated 21.87 live crabs per 1,000 square meters for the entire survey area. The density of blue crabs overall as well as for the Federal navigation channel was also significantly lower than the first year survey (51.4 and 62.0 live crabs per 1000 square meters, respectively). Sections of the channel that had been previously dredged had a density of 0.96 live crabs per 1000 square meters, as compared to 3.96 crabs per 1000 square meters in sections of the channel that had never been dredged. There was no significant difference between these two density estimates. Only a small fraction (0.22%) of the blue crab population in the lower Delaware Bay survey area resided in the Federal navigation channel during the winter survey (0.13% for the sections that could be dredged during the winter). The winter mortality during the second year survey was negligible. The winter population was estimated at 30.37 million live crabs for the entire survey area, and 66,977 crabs for the section of the navigation channel included in the survey. The absolute abundance of fully recruited crabs (120 mm and greater carapace width) in the entire survey area was 19.77 million crabs, and 47,021 crabs for the navigation channel (0.24% of the total).

For the section of the channel that would require dredging (9.86 square km in area, revised up from the first year survey) the estimated density was 4.02 crabs per 1,000 square meters, and the absolute abundance of live crabs across size and sex groups was 39,635 crabs. The number of crabs in the potentially impacted area constituted about 59% of the live crabs that were over-wintering in the Federal navigation channel, and 0.13% of all crabs over-wintering in lower Delaware Bay.

The surveys indicated that in the portions of the Federal navigation channel that could be dredged during the winter, the percentage of blue crabs likely to be impacted would be very small relative to the entire population of crabs over-wintering in Delaware Bay (less than 0.2%). While this would not likely have a significant impact on the total blue crab population in Delaware Bay, it could result in the loss of 40,000 to 70,000 live crabs. Due to the commercial and recreational importance of the blue crab in Delaware Bay, the selected plan for channel deepening in this portion of the project is to avoid the blue crab over-wintering period (December 1 through March 31). By observing this time of year dredging restriction there will be no significant impact to the blue crab population.

4.2.3.2 Horseshoe Crab

Several species of migratory shorebirds and resident laughing gulls feed extensively on eggs of the horseshoe crab, *Limulus polyphemus* L., during its spring spawning season. For some shorebird species migrating to their arctic nesting grounds, the stopover on Delaware Bay beaches to feed on *Limulus* eggs may represent the most critical part of their annual reproductive cycle. Migrating shorebirds have been shown to make body weight gains of 40%, or more, during their two to three-week stopover on Delaware Bay beaches in May.

In Delaware Bay, most *Limulus* spawning occurs from April through July, with May and June being the peak months of activity. Female *Limulus* spawn near the high tide line beneath the beach surface in "nests", where they produce one or more clusters of adhering eggs. Clusters are deposited below the feeding zone of shorebirds. However, many of these clusters become dissociated before the eggs hatch, and their constituent eggs are dispersed through beach sediments, toward the surface. A simple census, for egg clusters only, can underestimate actual egg numbers present on a beach. Several studies have sampled beaches to determine the populations of horseshoe crab eggs present in beach sediments. Researchers examining *Limulus* spawning behavior have taken a variety of approaches. However, no standardized sampling method for determining densities of *Limulus* eggs dispersed in beach sediments has emerged from the literature. Such a method would facilitate a variety of comparisons that would be especially useful in making coastal and estuarine management decisions. Examples include: quantification of dispersed-egg population densities on beaches most heavily used by migrating shorebirds, comparisons of dispersed-egg populations in heavily used beaches with egg populations of less-used beaches, comparison of annual variations in spawning activity on a particular beach, and investigation of the effects of beach erosion or beach replenishment on *Limulus* spawning.

Material dredged from Delaware Bay for construction of the deepening project would be used for shoreline restoration projects at Kelly Island and Broadkill Beach. These areas are known to attract shorebirds and spawning horseshoe crabs. These projects are expected to increase the

amount and quality of horseshoe crab spawning habitat, significantly improving the habitat quality for both horseshoe crabs and shorebirds. In order to determine whether the completed shoreline restorations will benefit species, it is necessary to collect and analyze quantitative and qualitative baseline data on horseshoe crab egg density prior to construction.

Currently an environmental window exists that prevents construction (i.e. sand placement) to take place from April 15 to August 31 to prevent impacts to spawning horseshoe crabs. This window follows the recommendations of the Atlantic States Marine Fisheries Commission's *Interstate Fishery Management Plan for Horseshoe Crab.* This window along with other recommended restrictions for the Atlantic sturgeon and over-wintering blue crab leaves only the first two weeks of April for construction. Site-specific information was collected to evaluate the value of Kelly Island and Broadkill Beach to the horseshoe crab and the impact of sand placement within the April 15 to August 31 closure window.

A study (Weber, 2002) was conducted during 2001 to estimate the amount of potential horseshoe crab spawning habitat that exists at each site, to:

- Sample horseshoe crab egg densities at these sites,
- To compare those egg densities to egg densities on other horseshoe crab spawning areas examined on the Delaware Bay coast in Delaware during the same period.
- The study was conducted on Kelly Island and Port Mahon (both in Kent County), and Broadkill Beach (Sussex County), in Delaware during the summer of 2001.

The following summarizes the efforts conducted.

Kelly Island is not actually an island, but rather a marshy peninsula lying between the Mahon River and Delaware Bay. The southern part of Kelly Island, near the mouth of the Mahon River, is the area considered for restoration. The shoreline runs more-or-less true north. At low tide, most of the shoreline consists of irregular, vertical peat "cliffs", ranging in height from ca. 0.5–1.3 meters above low water. The high ground consists of compacted mud and peat. There are few locations where the sandy areas of upper beach grade smoothly down to the low water line. The upper edge of the beach is separated from the background marsh by a variable wrack line, consisting mostly of coarse vegetable detritus, deposited during periods of storm flooding. Bayward from this storm wrack line, and running irregularly along beside it, is a discontinuous band of wave-deposited sand of varying depth, covering the mud and peat substrate. Depth of this band ranges from approximately 40 cm at the upper edge to 2 cm at the lower edge. The band ranges in width from 2.1 m (7 ft) to 8.5 m (28 ft), and in all but a few narrow places, is discontinuous with the tide flats, being separated from the low water line by variable expanses of mud and peat substrate which are well above the low water line. All egg clusters and eggs found on this beach were in this band of sand. The two study transects sampled on Kelly Island during the 2001 study were "North", and "South", whose upper (high beach) ends were located at N39°12.679', W075°23.913' and N39°12.431', W075°23.849', respectively. Approximate distance between the two transects was 418 m (1,373 ft). These transects were selected, after a preseason site assessment, as being representative of the other sandy sections examined along that shoreline. Owing to an error in communication, both transects were located beyond the northern boundary of the proposed restoration project. This was not discovered until after samples had all been collected and processed.

Port Mahon beach has a northeasterly-oriented Delaware Bay shoreline. A sand road closely parallels the shoreline. The southern midsection of the beach has several sections of vertical metal breakwater, which persist from early attempts to protect the roadway. Breakwater sections parallel the shoreline 1–2 m out past the low tide line. The road is separated from the water by a variable band of riprap, which consists principally of boulders in the 30 – 120 cm (1 – 4 ft) size range. The lower edge of the riprap runs variously up and down through the intertidal area. In some places the lower edge of the riprap reaches out nearly to the low tide line. In other cases the lower edge rises somewhat above the middle part of the intertidal area. At lunar tides, water rises completely over some sections of riprap, and wave action erodes the roadway. As a result, the road is subject to continual grading and repair, with additional sand being added several times each year. Sand from this erosion and subsequent replenishment migrates downslope through the riprap, to create the sections of sandy beach upon which the horseshoe crabs spawn. On the bay side of the riprap, the beach contains varying amounts of smaller (brick size) miscellaneous chunks of macadam, masonry rubble, etc., applied long ago in attempts to stabilize and maintain the road. This trash material, together with random layers of shell, is variably covered with sand. The color and size uniformity of the sand particles along the riprapped beach areas suggest that most sand present is the result of erosion from the material used to repair the road. Much of what appears to be sandy beach is actually shallow sand underlain by clay hardpan, dense layers of shell, or miscellaneous trash material, and is generally unsuitable for spawning. Female horseshoe crabs seldom spawn in situations where the sand is not at least deep enough to nearly cover their bodies, approximately 10 cm (4 in). The two study transects sampled on Port Mahon during the 2001 study were "North", and "South", whose upper (high beach) ends were located at N39°11.114', W075°24.071' and N39°10.794', W075°24.297', respectively. Approximate distance between the two transects was 671 m (2,203 ft). These transects were used for the study because they have been sampled in similar studies each year since 1998. They were selected in 1998 because they had the deepest, most uniform layers of sandy sediment along the Port Mahon shoreline.

Broadkill Beach differs from the other beaches studied, being a wide, continuous band consisting almost entirely of clean sand and small (<2 cm) gravel. Sediment depths are greater than 30 cm in most sections. The beach is currently protected by a series of regularly-spaced breakwater structures extending from high on the beach, out into the water at right angles to the shoreline. Shoreward, the beach is backed by varying widths of sparsely vegetated dunes, and a dense residential area. This beach is the southernmost of the beaches studied and is approximately 42 km (26 miles) from Port Mahon. The two study transects sampled on Broadkill beach during this study were "North", and "South", whose upper (high beach) ends were located at N38°49.961', W075°12.958' and N38°49.713', W075°12.692', respectively. Approximate distance between the two transects was 577 m (1,894ft). These transect sites were selected after a preseason assessment of the entire beach frontage. They were visually representative of all frontage examined, and were reasonably close to public access points.

In Delaware Bay, *Limulus* spawning activity seems to be more intense during the full and new moon tides. During the 2001 spawning season, full moon tides were on May 7, June 5, and July 5, and new moon tides were on April 23, May 22, and June 21. Beaches were sampled 2–4 days after each of these tides. For each sampling date, two transects which were at right angles to the waterline were sampled. Upper (high beach) transect endpoints were located by reference to

permanent visual markers, and recorded as GPS readings, and the same section of beach was sampled on each date. All transects were within the intertidal zone, where spawning activity is more concentrated.

On sample dates, 25 evenly-spaced core samples were collected along each transect. Each transect spanned 83% of the distance from the nocturnal high tide wrack line down toward the foot of the beach, where the flat began. The nocturnal high tide wrack line was used as the upper end of transects because nocturnal tides around the new and full moons (when spawning is believed to be heaviest) are higher on the beach than diurnal high tides of the same period. Although intertidal beach spans varied at the points where transects were located, the 25 sample cores along each transect were kept evenly, thus proportionally, spaced across the sample distance by use of transect lines made from bungee cord. These lines were marked off into 25 equal units of distance. Bungee cord lines can be stretched to fit beaches of varying widths, and since the marks spread apart at the same ratio as the line is stretched, cores are always equally spaced across the span to be sampled.

Sample cores consisted of beach sediment cores, 5.7 cm (2.25 in) in diameter x 20 cm (8 in) deep. The 20 cm depth of the sample cores spans the reported range at which most egg clusters are placed during spawning. Surface area (cross section) of each core was 25.65 cm2, giving a total cross section of the 25 cores taken per transect of 641 cm2. After each core was lifted, it was separated into two fractions: 0–5 cm and 5–20 cm depth. This was done by sliding a sheet metal divider through a transverse slit in the corer, located 5 cm from its top end. The divider was held in place until the lower, 5–20 cm, portion of the core had been dumped through a screen into a sample bucket, and then was removed so the 0–5 cm portion could be put through a screen into a second bucket. These core fractions are of interest because shorebirds forage in the surface sediments, while the clusters are deposited somewhat deeper. Knowledge of egg numbers present in the 0–5 cm part of a beach is therefore useful in estimating how many *Limulus* eggs are potentially available for shorebird use. Core sample fractions from each transect were combined into the appropriate bucket as they were collected, and all sediment material collected was processed to extract the eggs. When *Limulus* eggs are laid, they adhere together in tight clusters, and they continue to adhere tightly to each other during the first weeks of development. One, or more, tight aggregations of eggs was recorded as a single cluster. Thus, a single 20 cm core could have up to two clusters: one each from the 0–5 cm and 5–20 cm fractions. After being recorded, clumps were broken apart into the appropriate sample container, and their component eggs included in the final egg volume values. The 25 sample cores from a single transect (0–5 cm and 5–20 cm fractions, considered together) had a total volume of approximately 13.3 liters (3-1/2 gallons).

Samples were processed at the Delaware National Estuarine Research Reserve Center, on Kitts Hummock Road, south of Dover, DE. Eggs were separated into smaller, greenish undeveloped eggs ("eggs") and larger, visibly embryonated eggs ("embryos"). Only viable eggs were quantified. It is not necessary to also quantify embryos and trilobite larvae, because the eggs take sufficient time to develop that they are present in the beach for at least two sample periods before they hatch. When sample egg numbers were small, direct counts were made. When egg numbers were too great for direct counting to be efficient, the extracted eggs were measured volumetrically, using standard graduated cylinders, and a total egg count was estimated using an average egg value of 178 eggs per ml.

The following provides the project leader for this effort, Dr. Weber's thoughts and assessment of the situation at each location based upon the supplemental information gathered as a result of the the 2001 monitoring:

Kelly Island: Larvae of several species of flies and beetles (personal observation) attack *Limulus* egg clusters in the beach from approximately the middle of the intertidal zone up to the nocturnal wrack line. Most such infestations are found in the upper part of this span, and <5% of egg clusters seem to be infested (personal observation). When their development is complete, larvae pupate in the beach sediment near where they fed and grew. When adults emerge from the pupal stage, they burrow to the surface during low tide, leaving characteristic exit holes on the beach surface. Exit holes above the current tide range persist until destroyed by rain, lunar tides, human footprints, etc. Thus, presence of these insect emergence holes on the surface is evidence of *Limulus* egg clusters below, and, by extension, indicates sections of beach frontage where spawning has taken place. On Kelly Island, the presence of these insect emergence holes were used as indicators of frontage where *Limulus* spawning had occurred.

I walked 2,203 m (7,234ft) of frontage on this shoreline, to determine the amount of spawning habitat present. I began at the southern tip of Kelly Island, at the first section of sand with sufficient depth for spawning (N39°11.577', W075°23.781'), and continued northward along the storm wrack line to N39°12.872', W075°23.855. I used a GPS unit to record the lengths of sand stretches having sufficient depth for spawning. Center widths of these stretches were measured with a tape, so estimates of their surface areas could also be calculated. There were 901 m (2,957ft) of spawning habitat along this 2,203 m (7,234') of bay frontage. This represents 40.8% of the length I examined. The combined area of these sections of spawning habitat was 0.39 hectare (0.96 acre). The 2001 estimated egg load for the 901 m spawning frontage of the 2,203 m examined was 3.2 x 109 eggs.

Owing to the error mentioned earlier, the span of shoreline I examined extended from near the present south tip of Kelly Island to considerably north of the proposed restoration project. It was possible to calculate the percentage of spawning habitat that was within the limits of the proposed project. There were 933 m (3,062ft) of shoreline from the southern tip of Kelly Island to the northern limit of the proposed project. Within this span, there were 466 m (1,531 ft) of spawning habitat. This represents 49.9% of the span I examined that was within the limits of the proposed project. The combined area of the sections of spawning habitat within this span was 0.20 hectare (0.49 acre). The 2001 estimated egg load for the 466 m spawning frontage of this part of the shoreline was 0.83 x 109 eggs.

The finished bay frontage of the proposed project would be approximately 1,522 m (5,000ft). Length of bay shoreline of the completed project would then be 1.6 times greater than the length of shoreline south of the project boundary in 2001. When the project is completed, the spawning frontage would no longer consist of intermittent shallow sandy sections separated by variable spans of peat, as in 2001. Instead, the 466 m (1,531ft) of intermittent spawning habitat present in 2001 would be replaced with approximately 3.25 times as much *continuous* spawning frontage, comprised of sand deeper than ca. 1 m.

This is the first time Kelly Island has been evaluated as a *Limulus* spawning site. Judging from the evidence of a rapidly eroding shoreline—both on-site, from aerial photographs, and from the relevant USGS Quadrangle (1956)—the spawning habitat I evaluated in 2001 will very likely be altered by erosion before the next spawning season. Indeed, the impression gained from repeated sampling on the beach, and walking along the storm wrack line, is that this shoreline is not at all a constant or consistent spawning area. Some indication of recent changes along this shoreline can be obtained by simply noting the westward displacement of the sandy spawning areas I found in 2001 from the stretches of sand shown in a 1997 aerial photograph. The rate of erosion along this frontage has been variable, as shown by the varying distances between lines indicating 2001 spawning habit, and the sandy stretches present in 1997.

At my request, personnel with the Philadelphia office of the U.S. Army Corps of Engineers examined their aerial photographs and records of this area to provide me with an estimate of the rate at which this shoreline has been eroding. Their estimate is that the Bay shore of Kelly Island has been eroding westward for at least the last 100 years, at an average rate of 6 m (20ft) per year. The earliest aerial photograph of the area in their files was made in 1926. During the 75 years since, the shoreline has eroded westward approximately 457 m (1,500ft). By comparison of the 1926 aerial photograph with aerial photography of the same area done in 2001, their estimate is that the tip of Kelly Island has eroded northward approximately 487 m (1,600ft) during the same period.

It seems likely that some stretches of the Kelly Island shoreline with sand deep enough to be suitable for spawning in 2001 will still have enough sand next year. However, it is also likely that some stretches of shoreline suitable for spawning in 2001 will not be suitable next year. Further, some sections without any sand, or without a suitable depth of sand in 2001, could possibly have enough sand next year to support spawning. These are reasonable beliefs when the stretches of spawning habitat I found in 2001 are compared to the stretches of sand visible on the 1997 aerial photograph upon which they are plotted. Stretches of spawning habitat appear and disappear in response to continuing erosion of the shoreline. With reference to the 1997 photograph, in some places long stretches of sand present then are now gone. Other sandy spawning areas I found along those same sections of shoreline in 2001 are reduced in total length from stretches of sand visible in the photograph. Along some other sections of the shoreline, where no sand was visible in 1997, there was enough sand present in 2001 that spawning occurred.

Such comparisons must be made tentatively because the sandy stretches visible in the 1997 photograph were not checked to see how much spawning occurred on them. For Kelly Island, there is only the 2001 *Limulus* egg sampling and spawning habitat evaluation data, coupled with the understanding that spawning only occurs on sandy substrates. I have not observed *Limulus* to spawn in mud or peat substrates on any beach I have studied in Delaware. My experience in sampling Delaware beaches over the past five years is that they also do not spawn on beaches with only a shallow layer of sand (< 10 cm) over mud or peat. For this reason, stretches of sand shown in an aerial photograph do not necessarily indicate suitable spawning habitat.

Port Mahon: The spawning habitat along the Port Mahon shoreline is discontinuous, being interrupted by stretches of riprap and rubble. Along much of the shoreline, the high tide wrack line either falls within the area spanned by riprap, or actually reaches onto the roadway. Thus, it

was not possible to use insect emergence holes to verify that spawning had occurred on a particular section. Instead, for this beach I relied on observations made during low tides over the 2001-spawning season. These included stranded males, "buried" pairs, and "nests" left when females dug out after spawning. These observations were easily made each time I sampled the beach, since the roadway parallels the high water line over most of the beach's length. I verified these observations by walking all sandy sections.

I examined the entire 1,672 m (5,491 ft) frontage of the beach at low tide, to determine the amount of spawning habitat present. I began at the southern end of the beach (N39°10.654' W075°24.491') where a culvert passes under the road, and continued northerly to N39°11.358', W075°23.909' at the bait store. I used a GPS unit to record the waterline lengths of sand stretches with sufficient depth for spawning. Center widths of these stretches were measured with a tape, so their approximate surface areas could be calculated. There were 450 m (1,478ft) of spawning habitat along the beach. This represents 26.9% of the total length of Port Mahon beach. The combined area of these lengths of habitat was 0.44 hectare (1.08 acre). The amount of spawning habitat on this beach has remained essentially the same since I examined it in 1999. At that time, total area of spawning habitat was 0.39 hectare (0.96 acre), and 28.5% of total beach length. The 2001 estimated egg load for the 450 m spawning frontage of this beach was 22.3 x 109 eggs.

Typically, Port Mahon transects have been among the top transects for total numbers of *Limulus* eggs. Season total egg numbers for the beach have ranged between 400,000 and 500,000, while per-transect season total values have been 174,000 or higher. The 2001 total egg values from Port Mahon transects S and N, 268,000 and 233,000 respectively, were considerably higher than from any other transect sampled in a parallel study of other Delaware beaches done that same season. The next highest 2001 egg total observed was from Kitts Hummock S (135,000 eggs). In 2000, total egg values from Port Mahon transects N and S were 174,000 and 229,000, respectively. These were less than the value observed on Ted Harvey S (312,000) that year. The 1999 Port Mahon transect totals were both higher than any others, with the next highest 1999 total being Ted Harvey S (140,000).

Comparing the *Limulus* egg data from Port Mahon beach with similar data collected on other beaches sampled in this, and earlier, studies is problematic. For example, the approximately mile long frontage of Port Mahon contains a rather small percentage of shoreline where there is sufficient sand to allow spawning, and where coupled *Limulus* pairs come up to the water's edge. While other beaches generally provide a meter of spawning beach for each meter of shoreline, this is definitely not the case at Port Mahon. It seems probable that female *Limulus* in the waters along Port Mahon beach are forced to concentrate into the few areas where they can spawn. This seems unlikely to be the case on most other beaches where shoreline and suitable spawning habitat are essentially equal. While the N and S transects typically have high cluster and total egg counts, these may be high simply because individuals spread along the Port Mahon shoreline are forced to come to the same few locations suitable for spawning. This could account for the high cluster counts and total egg numbers observed there. However, this concentration effect is partly offset by the fact that *Limulus* are legally harvested from Port Mahon beach two days a week, during the spawning season.

Personal observations, and discussions with those harvesting, suggest that females coming onto the beach to spawn are the primary catch. These potential spawners are taken before they have a chance to lay eggs, since females full of eggs are more desirable as bait, their intended use. No data are available on the percentage of spawning females harvested from this beach each season, but the favored places to harvest are the few spawning areas, which include areas surrounding both the N and S transects. A further confounding factor for Port Mahon spawning areas is the fact that large numbers of *Limulus* adults, of both sexes, become accidentally wedged into interstices between rocks of the riprap shoreline erosion barrier. Some individuals are trapped during each spawning event. Many of these animals become so firmly wedged between rocks that they cannot get free. Gulls prey on the more accessible individuals; the others die of exposure or starvation.

Broadkill Beach: The entire length of this beach is one continuous, unbroken stretch that is visually similar with regard to sediment size, slope, and exposure to the Bay. For this reason, I equated spawning habitat with shoreline length. On this beach it was not possible to utilize insect emergence holes as indicators of spawning because apparently too few clusters were spawned there to attract flies. Even if heavy spawning had occurred, and flies had emerged in considerable numbers, the human foot traffic along the upper part of this beach would have obliterated them from many areas.

The area I evaluated began at N38°50.347', W075°13.493' and continued southward to N38°48.408', W075°11.397', at the boundary with Beach Plum Island Nature Reserve. Total frontage length, 4,723 m (15,506'), was determined by measurements taken from beach restoration project plans provided by USACE personnel. At 13 locations distributed along the frontage, I measured beach width from the nocturnal tide wrack line down to the foot of the beach slope. Widths for Broadkill beach ranged from 11.9 m (39') to 16.1 m (53ft), with an average width of 14.4 m (47ft). Frontage length of the beach was multiplied by the average width value to estimate the amount of spawning habitat present. The full length of shoreline consisted of sandy sediments, which appeared suitable for *Limulus* spawning. The potential spawning habitat on the beach was 6.4 hectares (15.8 acres). The 2001 estimated egg load for the 4,723 m of spawning frontage on this beach was 0.25 x109 eggs.

In terms of beach slope and sediment size distribution, the entire shoreline of Broadkill Beach appears to be equally suitable for spawning. However, only low numbers of eggs were found there during this study. It is unclear why this is so, although I usually found the wave height, and corresponding surf, to be greater than found on more northerly Delaware beaches on the same day, and within an hour or two. Waves from onshore wind reduce, or prevent spawning. This surf difference I observed may be due to influence of ocean waves. On more northerly Delaware Bay beaches, *Limulus* spawning does not take place when onshore winds create waves over ca. 30 cm (12 in) (personal observation). Waves observed on Broadkill during sampling periods were frequently over 30 cm high, and on several occasions, were ca. 50 cm (20 in) high. Whatever the cause of the low egg numbers on Broadkill Beach, the extremely low numbers indicate that it currently receives very little *Limulus* spawning.

Kelly Island, Port Mahon and Broadkill beaches varied widely from each other in their total egg numbers for the sampling season. Season egg totals (the sums of all eggs found on both transects of each study beach) were compared to the season egg totals (also the sums of all eggs found on

both transects of each beach) observed on Kitts Hummock, Pickering, and North Bowers beaches, also studied during 2001, in a parallel study. Port Mahon had approximately twice as many total eggs as the next most populous beach, Kitts Hummock (248,000). In turn, Kitts Hummock and Pickering (201,000) beaches each yielded more eggs than did Kelly Island. Pickering was approximately twice as productive as Kelly Island (104,000). North Bowers had approximately half as many eggs as Kelly Island (55,000). Broadkill beach had a season total, both transects combined, of 431 eggs.

A second horseshoe crab monitoring study was completed in 2004 (Versar, 2005). The following was taken from the report of that study. Since this study was conducted, construction of the wetland restoration at Egg Island Point has been deferred due to a lack of dredged material resulting from the Deepening Project.

The Delaware Bay shoreline provides spawning habitat to horseshoe crabs, which are endemic to the Atlantic coast seaboard. From April to July, crabs that have migrated from the Atlantic continental shelf emerge along the bayshore to spawn near the high tide line of primarily sandy beaches. The peak of spawning activity usually occurs during May and June, and coincides with the highest spring tides associated with full and new moon events. At these times, female crabs, attended by several males, lay clusters of eggs up to 20-cm deep within the beach sands. The eggs develop over a minimum of two weeks and hatch into trilobite larvae, the free-swimming stage of the horseshoe crab. Because of the intensity of spawning activity throughout the spawning period and the lengthy term of development, large numbers of eggs can become dislodged from their clusters and end up exposed on the beach surface. This abundance of eggs provides critical food resources for a number of species of migratory shorebirds during a brief springtime stopover period in Delaware Bay.

After hatching, juvenile horseshoe crabs make their way into the bay where they spend the remaining spring and summer developing. For the most part, the crabs occupy shallow water inshore habitats, where they undergo several molts before heading to deeper water at the end of the warm season. Not much is known of the ecology of juvenile horseshoe crabs during this phase of growth, such as habitat preference or local movement patterns, as they are very small and difficult to sample.

The objective of this study was to evaluate horseshoe crab use of Egg Island Point, New Jersey and Kelly Island, Delaware as spawning habitat, and similarly for near shore areas, as nursery habitat for juvenile crabs. The study was conducted to provide baseline information of horseshoe crab use of the islands prior to reconstruction and to provide a means to compare post-construction conditions to gauge the effectiveness of the beneficial use of sediments. Furthermore, as the monitoring period spans the Atlantic States Marine Fisheries Commission (ASMFC) window of constraint on construction, the study was designed to identify with greater precision the critical use of the two sites by horseshoe crabs. Finally, as other species of fishes and invertebrates inhabiting nearshore habitats might be affected by the reconstruction, baseline data on these species were collected off Egg and Kelly Islands in conjunction with the juvenile horseshoe crab surveys.

During 2004, from late April to July, egg count surveys were conducted at spawning beaches on Egg Island and East Point, New Jersey and Kelly Island, Delaware. The methods used to sample

horseshoe crab eggs differed somewhat between New Jersey and Delaware, and followed protocols developed independently by researchers in each state. Monitoring of horseshoe crab spawning by these researchers is ongoing and covers much of the Delaware Bay. By duplicating their respective sampling methods, it was possible to compare these egg counts with other monitoring studies and place the spawning effort observed at Egg Island and Kelly Island in to perspective with other parts of the Delaware Bay. Horseshoe crab eggs in New Jersey were sampled using methods developed by Drs. Mark Botton and Robert Loveland in Delaware Bay (primarily supported by New Jersey Sea Grant, New Jersey Department of Environmental Protection, and Public Service Electric & Gas Company). Delaware horseshoe crab egg counts followed survey protocols that have been implemented by Dr. Richard Weber of the Delaware National Estuarine Research Reserve (DNERR) (See procedure described for the 2001 horseshoe crab survey). Horseshoe crab egg samples collected from Delaware Bay beaches in New Jersey and Delaware were processed in a benthic laboratory. Sample material was washed on a 1 mm sieve to remove the formalin fixative. The material was transferred to sorting trays and inspected under a magnifying lamp. All viable horseshoe crab eggs were counted (blue-green in color) and totaled for each sample.

Juvenile horseshoe crab surveys were conducted in Delaware Bay in nearshore habitats adjacent to spawning beaches. Beaches surveyed in New Jersey and Delaware included the principal study beaches, West Egg Island, East Egg Island and Kelly Island, as well as reference beaches, East Point, Port Mahon, Kitts Hummock and North Bowers Beach. The surveys were conducted monthly from July to October during 2004. Two types of gear were used to collect juvenile crabs, a suction dredge assembly and a modified fish trawl. A survey area was delineated adjacent to each spawning beach. The survey areas were divided into 3 transect corridors, positioned parallel to shore and approximately 0.2 nautical miles (NM) in breadth. In order of proximity to shore, the corridors were defined as nearshore, midshore, and offshore habitats. Along the center of each corridor, 4 station targets were positioned at equal distances of approximately 0.2 NM apart. In total, 12 stations were defined for each beach. When sampling, the station targets were visually tracked using a Differential Global Positioning System (DGPS) during the deployment of gear. In this way, sample tows could be conducted within habitat corridors. In each of the four months of the survey period, 84 station targets were surveyed using both suction-dredge and trawl methods (7 beaches x 3 transects x 4 stations).

For suction dredging, a target station was approached while moving with the tide; when in position, the dredge was allowed to sink to the bottom. A centrifugal pump was started, and the outlet hose was monitored for sediment suspended in the discharge. As soon as the discharge was gauged acceptable, the outlet hose was directed into a catch-basin, while a 50 meter tagline was deployed over the side to standardize distance towed. At the end of the tow, the outlet hose was removed from the catch-basin, boat speed was increased to raise the dredge from the bottom, the discharge was monitored for clarity, and lastly the centrifugal pump was switched off. In this way, the suction dredge was kept from fouling. Juvenile horseshoe crabs collected by the suction dredge were sorted by hand from material within the catch-basin. Each crab was inspected for viability (many shell casts closely resembling live crabs were also collected). Most crabs passed through the dredge and pump apparatus without suffering physical damage. Up to 30 crabs were measured for prosomal width (i.e., helmet width), and any additional crabs were counted. Following sample processing, all live crabs were released overboard.

Trawl sampling was conducted using a 16-foot semi-balloon otter trawl with 1.5-inch stretch mesh in the wings and body, and 0.5-inch stretch mesh liner in the cod end. This is the same equipment used by the Delaware Division of Fish and Wildlife in their surveys for juvenile horseshoe crabs. Two-minute tows were conducted at each station. Up to 30 live horseshoe crabs, juvenile and adult, were measured for prosomal width, and released overboard. Fish collected as by-catch were identified, counted, and up to 30 were measured for total length (mm). Blue crabs collected as by-catch were measured for carapace width for up to 30 crabs, additional crabs were counted.

At the 84 stations surveyed for juvenile horseshoe crabs, samples of bottom sediment were collected during August. Sediment samples were collected using a petite-ponar benthic grab-sampler. For each station, material representing surface sediment was placed in a container labeled for station location, date, and time. Sediment samples were kept in a cooler on wet ice until they could be transferred to an analytical laboratory where they were stored in a freezer. Sediment samples were analyzed for grain size, percent silt-clay content, and total organic carbon (TOC) using ASTM Method D422-63.

The water quality parameters, salinity (ppt) and temperature (°C), were measured during the juvenile horseshoe crab surveys for each month of sampling. Most times, surface and bottom measures of the parameters were recorded midway through suction dredge sampling at each of the seven nearshore survey areas. Water quality was not measured at West Egg Island during the August/September survey period. Bottom water quality was not measured during the October/November survey period. Salinity and temperature were measured with a pre-calibrated YSI water quality monitoring probe.

The principal objective of this study was to evaluate horseshoe crab spawning on Egg Island, New Jersey and Kelly Island, Delaware. The evaluation was based on comparing spawning intensity as measured by egg counts with other regional spawning beaches. The information from this study was necessary to provide a baseline measure of spawning prior to reconstruction, and to better define the spatial and temporal spawning characteristics along the affected beaches. A second objective was to evaluate juvenile horseshoe crab presence in nearshore habitats adjacent to the spawning beaches.

Horseshoe crab spawning at Delaware Bay beaches along the shores of Egg Island and Kelly Island followed an expected pattern during 2004. The onset of spawning in the spring was characteristically sudden and egg-laying by adult crabs was most intense during the months of May and June. Spawning of horseshoe crabs is usually synchronized with high (spring) tides associated with full or new moon phases. Survey methods for adult spawning crabs are usually scheduled around these times on the evening high tide. As our sampling schedule roughly followed 2-week intervals, we could not directly gauge the intensity of spawning, however on a number of occasions coupled adults were noted off spawning beaches, particularly at times near high tide.

Horseshoe crab spawning at Egg Island beaches was markedly different between the east and west sides of the Island. Egg counts along the west shore of Egg Island were the least productive among the New Jersey beaches. More than likely, this is in part due to the nature of the intertidal zone along this shore. In many parts, the intertidal zone leading up to the high beach is very

broad and punctuated with clumps of decaying salt marsh. In effect, these might serve as obstacles to adult crabs trying to reach the higher beach to spawn. This observation is reinforced by sampling event 3 (28 May) on west Egg Island that produced high numbers of eggs. This event followed an extremely high tide that may have provided spawning adults access to this particular beach that was consistently unproductive at all other times. Spawning along the east side of Egg Island was much more prolific. Egg counts at the two beaches surveyed were comparable to those at East Point, the reference beach historically known for spawning. The east side of the island presents a more favorable habitat for spawning. The beaches have a more gradual slope and the high beach area preferred for egg-laying is much closer to the low tide mark. The spawning evaluation for Egg Island and the reference beach of East Point would benefit from a comparison with regional beaches surveyed using the same methods. At this time, comparative data are not available.

Horseshoe crab spawning at Kelly Island in Delaware was comparatively low during 2004. Egg counts from the island ranked among the lowest of 6 beaches sampled by DNERR, and several times lower than the proximal beach, Port Mahon. This last point is encouraging for the future of spawning on Kelly Island as it indicates that a fair number of crabs already spawn nearby. Spawning along the Delaware shore generally follows a consistent pattern with respect to location. For the years 2003 and 2004, a comparison among the 6 DNERR beaches by the total number of eggs collected has produced the same rankings. The intertidal zone at Kelly Island is interrupted in many places by a steep face of decaying salt marsh that might prevent horseshoe crabs from reaching optimal spawning beaches except during the highest tides that surmount the marsh.

Juvenile horseshoe crabs were successfully collected in nearshore habitats adjacent to New Jersey and Delaware spawning beaches. The suction dredge provided a quantitative means by which to survey the youngest of crabs. The juvenile crabs were most abundant in the nearshore habitats during July and August. This is consistent with previous descriptions of juvenile habitat preference for intertidal flats near breeding beaches. Although it is suggested that they remain there for their first and second summers, juvenile crabs from our survey appeared to be moving farther from shore and to locations further down the bay by the end of summer. The impact of the reconstruction project on juvenile horseshoe crabs is not expected to be as great as that for the eggs. Shortly after hatching and reaching the bay, crab larvae molt into the juveniles capable of motility. In that regard, they at least have the ability to disperse into extensive intertidal habitat in the Delaware Bay.

Bottom sediment characterization of nearshore habitats did not correlate with the abundance of juvenile horseshoe crabs, suggesting that the juveniles were not selecting a specific sediment type. However, a limitation of this element of our study was point sampling for sediment in the vicinity of the track towed during suction dredging which sampled crabs 25 feet to either side of the station. If the bottom habitat was more heterogeneous around the station point with respect to sediment type, this would obfuscate potential correlations. An alternative method would have been to take benthic grabs over a broader area. For example, a high count of 300 crabs was obtained in an individual tow. This reflects 6 crabs/m2 assuming 100% efficiency of the gear. By replicate sampling within these high catch areas, crab density might be better correlated to bottom sediment type.

Trawl studies also highlighted several patterns of seasonal fish usage of inshore habitats in the vicinity of the reconstruction areas. Foremost, weakfish and Atlantic croaker (drum species) are abundant during early summer and late summer, respectively. Impacts from reconstruction may also occur for these species, but are less likely given their free-swimming abilities. Blue crabs were also frequently found in the nearshore habitats but are also capable of avoidance. The information from trawl studies will provide a comparative data set for surveys conducted post construction that will better assess the beneficial use of dredged materials for reconstruction.

Due to competing time of year work restrictions for shoreline construction and dredging in Delaware Bay, it is not possible to construct the Kelly Island and Broadkill Beach projects and adhere to all recommended restrictions. For protection of over-wintering blue crab, no dredging will occur in this portion of the channel between December 1 and March 31. Construction at Kelly Island and Broadkill Beach will begin in April since April and May are acceptable dredging months. Construction activity on Broadkill Beach will last four months and is scheduled from April through July. Construction activity on Kelly Island will last six months and is scheduled from April through September. As such, there would be some level of impact to spawning horseshoe crabs at both sites. This level of impact is not considered significant because the studies presented above indicate that horseshoe crab spawning at both sites is low in comparison to other monitored bay beaches. Reconstruction of the Kelly Island site will provide suitable horseshoe crab spawning habitat along its entire length, which should greatly improve the spawning productivity of the area. Monitoring can be employed during construction of Kelly Island to remove horseshoe crabs that attempt to access the work area and relocate them to a suitable spawning beach.

4.2.3.3 American Oyster

Turbidity generated by a hopper dredge working in the Delaware Bay channel is a concern where the channel is in close proximity to oyster beds. Oysters are broadcast spawners, meaning they release eggs and sperm into the water column. Fertilized eggs develop into planktonic (free-swimming) larvae. After a period of growth, a foot develops and the larvae settle to the bottom of the water column where they seek a hard substrate (cultch). When a suitable surface (ideally adult oyster shell) is located, the larvae cement themselves and grow to the adult form. Sediment accumulation on oyster beds reduces the ability of the bed to provide the appropriate substrate for larvae to successfully set.

Hopper dredges are self-propelled ships equipped with propulsion machinery, hoppers for dredged material storage, and dredge pumps. Dredged material is hydraulically raised through trailing dragarms in contact with the channel bottom and is discharged into the hoppers. The material is then held in the hoppers until placed at the disposal site.

Hopper dredges are often loaded past the point of overflow for economic reasons. As the hopper is filled, dredged material is stored in the hopper bins until overflow begins. The density of the hopper contents is increased by allowing the low-density supernatant to overflow back into the waterway. As the low-density supernatant overflows, the average density of the hopper contents increase. Thus, more material can be transported per trip to the disposal site or facility. This practice of overflowing hoppers to achieve a high-density load is referred to as economic loading.

In considering overflow, there is normally a tradeoff between the potential economic benefits and potential environmental effects. Overflow results in increased water column turbidity, and supernatant solids may be redeposited near the dredge site. Also, if sediments are contaminated, the overflow may result in some release of contaminants to the water column. Therefore, the relationship between dredge production, density of the hopper load, and the rate of material overflow are important variables in maximizing the efficiency of the dredging operation while minimizing contaminant release.

State environmental resource agencies have expressed concerns regarding turbidity, sedimentation of suspended solids, and potential contaminant release from hopper dredge overflow in the vicinity of oyster seedbeds in some areas near the Delaware Bay navigation channel. To address these concerns a hopper dredge overflow study was conducted (Miller et al., 2002). Currently, overflow is not permitted at any location within the Delaware River Basin and is not proposed for the Main Channel Deepening Project. But for comparison purposes, the study also evaluated non-overflow events. Turbidity plume monitoring was one element of the study.

Monitoring of the sediment plumes was accomplished using a boat-mounted 1,200-kHz Broad-Band Acoustic Doppler Current Profiler (ADCP). The instrument collects velocity vectors in the water column together with backscatter levels to determine the position and relative intensity of the sediment plume. Along with the ADCP, a MicroLite recording instrument with an Optical Backscatterance (OBS) Sensor was towed by the vessel at a depth of 15 ft. The MicroLite recorded data at 0.5-sec intervals. Navigation data for monitoring were obtained by a Starlink differential Global Positioning System (GPS). The GPS monitors the boat position from the starting and ending points along each transect.

Transects were monitored in the test area to obtain the background levels of suspended materials prior to dredging activities. A period of 8 min following the dredge passing during non-overflow dredging showed the level of suspended material to be returning to background levels. No lateral dispersion of the plume out of the channel was observed during the non-overflow dredging operation.

During overflow dredging, a wider transect was performed to determine the lateral extent of the plume. No significant change above background levels could be detected. At 1-hr elapsed time following the end of the overflow dredging operation, the levels of suspended material returned to background conditions. Again, no lateral dispersion of the plume out of the channel area was observed.

Based on these results it is concluded that non-overflow hopper dredging activities in the vicinity of oyster beds will have minimal impact regarding the rate of sediment accumulation on the beds.

Another concern relating to oysters and the deepening project is potential changes in Delaware Bay salinity patterns resulting from a 5-foot deepening. Two disease-causing organisms, *Haplosporidium nelsoni* (MSX) and *Perkinsus marinus* (Dermo), and the predatory oyster drill are the primary causes of adult oyster mortality in the bay. These organisms have severely impacted the oyster population in Delaware Bay. Prevalence of these organisms declines with

lower salinities. The MSX and Dermo parasites exhibit reduced virulence in the lower salinities of the upper bay, resulting in considerably lower mortality on seedbeds. This permits oysters in those areas to grow to near market size with lower losses than would occur in the down bay leased grounds. If channel deepening increases salinity in the bay, additional oyster beds could be affected by these organisms to a greater extent than the existing condition.

To address concerns related to salinity, a 3-D numerical hydrodynamic model was developed and several scenarios were selected to evaluate the impact of channel deepening on salinity patterns within the estuary (See Section 4.1.2.1 of this document). The model suggested that a negligible movement of the salt line would result from the deepening. The findings from the salinity model indicated that the predicted range of salinity changes would pose no adverse impact on oyster resources.

As part of a series of studies to characterize pre-construction conditions, the Philadelphia District conducted water quality and oyster bed monitoring in lower Delaware Bay during the 2000 and 2001 calendar years (Versar, 2001b). Water quality monitoring was conducted to provide the physical/chemical data needed to help interpret oyster population health and to provide a means to verify the hydrodynamic model predictions of potential salinity changes that may result after the channel is deepened. In consultation with the New Jersey Department of Environmental Protection, the Philadelphia District agreed to confirm and further evaluate the effects of potential salinity changes on oyster populations due to the deepening project and to implement a monitoring plan to assess any effects of the project to the oyster beds. The purpose of the 2000/2001 study was to examine the health and productivity of oyster populations on the natural seedbeds in the Delaware Bay prior to the deepening and to obtain pre-construction data on water quality. The data developed from this program will be used after the project is completed to determine if the deepening significantly impacted oyster populations in Delaware Bay.

4.2.3.4 Sabellaria

For the deepening project, material dredged from the Delaware Bay channel would be placed for shoreline restoration at Broadkill Beach. This area has been known historically and recently to have sandbuilder worm reefs. Since shoreline restoration has the potential to bury and disrupt these reefs, it is necessary to determine the extent and location of present reefs as baseline data prior to construction activities. The purpose of this study was to document the presence, extent and locations of *Sabellaria vulgaris* colonies at Broadkill Beach in summer, 2001, with respect to habitat type, tidal stage, and other environmental factors.

A survey of the sandbuilder worm colonies at the Broadkill Beach sand placement site was conducted in July 20 and 21 2001 (Miller, 2002). Within an hour of the afternoon low water, the beach was walked by the contractor and his associates in two segments: on July 20, from the north end at California Avenue south to Route 16, and on July 21, from the boundary of Beach Plum Island State Park north to Route 16. These dates were chosen to be near the lowest spring tides of the month and represent the best opportunity for the colonies to be observed and measured in the intertidal and nearshore subtidal zones along this beach. The following operational definitions were used: a colony is defined as an aggregation of worm tubes, usually small in size (< 1 m across) and somewhat isolated from other worm tubes. A reef is defined as a larger structure, a meter or more across, with 5 cm or more of vertical worm tube growth.

Where sandbuilder colonies or reefs were observed, their location was determined with a handheld GPS (Garmin model GPSMAP 76) and associated with nearby streets or landmarks. The dimensions of the colony or reef, along the shore and distance seaward from the beach-slope break, were determined with a measuring tape. Various digital photographs of the whole reef, as well as close-up sections, were made to document the reef shape and structure. An on-site determination of the overall condition of the reef was made as indicated by new tube growth (tubes with a "flare" or "porch,"), tube erosion, over-settlement by mussels or tube worms, crab burrows, *et cetera.*

Reef observations and notes were recorded in the field on data sheets and additional observations were made on the study area shoreline, especially where rock, cobbles and gravel were present at the tidal level typically associated with sandbuilder reefs. At the *Sabellaria* reefs and other sites along Broadkill Beach, additional measurements were made to more fully characterize environmental conditions in the study area. These included: seawater temperature and salinity (handheld YSI model 30 meter), beach slope (inclinometer), and sediment grain size (standard dry sieving methods).

In a July, 2001 survey of Broadkill Beach, sandbuilder worm colonies were found in reef-like masses at three locations: two on the rock groins at Alabama and at Georgia Avenues, and the largest on the Old Inlet Jetty south of Route 16 and north of the Beach Plum Island boundary. At each location, sandbuilder reefs were associated with large rocks comprising the groins and jetty. No colonies were found along the beach near the beach slope break, low in the intertidal zone where they presently occur at nearby beaches in the lower Delaware Bay. In comparison with other sites studied by the contractor, sand beaches at Broadkill Beach lack the stable, cobble-sized or larger substratum to which colonies attach at nearby beaches. All colonies at Broadkill Beach are associated with large rocks on artificial structures.

Sandbuilder worms have a life cycle with a planktonic larval stage that permits broad dispersal. Larval settlement occurs over extended periods in the summer and early fall and is often gregarious. Stable substratum, for example gravel and rock of sufficient size not to be overturned by wave action, placed near mean low water should provide favorable habitat for sandbuilder worm settlement and reef development.

Sandbuilder worms are epifaunal and require water flow and wave action to provide food particles, oxygen and sand grains for tube building. While they have some capability to withstand burial under thin layers of sand, shoreline restoration would be expected to bury the present reefs at Broadkill Beach resulting in a substantial loss of this habitat. This impact could be compensated by placing suitable substratum, large rock in groins or jetties or cobble-sized gravel on sand beaches at mean low water during the summer or early fall following shoreline restoration. Other possibilities include removing current reef masses to new shoreline locations to reconstruct or reseed from enhanced larval settlement on the restored reefs.

A second study was conducted to document the presence, extent and locations of *Sabellaria vulgaris* colonies and reefs at Broadkill Beach, Kelly Island, and Port Mahon with respect to habitat type, tidal stage, and other environmental factors for both intertidal and subtidal colonies (Miller, 2004). Colonies at Slaughter Beach were surveyed as a control site, and various

substrates at Broadkill and Slaughter Beaches were monitored for colonization over several months.

A survey of the intertidal sandbuilder worm colonies and reefs at Broadkill Beach, Slaughter Beach, Port Mahon and Kelly Island was conducted on the spring tides in late June and early July 2004. The basic methodology used was identical to that employed previously in the July 2001 survey of Broadkill Beach.

Following the intertidal surveys, settling plates were deployed at Broadkill and Slaughter Beaches and monitored monthly on low spring tides. These plates were replicate pairs of numbered stone pavers of slate and quartzite stone material placed on or adjacent to the reef in accessible locations. Deployment coincided with noticeable new, small *Sabellaria* tubes visible at both sites. These plates were monitored for *Sabellaria* settlement and tube growth through December 2004. Additional plates were deployed in September, October and December as needed to monitor for additional settlement. Recovered plates were photographed and measured in the field, and then either returned to their location in the field or in some cases returned to the laboratory for further analysis. In addition to photographing the natural reef on monthly site visits, additional water column and sediment measurements were made.

*Sabellaria* colonies and reefs were widely distributed at Broadkill Beach, Slaughter Beach and Port Mahon, but no colonies were found on the Kelly Island shoreline. This distribution is explained by the availability of stable substratum near mean low water. Favorable substrata for sandbuilder worm settlement and reef development appears to be any material of sufficient size not to be overturned by wave action. Natural substrata include gravel and rip rap rock, but colonies were also found on wood groins, horseshoe crab carapaces, and discarded tires. Smaller colonies, formed by settlement in situ or by fragmentation are present near the large reefs. While these smaller colonies were in some cases observed to have live worms and exhibit active tube growth, the longevity of these colonies is uncertain. Some colonies with low vertical relief appear susceptible to burial by natural sedimentation.

Monthly monitoring of settlement plates confirmed the suitability of two different rock substrata for settlement and tube growth, and plates deployed in late August or early September appear most favorable for tube growth in the form that results in reef formation. Tube growth rates of a centimeter or more per month were observed. Timing of available bare substratum appears to be more important than the type of material.

Construction impacts to *Sabellaria* can be compensated by placing suitable substratum, large rocks in groins or jetties or cobble-sized gravel on sand beaches at mean low water during the late summer or early fall settlement period following shoreline restoration. Kelly Island and Broadkill Beach will be evaluated prior to construction to determine the most appropriate course of action.

4.2.4 Finfish

4.2.4.1 Sandbar Shark

The habitat along the lower Delaware Bay coast in Delaware has been designated as "Habitat Areas of Particular Concern" by the NMFS. Pratt (1999) believes that there will be a great potential to impact shark pups rend 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 1 – 4 m deep) in the nursery season. Potential impacts may include but not be limited to: changing the habitat characteristics, depth, profile, odor, turbidity and fauna of the area. Loss of forage would also occur. 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. A "closed" window from 1 May to 15 September was recommended by the National Marine Fisheries Service (Gorski, 2000) to prevent potential impacts to newborn and juvenile sharks such as suffocation. After this time period, the young sharks have reached a larger size where they would be more able to avoid the sand placement operations.

On 7 November 2000 representatives from the Corps and the NMFS held a teleconference to explore methods to place sand on Broadkill Beach during the Spring/Summer without significantly impacting the sandbar sharks pupping (females giving birth to live-born young) and the nursery area that is located offshore in shallow waters. It was agreed that sand placement can be performed during the period from 1 May to 15 September using the following conservation measures:

A sand dike, 200 to 300 feet in length, will be constructed above mean high water (MHW) to contain dredged material that is pumped landward of it. The dike will be constructed using existing sand on the beach. The dike will be long enough that most dredged material will drop out on the beach and not return to the bay. As material is deposited the dike may be repositioned seaward to contain the required tilling above MHW for that section of beach. The slurry will still be controlled by the dike along the shoreline. No dredged material will be hydraulically placed below MHW during the restricted period. The dike will be extended down the beach as the area behind the dike is tilled and the dredged pipe is lengthened. The dredged material that has been deposited will be built into dunes. It is expected that little of this material will be re-deposited by wave action during the spring/summer window period since weather is generally mild, except for possible hurricanes. After September 15, some dredged material will be graded into the bay to widen the beach.

The dredge pipe will be placed on pontoons for a minimum of 1000 feet, beginning at approximately elevation -4.7 NGVD, extending offshore to avoid disrupting along shore traveling by the young sandbar sharks. This distance will be determined by the National Marine Fisheries Service. The remainder of the pipeline extending to the beach, and back to the dredge, can rest on the bottom.

4.2.4.2 Winter Flounder

Winter flounder in Delaware Bay are part of the Mid-Atlantic population that migrate inshore in the fall and early winter and spawn in late winter and early spring. In Delaware Bay, spawning takes place January, February and March, with early life stages being present in April and May

(Riportella, 2001). Trawl surveys by the Delaware Department of Natural Resources and Environmental Control indicate that they are not abundant and that they occur in the lower portion of Delaware Bay where there are higher salinity levels (Michels, 2000). Generally the concern for winter flounder extends from the mouth of Delaware Bay to River Mile 35.

Deepening the Navigation Channel has the potential to impact winter flounder if they were present; however, it is unlikely that the navigation channel has any significant use by this species.

The Deepening Project has the potential to impact eggs during the dredging of the channel and during the placement of the dredged material. It is likely that dredging will have a minimal impact on eggs of this species for the following reasons. First, there will be no dredging in lower Delaware Bay in January, February and March, which is the winter flounder spawning period. Also, most eggs have been found in shallow water, less than 5 meters. The navigation channel is presently 40 feet (12.2 meters) or greater and will be deepened to 45 feet (13.7 meters). Although eggs have been found in the 45 feet deep navigation channel of New York Harbor, the adjacent, shallow areas had greater densities, indicating that the more shallow water areas are preferred spawning habitat (Gallo, 2001). Another reason that winter flounder are likely to prefer areas adjacent to the navigation channel is that the deep draft vessels currently using the channel are creating more turbid conditions in the channel with their prop-wash that is likely to adversely impact spawning.

Since the larvae are non-dispersive, they are believed to occur in the same areas as the eggs, i.e. in shallow water. Because of the reasons listed above for eggs, it is unlikely that the navigation channel would provide preferred habitat for larvae.

Any juveniles or adults that use the channel could be adversely impacted by dredging, either by entrainment or increased turbidity. However, because of the channel's use by deep draft vessels and the resulting turbidity and prop wash, it is unlikely that the navigation channel has significant use from these life stages of winter flounder.

The placement of dredged material along the shallow shoreline of Delaware at the Kelly Island wetland restoration and the beach restoration at Broadkill Beach are more likely to have adverse impacts on spawning adults and early life stages (larvae and juveniles) than channel dredging. However, the impacts are not expected to be significant for the following reasons. First, as stated above, there would be no dredging during the winter flounder spawning period. Also, data from New Jersey and Delaware indicate that winter flounder populations currently using Delaware Bay are smaller than those further north in the range and become less abundant moving from northern New Jersey to southern New Jersey. In addition, the wetland restoration at Kelly Island will create tidal guts in the wetlands with abundant invertebrate fauna that will be beneficial to early life stages of winter flounder that will compensate for any temporary, minimal impacts that would occur from construction of the wetland restoration (Goodger, 2001). At Broadkill Beach, material will be contained on the beach until after September 15 for the protection of sandbar shark. This will also provide protection to eggs and early life stages of winter flounder within the project area. It is also noted that construction is a onetime event except for occasional maintenance that can be done outside the winter flounder window.

4.2.4.3 Anadromous Species

To protect the anadromous fish (striped bass, American shad, river herring) spawning run in the Delaware River the Delaware Basin Fish and Wildlife Cooperative recommends that dredging be restricted between the Delaware Memorial Bridge and the Betsy Ross Bridge from March 15 to June 30 for hopper dredging and March 15 and July 31 for hydraulic dredging (Appendix C). These restrictions would apply to Reaches AA, A, and B of the project area (See Section 2.5.1 for the location of these Reaches). These restrictive periods will be met throughout the construction period (See the construction schedule provided in Section 2.7). As such, construction of the project is not expected to adversely impact anadromous species of fish in the Delaware River.

4.2.4.4 Essential Fish Habitat Evaluation

In compliance with Section 305(b)(2) of the Magnuson-Stevens Fishery Conservation and Management Act (1996 amendments), the Philadelphia District, U.S. Army Corps of Engineers has prepared an assessment of the potential effects of construction and maintenance of the Federally authorized Delaware River Main Stem and Channel Deepening Project PA, NJ & DE. The assessment addresses the physical effects of further deepening from 40 to 45 feet the existing Delaware River Philadelphia to the Sea navigation channel and construction of the Kelly Island and Broadkill Beach beneficial use projects in Delaware Bay, including a description of the physical habitat, the listed managed species, including specific life stages, and associated major prey species. Based on the potential for adverse effects on designated species Essential Fish Habitat (EFH), recommendations are made for best management practices, which minimize potential adverse effects. The Essential Fish Habitat Evaluation for the Delaware River Main Channel Deepening Project can be found in Appendix B of this document. This EFH evaluation has been provided to the National Marine Fisheries Service for their review.

4.2.5 Wildlife

4.2.5.1 Shorebirds

Delaware Bay is recognized as one of the most critical stopovers worldwide for shorebirds migrating from their wintering grounds in Central and South America to their Arctic and Sub-Arctic breeding grounds. Each spring shorebirds arrive by the hundreds of thousands on their staging grounds along the Delaware Bay to fuel up for the last leg of their northward journey. Their stopover coincides with the peak of horseshoe crab spawning. The millions of horseshoe crab eggs laid in the sand along bayshore beaches comprise an important food source for the migrants. Previous studies have called attention to apparent declines in the numbers of several shorebird species on their staging grounds and point to the importance of habitat protection in the conservation of these species.

For the deepening project, material dredged from the Delaware Bay channel will be used for wetland restoration at Kelly Island and beach nourishment at Broadkill Beach. Shoreline beaches on Delaware Bay are known to attract high numbers of shorebirds. In order to determine whether the shoreline restoration projects will benefit migratory shorebirds, quantitative and qualitative baseline data on shorebird use of the sites was collected prior to

construction (Manomet Center for Conservation Services, 2002). This effort provided baseline data completed during May and June 2001. Principal emphasis was on documenting usage by shorebirds at the locations proposed for restoration, and in one case (Prime Hook), at a comparable abutting location not slated for restoration. At the time Port Mahon was a candidate site for restoration and was surveyed. Port Mahon is no longer a restoration site for this project. Rapid assessments also were made of common invertebrate animals in the same areas.

Migratory shorebird surveys were conducted at four locations on the Delaware coast during May 2001. Bird surveys were made with binoculars and a 20x telescope, and were conducted from vantage points that caused minimal disturbance to birds along the shoreline. Counting focused mostly on shoreline habitats, but flight-line counts of shorebirds moving between shoreline and nearby marshland habitats also were made near Port Mahon. Each shoreline section was divided into 25-31 subsections and marked. Counts were kept for each subsection.

Knowing what tidal stage is best for counting shorebirds is important to designing sequel studies. Between two and eight shoreline surveys were made at each location each week. Shorebirds were counted at predicted mid-tide times (roughly half way between low and high tides) on each day that counts were made. A second count also was made either 3 hr before or 3 hr after the predicted mid-tide time, i.e. at approximately the time of predicted low or high tide. Correlation analysis was used to describe overall relationships between counts made at mid- versus low tide, and between counts made at mid- versus high tides. Analysis of variance was used to compare counts between the 4 study areas.

The methodology of the shoreline surveys closely followed that used by The Nature Conservancy and Manomet Center for Conservation Sciences for shorebird monitoring at Port Mahon in 1997 and 1999. The study areas were as follows:

- Kelly Island (restoration site): this area extends north along the shoreline from the mouth of the Mahon River for about 1.6 km to Deepwater Point;
- Port Mahon (proposed restoration site at the time of study): the area is a 1 km stretch of shoreline just south of the mouth of the Mahon River where Port Mahon Road runs parallel to Delaware Bay;
- Broadkill Beach (restoration site): the study area is a 4.4 km stretch of shoreline from Arizona Avenue south to the end of the paved road; and
- Prime Hook Beach: an equivalent area of habitat similar to Broadkill Beach was surveyed as a future control site.

The study areas on Port Mahon and Broadkill beaches were divided into linear sections and marked. Similar linear segments were measured on Kelly Island and Prime Hook Beach. Marker locations were also GPS-located for future reference.

To assess the levels of shorebird use of marshlands proximate to the study beaches, birds were counted moving between the marsh and the shore during peak migration weeks. These surveys

were made near the north end of the Port Mahon study site for 10 minutes at dawn and/or dusk, times when shorebirds are expected to be moving to and from roosting sites.

At each of the 4 study locations (at the tideline in transect 1, 10, 20, and 25), core samples were collected during visits to the study sites after May 15th. Samples were sorted with a standard 1 mm screen to identify macro-invertebrate taxa. Fifty-two samples were assessed. Cores were collected on site, screened in the field, and washed with salt water into suitable containers marked for date and location, refrigerated, and sorted within 36 hours.

Invertebrates were identified as follows:

- Gastropods and bivalves to genus (or better)
- Amphipods and polychaete worms to family (or better)
- Shrimps to genus (or better)
- Crabs to genus (or better)
- Insects and spiders to order (or better)
- Scarce invertebrates (occurrence < 5% by head count) to class.

The shoreline at Port Mahon is highly eroded and has been extensively affected by human efforts to fortify the shoreline against erosion. Natural shoreline substrates are sand (or marsh peat in some areas) on higher sections of the beach and unconsolidated mud at lower tide locations. The vestiges of remaining sand beach are littered with rock, cement blocks, and other materials that historically were used in attempts to control erosion. Little beach remains exposed at high tides, leaving little habitat for foraging or resting birds and little material suitable for nesting horseshoe crabs, many of which become trapped in rocks and other erosion-control materials. Note that more intertidal mud exists on the unarmored section of shoreline south of Port Mahon Rd.

Kelly Island is immediately north of Port Mahon. The Kelly Island shoreline is substantially eroded, with some sections having a thin, sandy beach near the high tide line, and other sections having an eroded marsh peat shoreline. Mud is the principal substrate in the lower tidal reaches. Because little sand remains on the Kelly Island shore, there is little habitat for horseshoe crab nesting, and so it is not a key feeding area for shorebirds during May. On the other hand, the shoreline of Kelly Island is difficult for people to access, and so it is little disturbed, and serves shorebirds well as a resting area.

Prime Hook and Broadkill beaches are close to the mouth of Delaware Bay and are about 20 miles from the Port Mahon/Kelly Island locations. The bayshore in the Prime Hook region has much more extensively developed (wider) beaches than shorelines farther up the bay, and so provide better substrates for nesting horseshoe crabs. Beaches fronting the Broadkill community have groins built in efforts to control sand erosion. Sections of the beach that are less populated by people provide good potential foraging areas to shorebirds during the May and early June migration period, as do nearshore, intertidal sandflats. In addition, banks of marsh peat are sometimes exposed in eroded sections of beach (more so on the Prime Hook than the Broadkill section), which can provide good shorebird foraging and roosting habitat.

In addition, the researchers that participated in this effort provided the following findings: This project was oriented to provide baseline information on shorebird use of three areas proposed for environmental restoration on the Delaware Bay shore. An additional area (Prime

Hook) where no restoration is planned also was also evaluated with hopes that 'before' and 'after' studies could be made of a restored and an abutting 'unrestored' site. The premise underlying this design was that the Prime Hook site would act as a 'control' in comparisons that would be made after restoration efforts were completed.

We believe that the bird counts from May/June 2001 provide a good basis for describing the numbers of shorebirds using the 4 shoreline sections. The counts at the southern (Broadkill/Prime Hook) location were similar to each other, and the northern counts (Port Mahon/Kelly Island) were similar to each other. In contrast, the northern pair of sites had much higher counts than the southern pair.

The level of invertebrate sampling that we were able to collect was insufficient to reliably quantify differences of the invertebrate animal populations between the sites, but it is clear that horseshoe crab eggs were far and away the most available food item, and that they were apparently more abundant at Port Mahon than at the other three locations. A more quantitative evaluation would be needed to verify this.

Field time also was inadequate for documenting activities of shorebirds, including prey selection, while they were being counted. But it was clear that for most species Kelly Island was used principally as a roosting site whereas the other three areas were used primarily as foraging sites. If Kelly Island was used principally for roosting, we would expect greater numbers of shorebirds to have been counted there at times when foraging habitats were restricted or inaccessible, i.e. during high tides. We have only limited samples for evaluating this, and they show the expected pattern; however, the differences are not statistically significant, perhaps due to the small sample sizes.

Ideally the pairs of sites we selected for this work would have been identical with respect to bird numbers, species composition, activity budgets of the birds, and accessibility of prey populations. This, of course, was not the case. Perhaps the most important disparity was the difference of foraging activities between the Port Mahon and the Kelly Island restoration sites. It remains to be seen whether this difference will be maintained after restoration work is completed, i.e. whether Kelly Island will continue to be principally used by shorebirds as a roosting site or whether alterations to it will make it an attractive foraging site. Another consideration is human activity at the sites. Human activities were not comparable between the two sites at both the northern and the southern locations. The Port Mahon site is substantially more accessible to human activities than the Kelly Island restoration site; this did not appear to be a major issue in 2001 with respect to numbers of birds counted. However, human activities may have contributed to the lower counts at the Broadkill versus Prime Hook locations, but we had insufficient data to analyze for this.

The shorelines at Port Mahon and Kelly Island are highly eroded and provide limited habitat for horseshoe crab nesting, thus limited foraging habitat for shorebirds. Because the Kelly Island shoreline receives little disturbance from people, it does provide resting habitat for shorebirds. Prime Hook and Broadkill beaches are wider and provide good potential foraging areas for shorebirds. Human activity can limit shorebird use. Areas less populated by people provide the best habitat.

The purposes of the Kelly Island restoration are to stem erosion of the Kelly Island shoreline estimated at 20 feet per year, provide extensive sandy beach for spawning horseshoe crabs, which in turn provide valuable food resources for shorebirds, and to provide continued protection to the entrance of the Mahon River. As shown in the construction schedule (See Section 2.7), the restoration will take six months of shoreline work. The work is scheduled to span from April to September. The April start was selected to avoid dredging impacts to overwintering blue crabs, which can be buried in channel sediments from December through March. The restoration can not be constructed in pieces over several years because the site will not be stable and resistant to erosion until it is completed. As such, there will be construction disturbance at the Kelly Island site for one shorebird migratory season. As stated above, Kelly Island provides limited foraging habitat for shorebirds but good roosting habitat. Post-construction the site should provide good habitat for both foraging and roosting.

Restoring wetlands in this environmentally sensitive area has been a high priority for the State of Delaware. Construction activities will only take place at one portion of the site at a time, and would not preclude shorebird use of the entire site. Site disturbance during one shorebird migratory season is an acceptable trade off considering the long-term habitat benefits that will be accrued to shorebirds. The impact to shorebirds is not significant.

Broadkill Beach is also a high priority site for the State of Delaware. Delaware was the non-Federal sponsor for the Delaware Bay Coastline – Delaware and New Jersey Broadkill Beach, Delaware Interim Feasibility Study. The selected plan for the Feasibility Study (beach nourishment) was authorized by Congress for construction by Title I, Section 101 (a) (11) of the Water Resources Development Act of 1999 and is the same as the current plan. The project is scheduled for construction between the months of April and July. Again, the April start was selected to avoid dredging impacts to overwintering blue crabs, which can be buried in channel sediments from December through March. Similar to the Kelly Island site, there will be construction disturbance at the Broadkill Beach site for one shorebird migratory season. Broadkill Beach already receives human disturbance during the migratory season due to the residential community. Also, construction activities will only take place at one portion of the site at a time, and would not preclude shorebird use of the entire site. Site disturbance during one shorebird migratory season is an acceptable trade off considering the long-term benefits to the community of Broadkill Beach. The impact to shorebirds is not significant.

4.2.5.2 Pea Patch Island Heronry

The critical periods for different nesting species of herons vary but an all inclusive period on Pea Patch Island is from 1 April through 30 August. The Philadelphia District has committed to restricting dredging within close proximity of the heronry during this period for initial construction and subsequent maintenance of the 45-foot channel to preclude any disturbance (USACE, 1997a). Some dredging is required in the vicinity of Pea Patch Island for initial construction.

4.2.6 Threatened and Endangered Species and Other Species of Special Concern

4.2.6.1 Sea Turtles

Sea turtle observer(s) shall be on board any hopper dredge working in areas of concern during the first week of the dredging operation from 1 June to *15* November. Following the first week, the observer shall be on board the dredge on a biweekly basis or as appropriate so that the total aggregate time on board the dredge equals 50 percent of the total time of the dredging operation. While on board the dredge the observer shall provide the required inspection coverage on a rotating, six hours on and six hours off, basis. In addition, these rotating six hour periods should vary from week to week. All such dredging and monitoring will be conducted in a manner consistent with the Incidental Take Statement issued by NMFS for this District. The District will continue to coordinate monitoring results with NMFS, and work to develop appropriate measures to minimize impacts.

4.2.6.2 Whales

Due to the slow nature of Right whales it is the District's intention to slow down dredging vessels to 3 - 5 mph operating speed after sun set or when visibility is low when a Right whale is known to be in the project area. Contract plans and specifications will require the hopper dredge operator to monitor and record the presence of any whale within the project vicinity.

4.2.6.3 Shortnose Sturgeon

The Delaware River Basin Fish and Wildlife Management Cooperative has established dredging restrictions for the protection of fisheries resources that restricts blasting in the Delaware River to the winter months (December 1 to March 15). This restriction was primarily imposed to protect springtime anadromous spawning fish and summer spawning and nursery activity in the river. The deepening project requires blasting to remove rock outcrops located in the Marcus Hook, Chester, Eddystone and Tinicum ranges of the channel. While blasting in the winter months should protect most fish species that use the Delaware River in the spring and warmer months, Atlantic sturgeon (*Acipenser oxyrinchus*) and shortnose sturgeon (*Acipenser brevirostrum*) may be susceptible to blasting mortality if they use this area during the winter.

During the winter of 2005, a study was coducted to determine if sturgeon adults and juveniles inhabit the Marcus Hook to Tinicum reach of the Delaware River during the winter blasting period, and if so, to evaluate the abundance of sturgeon in the project area relative to that in known upriver over wintering habitats near Trenton, New Jersey (Versar 2005a).

Little historical data on sturgeon use of this part of the river exists, particularly during winter. The lack of information on sturgeon populations in the Marcus Hook region is partially a function of the difficulties that the physical conditions of the area pose to routine fisheries survey techniques (i.e., trawling and gillnetting). The Delaware River near Chester, Pennsylvania is subject to high tidal currents (4-5 knots), and heavy commercial tanker traffic, and has rocky bottom features and other snags that make trawling with nets and other traditional sampling devices extremely difficult and dangerous.

Surveys for the presence of Atlantic and shortnose sturgeon were conducted between March 4 and March 25, 2005 primarily using a Video Ray® Explorer submersible remotely operated vehicle (ROV). The Video Ray® was attached to a 1.0 x 1.0 x 1.5 meter aluminum sled which was towed over channel bottom habitats behind a 25-foot research boat. All images captured by

the underwater camera were transmitted through the unit's electronic tether and recorded on 60-minute Mini Digital Video Cassettes with a Sony GV-D1000 NTSC Digital Video Cassette Recorder. The recorded images were captured through the video monitor feed on the control unit of the ROV. A total of 43 hours of bottom video were collected on 14 separate survey days. Twelve days of survey work were conducted in the project area, specifically the Marcus Hook, Eddystone, Chester, and Tinicum ranges, while two separate days of survey work were conducted up river near Trenton, New Jersey, at an area known to have an over wintering population of shortnose sturgeon.

After deploying the sled and bottom contact was confirmed, the recording of digital video was initiated. The sled was generally towed on the bottom parallel to the centerline of the channel and into the current at 0.8 knots. Tows were attempted with the current to reduce the amount of "snow" created in the recordings from passing particles. This tow method was abandoned after hanging the sled up on debris and determining that the speed over the bottom could not be properly controlled. Tow track logs were maintained throughout the survey and any fish seen on the ROV monitor was noted. Boat position during each video tow was recorded every five minutes with the vessel's Furuno GPS. The Sony digital recorder recorded a time stamp that could be matched with the geographic coordinates taken from the on-board GPS.

Digital tapes were reviewed in a darkened laboratory at normal or slow speed using a high quality 28-inch television screen as a monitor. When a fish image was observed the tape was slowed and advanced frame by frame (30 images per second were recorded by the system). The time stamp where an individual fish was observed was recorded by the technician. Each fish was identified to the lowest practical taxon (usually species) and counted. A staff fishery biologist reviewed questionable images and species identifications. Distances traveled by the sled between time stamps were calculated based on the GPS coordinates recorded in the field during each tow. Total fish counts between the recorded coordinates within a particular tow were converted to observed numbers per 100 meters of tow track.

Limited 25-foot otter trawling and gillnet sets were conducted initially to provide density data, and later to provide ground truth information on the fish species seen in the video recording. Large boulders and other snags that tore the net and hung up the vessel early on in the study prompted abandoning this effort for safety reasons given the high degree of tanker traffic in the lower Delaware River. The trawl net was a 7.6-m (25-foot) experimental semi-balloon otter trawl with 44.5-mm stretch mesh body fitted with a 3.2-mm stretch mesh liner in the cod end. Otter trawls were generally conducted for five minutes unless a snag or tanker traffic caused a reduction in tow time. Experimental gillnets were periodically deployed throughout the survey period in the Marcus Hook area. One experimental gillnet was 91.4-m in length and 3-m deep and was composed of six 15.2-m panels of varying mesh size. Of the six panels in each net, two panels were 50.8-mm stretch mesh, 2 panels were 101.6-mm stretch mesh and two panels were 152.4-mm stretch mesh. Another gillnet was 100 m in length and consisted of four 25 x 2-m panels of 2.5-10.2-cm stretched monofilament mesh in 2.5 cm increments. Gill nets were generally set an hour before slack high or low water and allowed to fish for two hours as the nets had to be retrieved before maximum currents were reached.

Turbidity in the Marcus Hook region of the Delaware River limited visibility to about 18 inches in front of the camera. However, despite the reduced visibility, several different fish species were recorded by the system including sturgeon. In general, fish that encountered the sled between the leading edge of the sled runners were relatively easy to distinguish. The major fish

species seen in the video images were confirmed by the trawl and gillnet samples. In the Marcus Hook area, a total of 39 survey miles of bottom habitat were recorded in twelve separate survey days. Eight different species were observed on the tapes from a total of 411 fish encountered by the camera. White perch, unidentified catfish, and unidentified shiner were the most common taxa observed. Three unidentified sturgeon were seen on the tapes, two in the Marcus Hook Range, and one in the Tinicum Range. Although it could not be determined if these sturgeon were Atlantic or shortnose, gillnetting in the Marcus Hook anchorage produced one juvenile Atlantic sturgeon that was 396 mm in total length, 342 mm in fork length, and weighed 250 g.

Water clarity in the Trenton survey area was much greater (about 6 feet ahead of the camera) and large numbers of shortnose sturgeon were seen in the video recordings. In a total of 7.9 survey miles completed in two separate days of bottom imaging, 61 shortnose sturgeons were observed. To provide a comparative measure of project area density (where visibility was limited) to up river densities (where visibility was greater), each of the 61 sturgeon images were classified as to whether the individual fish was observed between the sled runners or whether they were seen ahead of the sled. Real time play backs of video recordings in the upriver sites indicated that the sturgeon did not react to the approaching sled until the cross bar directly in front of the camera was nearly upon it. Thirty of the 61 upstream sturgeon images were captured when the individual fish was between the runners. Using this criterion, approximately 10 times more sturgeon were encountered in the upriver area relative to the project site near Marcus Hook where three sturgeons were observed. Using the number of sturgeon observed per 100 meters of bottom surveyed, the relative sturgeon density in the project area was several orders of magnitude less than those observed in the Trenton area. The relative density of unidentified sturgeon in the Marcus Hook area was 0.005 fish per 100 meters while the densities of shortnose sturgeon between the sled runners in the upriver area was 0.235 fish per 100 meters.

The results of the video sled survey in the Marcus Hook project area confirmed that sturgeons are using the area in the winter months. However, sturgeon relative densities in the project area were much lower than those observed near Trenton, New Jersey, even when the upriver counts were adjusted for the higher visibility (i.e., between runner sturgeon counts). The sturgeons seen near Trenton were very much concentrated in several large aggregations, which were surveyed in multiple passes on the two sampling dates devoted to this area. The lack of avoidance of the approaching sled seen in the upriver video recordings suggests that little to no avoidance of the sled occurred in the low visibility downriver project area. Video surveys in the downriver project area did not encounter large aggregations of sturgeon as was observed in the upstream survey area despite having five times more sampling effort than the upstream area. This suggests that sturgeons are more dispersed in the Marcus Hook region of the Delaware River. Although the video survey data suggests that large aggregations of sturgeon do not exist in the blasting area, impacts to even a small number of shortnose or Atlantic sturgeon may not be acceptable to fisheries agencies. Measures to move fish away from the blast zone or otherwise protect them from the blast will be employed.

The measures listed below focus on preventing physical injury to juveniles that may be near the blasting area but would likely protect the larger adult fish if any were present since there is evidence that smaller fish are more vulnerable to injury than larger fish. Studies have shown that size of charge and distance from detonation are the two most important factors in determining fish mortality from blasting (Teleki and Chamberlain 1978, Wiley et al. 1981, and Burton 1994).

In addition, the measures listed below were used in North Carolina to successfully minimize impacts to shortnose
sturgeon:

Before each blast, four sinking gillnets (5.5 inch stretched mesh. 328 feet [I00 meters] long, 9.8-13.1 feet [3-4 meters] high) will be set to surround each blast area as near as feasible. These nets shall be in place for at least 3 hours and none of the nets will be removed any sooner than 1 hour before the blast. This may require ovenight sets. The nets shall be manned continuously to prevent obstructing the channel to ship traffic. Any sturgeon removed (shortnose or Atlantic) shall be tagged and released at a location approved by the NMFS.

Within 10 minutes of blast, channel nets (1-2 inch mesh) will be set during daylight hours downcurrent of the blast area and within approximately 300 feet from the blast area in order to capture and document dead or injured fish. The channel net shall have a minimum head rope length of 100 feet and should be retrieved approximately one how later.

Surveillance for schools of fish will be conducted by vessels with sonar fish finders (with a LCD display screen) for a period of 20 minutes before each blast. The surveillance zone will be approximately circular with a radius of about 500 feet extending outward from each blast set. If fish schools are detected, blasting will be delayed until they leave.

Two scare charges shall be used at each blast. The scare charges shall be detonated in close proximity to each blast. Each individual scare charge shall not exceed a TNT-equivalent weight of 0.1 lb. The detonation of the first scare charge will be at 45 seconds prior to the blast, with the second scare charge detonated 30 seconds prior to the blast. It is necessary to employ the scare charges and conduct the surveillance surveys before each blast, as some fish have been found to recolonize the blast zone soon after a detonation.

All blast holes will be stemmed to suppress the upward escape of blast pressure from the hole. The minimum stemming shall be 2 feet thick. Stemming shall be placed in the blast hole in a zone encompassed by competent rock. Measures shall be taken to prevent bridging of explosive materials and stemming within the hole. Stemming shall be clean, angular to subangular, hard stone chips without fines having an approximate diameter of 1/2-inch to 3/8-inch. A barrier shall be placed between the stemming and explosive product, if necessary, to prevent the stemming from setting into the explosive product.

Blast pressures will be monitored and upper limits will be imposed on each series of 5 blasts. Average peak pressure shall not exceed 70 pounds per square inch (psi) at a distance of 140 feet.

Maximum peak pressure shall not exceed 120 psi at a distance of 140 feet.

Pressure will be monitored for each blast only at a distance of 140 feet.

This plan is being coordinated with the National Marine Fisheries Service under Section 7 of the Endangered Species Act.

4.2.6.4 Atlantic Sturgeon

Much of the recent data on Atlantic sturgeon populations have been developed through the efforts of Dewayne Fox and Philip Simpson from the Delaware State University (Simpson and Fox 2007). Their primary research objectives have been 1) determine the status of Atlantic sturgeon populations in the Delaware River, 2) identify both the spatial and temporal extent of spawning, 3) identify critical habitats used during pre-and post-spawning movements and 4) determine duration of fresh-water residency.

Sonic tags were implanted in adult and juvenile Atlantic sturgeon captured in gill net sets and bi-catches from commercial fishing operations. Sturgeon movements were tracked using both active tag returns (boat mounted listening devices) and passive tag returns from an array of Vemco VR2 receivers mounted on navigational buoys ranging from the lower Delaware Bay to the head of tide in Trenton, New Jersey. Telemetry relocations of Atlantic sturgeon were overlaid with sediment-type data collected by Sommerfield and Madsen (2003) to determine habitat preferences. Sommerfield and Madsen utilized side scan sonar methods to produce a benthic map of the Delaware River from the region just north of Pea Patch Island upriver to approximately Bridgeport, NJ as well as the lower bay. To evaluate potential spawning locations egg mats (diameter 56-cm) were deployed in areas of the river where spawning was believed to be occurring based on active telemetry data and substrate sampling. Telemetry results indicated Atlantic sturgeon undergo a late spring/early summer upriver migration, followed by a period of dampened movement during the warm summer months of August and September, then an out migration during October and November. During the summer months juvenile Atlantic sturgeon displayed little movement compared to spring and fall months. Juvenile Atlantic sturgeon concentrated in three specific areas: Artificial Island, Cherry Island Flats, and the Marcus Hook anchorage. The deployed egg mats produced no sturgeon eggs but based on the gonadal biopsies of captured Atlantic sturgeon the lower limit of spawning appeared be near Tinicum Island while the upper limit is likely at the fall line near Trenton, NJ. Based on the findings of Sommerfield and Madsen (2003), Simpson and Fox postulated that the substrate composition between Marcus Hook and Tinicum Island represent suitable spawning habitat for Atlantic sturgeon.

Delaware State University's Philip Simpson and Dewayne Fox have been investigating the role of tidal flow on the migratory behavior of Atlantic Sturgeon in the Delaware Estuary. Using telemetry information they examined relationship between tidal flow and river depth on movement patterns of sonically tagged sturgeon. Out of 135 sturgeon movement tracking records, 99 resulted in a positive correlation with fish movement and tidal direction, while 14 were negatively correlated, and 22 were inconclusive. They also reported that Atlantic sturgeon do not appear to be exploiting the shallow habitats at night. These studies suggested that Atlantic sturgeons in the Delaware River were using passive tidal transport in addition to active swimming.

Surveying Atlantic sturgeon populations and their affinity to the navigational channel using traditional fisheries techniques (i.e., gill nets and trawling) is problematic due to commercial traffic, high tidal velocities, and bottom nags. Two recent studies investigated methods to document the presence of sturgeon using remote sensing techniques.

To evaluate the importance of the navigation channel as an over wintering habitat for sturgeon near Marcus Hook the USACE, Philadelphia District sponsored a remote sensing survey in the winter of 2005 (Versar, Inc. 2005a). The study employed the use of a Video Ray® Explorer submersible attached to an aluminum sled that was towed over navigational channel bottom. Images captured by the underwater camera were recorded on 60-minute Mini Digital Video Cassettes. A total of 43 hours of bottom video were collected on 14 separate survey days. Twelve days of survey work were conducted in the Marcus Hook, Eddystone, Chester, and Tinicum navigational ranges. Water clarity was sufficient to image the bottom and fish that came within 1-2 feet of the camera lens. Three unidentified sturgeon (Atlantic or Shortnose) were seen on the tapes, two in the Marcus Hook navigational Range, and one in the Tinicum navigational range. Gill net collections in the Marcus Hook anchorage during the video survey produced one Atlantic sturgeon juvenile.

Dewayne Fox from the University of Delaware investigated the feasibility of using Dual-Frequency Identification Sonar (DIDSON) and split-beam hydroacoustics to image sturgeon in hard to sample and low visibility environments. They compared split-beam and DIDSON technologies in controlled pond environments to assess the potential for conducting large-scale field surveys of Atlantic sturgeon and shortnose sturgeon in the Delaware River. In hatchery pond trials, fish sizes estimated from DIDSON images showed clear separation between the two size groups of juvenile Atlantic sturgeon. Field trials in the Delaware River suggested that although the DIDSON technology had some limitations (i.e., fish close to the bottom were difficult to image) the imaging system showed promise as a tool for determining habitat, identifying sturgeon, and estimating the abundance of sturgeon where traditional fisheries sampling cannot be conducted.

To protect Atlantic sturgeon, the Delaware Basin Fish and Wildlife Cooperative has recommended various windows for hopper dredging, cutterhead pipeline dredging, bucket dredging and blasting. All of these windows will be met during construction of the deepening project except for hopper dredging in Delaware Bay. In Delaware Bay (mouth to River mile 32) the Cooperative recommends restricting hopper dredging between 1 June and 30 November. Because of a competing restriction with over wintering blue crab it is not possible to observe this restriction. Hopper dredging will be required during the month of June for construction of the Broadkill Beach beneficial use project and during the months of June, July and August for construction of the Kelly Island beneficial use project (Figure 2-7). For the protection of sea turtles, a trained observer(s) is required on board any hopper dredge working below the Delaware Memorial Bridge during June through November. These observers will also be responsible for monitoring hopper dredge activity and potential impacts to Atlantic sturgeon. In addition, the monitoring program that will be employed to protect fish during the winter blasting period will also protect Atlantic sturgeon and immediately identify any problems.

Dredging provides safe passage for commercial shipping and recreational boat traffic in many river systems were sturgeon occur. Sturgeon encounters with boating traffic is common particularly in high traffic rivers like the Delaware. Ten adult Atlantic sturgeon were found in the Delaware River in 2004, six in 2005, and six in 2006 that were clearly struck by a passing ship or boat. The fish are usually 120 cm to 240 cm in length. Based on the external injuries observed, it is suspected that these strikes are from ocean going vessels and not smaller boats, although at least one fisherman reported hitting a large sturgeon with his small craft. Three

carcasses of mature fish have been documented from the lower river and upper Bay during the spawning season, including two gravid mature females and one male (NOAA 1998). An eight-foot female Atlantic sturgeon was found dead on June 14, 1994, adjacent to Port Penn. A pectoral spine was used to age it at approximately 25 years old. A second female sturgeon was found in late spring/early summer of 1997 adjacent to Port Penn, just south of the eastern end of the C&D Canal. The third sturgeon, a male, was located on May 19, 1997, just north of the mouth of the Cohansey River, on Beechwood Beach. This fish appeared to have been cut in half by the propeller of a large vessel. Gonadal tissue and a pectoral spine were collected and sent to USFWS-NEFC, Fish Technology Section, Lamar, PA for analysis, which confirmed that it was a male.

Similarly, five sturgeons were reported to have been struck by commercial vessels within the James River, VA in 2005, and one strike per five years is reported for the Cape Fear River, North Carolina. Subpopulations may be affected by these incidental strikes. It is unknown what the overall impact of boat strikes is to Atlantic sturgeon subpopulations, but in small subpopulations the loss of any spawning adults could have a substantial impact on recovery. Locations that support large ports and have relatively narrow waterways seem to be more prone to ship strikes.

Although sturgeon mortality from encounters with commercial traffic occurs in the Delaware River, the main channel deepening project will not increase the frequency of ship strikes since an increase in the number of ships traversing the river is not anticipated. The main channel 45-foot deepening will primarily reduce the lightering of crude oil tankers in lower Delaware Bay allowing vessels to off-load more of their crude oil directly at upper river port facilities. The distance between the keel of the vessel and the deeper navigational channel bottom will essentially be the same as it is in the current 40-foot depth.

#### 4.2.6.5 Bald Eagle

In October 1995 the Philadelphia District initiated formal consultation under Section 7 of the Endangered Species Act with the U.S. Fish and Wildlife Service for potential effects of the Main Channel Deepening Project on the bald eagle and peregrine falcon. The Biological Assessment concluded that there would be no impact that would jeopardize the continued existence of these species, or their critical habitat. In a letter dated January 18, 1996, the U.S. Fish and Wildlife Service concurred with this determination. Since that time both species have been removed from the Federal Endangered Species list.

At the time of the 1995 consultation, the following reasonable and prudent measure to minimize impacts was adopted. Prior to any construction activities at upland dredged material disposal areas, the Philadelphia District would coordinate with the U. S. Fish and Wildlife Service and the New Jersey Department of Environmental Protection to determine if there are any bald eagle nests within 0.25 miles or a line of site distance of 0.5 miles from an upland dredged material disposal area. If there is an active nest within these distances, construction of the site and the use of the site for the disposal of dredged material would be staged to avoid disturbance impacts. This measure will still be followed.

4.2.6.6 Peregrine Falcon

The following reasonable and prudent measures were identified for the peregrine falcon.

1. Coordination with the USFWS and the NJDEP before initiating any new work at the Raccoon Island upland dredged material disposal site between 15 March and 15 April. This site is no longer required for project construction.

2. The Philadelphia District will move the nest structure located at Egg Island Point to a safer location as determined in coordination with the NJDEP. Due to the reduction in the quantity of material to be dredged for the deepening project the Egg Island Point wetland restoration will be deferred.

The Philadelphia District will coordinate with the USFWS and NJDEP regarding potential nesting impacts to both the bald eagle and peregrine falcon.

4.2.6.7 Red Knot

Refer to Section 4.2.5.1 for potential project impacts to the red knot.

4.2.6.8 Other Species of Concern

In their August 2007 Water Quality Certification for continued maintenance of the existing Delaware River Philadelphia to the Sea navigation channel, the New Jersey Department of Environmental Protection requested survey programs for freshwater mussels and wild celery (Vallisneria americana). Several species of freshwater mussels are of concern in the Delaware Estuary. These include: dwarf wedgemussel (*Alasmidonta heterodon*), triangle floater (*Alasmidonta undulate*), brook floater (*Alasmindonta varicose*), alewife floater (*Anadonta implicata)*, eastern elliptio (*Elliptio complanata*), yellow lampmussel (*Lampsilis cariosa*), eastern lampmussel (*Lampsilis radiata*), green floater (*Lasmigona subviridis*), tidewater mucket (*Leptodea ochracea*), eastern pondmussel (*Ligumia nasuta*), eastern pearlshell (*Margaritifera margaritifera*), eastern floater (*Pyganondon cataracta*), and squawfoot (*Strophitus undulatus*). In the Fall of 2008, a freshwater mussel survey was conducted in the Pedricktown North confined disposal facility, which contains sediments dredged from the Marcus Hook range of the channel. The only shells found were *Corbicula,* which is a common and ubiquitous bivalve in the Delaware River and is not threatened or endangered. In addition, the NJDEP requested a wild celery survey to insure that pipelines coming onshore would not impact existing plants. The entire Pedricktown North shoreline was surveyed but no submerged aquatic vegetation was found. These surveys will continue in the future as sites are prepared for use to collect more information on the potential impact of dredging and dredged material disposal on these species.

4.3 Cultural Resources

In order to fulfill responsibilities under the National Historic Preservation Act of 1966, as amended, the Philadelphia District has worked closely with the Pennsylvania, New Jersey and Delaware State Historic Preservation Offices (SHPO'S) to coordinate extensive cultural resources investigations in the project area. This work involved a synthesis of previous

investigations, documentary research, a remote sensing survey, underwater investigations and a shoreline survey (Cox 1988, Cox 1995, Cox & Hunter 1995, 1995a). Project areas included bend widening, channel deepening, channel side-slope, proposed submerged sand stockpile and wetland restoration areas. Nineteen high probability targets exhibiting cultural resource characteristics were identified out of a total of 225 remote sensing targets documented in project areas. Phase I underwater ground truthing operations and Phase II underwater site investigations identified 2 of these 19 targets as significant cultural resources eligible for listing on the National Register of Historic Places - the Canal Barge Site (E-1, 1:5) and the "Excelsior" Steamboat Site (E-2, 4:16). Both sites are located in New Jersey waters. No significant submerged cultural resources were identified in Delaware or Pennsylvania. Phase I shoreline surveys were conducted in two proposed wetland restoration locations on Egg Island Point, New Jersey (PN-la) and Kelly Island, Delaware (LC-9). These low-tide surveys identified the remains of lighthouse foundations in both study areas and concrete footings along the shoreline in the vicinity of Port Mahon, Delaware. There are no shoreline or upland project areas located in Pennsylvania. Cultural resources investigations were not conducted in the 13 upland disposal areas and the Marcus Hook Anchorage due to previous dredging and disposal activities at these locations.

Based on the results of cultural resources investigations, the Philadelphia District determined that the project will have "No Effect" on significant cultural resources. The District plans to completely avoid the Canal Barge Site (E-1, 1:5), the "Excelsior" Steamboat Site (E-2, 4:16) and the Egg Island Point Lighthouse Site by placing a 200 foot buffer around each location and then monitoring each site to ensure that no impacts occur to these sites during construction. Although Phase I survey data did not determine the National Register eligibility of the Port Mahon Lighthouse site and the Oyster Shucking House site identified in the Kelly Island (LC-9) study area, both sites are located well south of the wetland restoration construction area and will not be impacted by construction activities.

The draft report of the final cultural resources investigation (Cox & Hunter 1995) and the District's finding of "No Effect" was submitted to the Pennsylvania, New Jersey and Delaware SHPO's in September and October, 1995. The Pennsylvania and New Jersey SHPO'S concurred with the District's finding in letters dated November 21, 1995 (PASHPO) and December 23, 1996 (NJSHPO).

In a letter dated February 4, 1997, the DESHPO provided a review of the DSEIS and concurred with the District's finding of "No Effect" for Delaware project areas at Reedy Point North and South, Buoy 10, Kelly Island, and proposed sand stockpiling locations MS-19 and LC-5. However, the DESHPO expressed the strong opinion that the project would have an adverse effect on archaeological deposits located along the shoreline of Pea Patch Island. It was ultimately determined that the deepening of the Delaware River main channel to a depth of 45 feet would have an adverse effect upon historic Fort Delaware on Pea Patch Island. Both the fort and the island are properties listed in the National Register of Historic Places. Pursuant to Section 106 of the National Historic Preservation Act of 1966, as amended, the District Engineer signed a memorandum of agreement in 1999 with the Delaware State Historic Preservation Officer (SHPO) and the Advisory Council on Historic Preservation in which the Corps committed to the installation of extensive shoreline erosion control measures (See Section 3.4.1). These shoreline erosion control measures have been constructed and it is concluded that

deepening the navigation channel to 45 feet will not increase shoreline erosion on Pea Patch Island, and consequently, will not impact significant cultural resources along the shoreline. In a letter dated September 10, 1996, the DESHPO concurred with the District's finding of "No Effect" for the Broadkill Beach beach nourishment project.

### 4.4 Air Quality

#### 4.4.1 General Conformity Analysis

The U.S. Army Corps of Engineers (USACE) performed an emissions analysis and mitigation study (*Delaware River Main Channel Deepening Project General Conformity Analysis and Mitigation Report*, February 2004 Moffatt & Nichol, 2004) to determine if construction activities associated with the deepening project would generate pollutant concentrations that exceed de minimis threshold limits that have been set and, if so, how to mitigate so that the Project could reach conformity.

Due to the reduction in dredging quantities and associated changes to the dredged material disposal plan for the Delaware River and beneficial use of dredged material in Delaware Bay, the emissions generated from construction of the deepening project will be less than estimated in 2004. USACE is in the process of updating the emissions analysis.. While emissions will be less, it is anticipated that some annual de minimis threshold limits will be exceeded, thus requiring mitigation. The updated analysis will re-evaluate mitigation alternatives to determine the most cost effective plan.

For the 2004 project plan, emission sources consisted of marine and land-based mobile sources that would be utilized during a six-year project construction period (five years for the project and one year for the berthing areas). The marine emission sources included various types of dredges (clamshell, hydraulic, and hopper) as well as all support equipment. The land-based emission sources included both off-road and on-road equipment. The off-road equipment consisted of heavy equipment utilized to construct and maintain the disposal sites. The on-road equipment was made up of employee vehicles and any on-road trucks utilized for the project. The marine emission sources and off-road equipment consisted primarily of diesel-powered engines. The on-road vehicles were a combination of gas and diesel-powered vehicles.

Once the operational information for the various engines was obtained from the project cost estimates, the engine load factors and emission factors were determined using EPA guidelines. The air emissions were determined on an annual basis for each piece of equipment. The emissions were then totaled on an annual basis for all equipment (regardless of where construction was taking place). The annual emissions for the project were then compared to the de minimis threshold level for the combined non-attainment area. In 2004 the project area was classified as severe non-attainment for ozone (composed of NOx and VOC), the de minimis level for each was 25 tons per year. The project area was also classified as a maintenance area for CO, the de minimis level was 100 tons per year.

It was found that the NOx emissions exceed the de minimis threshold limits in every year of the project. The NOx emissions varied from 102 tons per year to 849 tons per year. The VOC emissions were under the de minimis limit (25 tons per year) for all years of the project. The CO emissions exceeded de minimis in Year 4 (106 tons).

The General Conformity ruling (40 CFR 93.158(a)(2)) states that once a project has exceeded the established de minimis threshold(s), emissions from the project must be reduced "so that there is no net increase in emissions of that pollutant." Consequently, the project was required to reduce or offset its annual emissions of CO (Year 4 only) and NOx (all years) to zero.

### 4.4.2 Mitigation Plan

The emission reduction plan selected in 2004 consisted of three components: on-site SCR, off-site maintenance dredging electrification, and off-site Corps' dredge McFarland. The plan would achieve General Conformity for both CO and NOx.

On-Site SCR

Construction contracts advertised for the project would require installation of Selective Catalytic Reduction (SCR) equipment on all hopper dredges, hydraulic dredges and booster pumps used in connection with the project. Alternatively, the contractor could be afforded the opportunity to achieve the emission reduction benefits required by the project through other emission control methods as long as the net result of those methods met or exceeded the reductions specified in the selected emission reduction plan. The Corps would ensure that these reductions were being attained by conducting emissions testing to verify emissions reductions.

Off-Site Maintenance Dredging Electrification

The Corps would pursue converting maintenance dredging activities to electric power at recurring maintenance dredging sites. Details were to be developed as part of the plans and specifications for implementing this portion of the plan. Specifications to ensure that these methods were used would be coordinated with appropriate federal, state and local agencies and Metropolitan Planning Organizations and added to the appropriate contracts.

Off-Site Corps' Dredge *McFarland*

The Corps' hopper dredge *McFarland* was to be utilized as part of the mitigation plan. The vessel would be retrofitted and work a minimum of 87 days (2,076 hours) during Years 3 through 6 of construction of the project.

### 4.5 Unavoidable Adverse Environmental Effects

Unavoidable adverse environmental impacts associated with dredging include loss of benthic organisms in areas to be dredged and water quality impacts that result from the suspension of bottom sediments during the dredging process. These impacts do occur now, but to a lesser degree, because maintenance of the existing channel requires dredging. Also some existing ship traffic that utilizes most of the 40-foot depth of the channel suspends bottom sediments. The use of explosive charges to remove rock from the channel would have an adverse impact on the aquatic environment. Blasting will be done in accordance with approved seasonal windows and will be monitored to insure minimal impact. A five-foot deepening is likely to promote a measureable upstream movement of saline water. Based on conservative modeling, the projected

increases under conditions that occurred during the 1960's drought of record would be well within the existing standards. Disposal of dredged material at the upland confined disposal facilities would result in the loss of existing vegetation. All sites are currently used for dredged material disposal and are disturbed. These areas do provide some wildlife habitat and will continue to do so. The environmental impacts associated with use of existing sites is considerably less than use of new areas. In Delaware Bay, dredged material will be used for beneficial purposes including wetland restoration and beach nourishment. While there would be environmental disturbance during construction, the completed projects will be more productive and beneficial.

4.6 Short-term Uses of the Environment and Long-term Productivity

This section considers the relationship between the short-term use of the natural environment and the long-term productivity of the Delaware River port complex. This complex is considered to be the world's busiest freshwater port. The deepening of the existing channel to these ports is considered a significant part of keeping the ports competitive with others in the United States.

Short-term use of the natural environment would be necessary to achieve long-term productivity of the Delaware River ports. Dredging does place some stress on the aquatic environment. This stress is primarily felt during the actual dredging process, with limited long-term effects. While dredging is currently employed to maintain the existing channel, there would be a higher level of dredging required to initially construct, and then to a lesser degree, maintain a deeper channel. Additional dredging also requires additional dredged material disposal capacity. There is sufficient dredged material disposal capacity in existing Federal confined disposal facilities to construct and maintain the 45-foot project for a 50-year project life. No new dredged material disposal sites are required for this project other than the beneficial use projects planned for Delaware Bay.

4.7 Irreversible and Irretrievable Commitments of Resources

Construction would involve utilization of time and fossil fuels, which are irreversible and irretrievable. Adverse environmental impacts associated with dredging are short-term in nature and will subside after dredging is completed. The actual deepening of the existing channel is not irreversible as it would shoal to a shallower depth in areas if maintenance dredging is not continued. The use of dredged material disposal areas does not represent an irreversible or irretrievable commitment of resources. All upland sites are existing, currently used sites for dredged material disposal. The sites will continue to provide the existing level of wildlife habitat benefits. There is sufficient dredged material disposal capacity in existing Federal confined disposal facilities to construct and maintain the 45-foot project for a 50-year project life. No new dredged material disposal sites are required for this project other than the beneficial use projects planned for Delaware Bay. Placement of dredged material at the beneficial use sites would fill in portions of Delaware Bay. This would be irreversible and irretrievable, however these are eroded areas and the completed projects would restore the sites to a previous condition, and protect against future losses.

4.8 Cumulative Effect

The authorized project is formulated on the basis that the mix and volume of cargoes coming to the benefiting terminals will be the same for either the current 40 foot or proposed 45 foot channel depths. The project's navigation benefits from the channel deepening are based upon transportation cost savings from more efficiently managing vessel operating costs. There is no induced tonnage as a result of the deepening project and consequently, any future decision by port interests to expand existing benefiting facilities would be independent of the deepening project.

4.9 Environmental Justice

The project as described in this document is expected to comply with Executive Order 12989-Environmental Justice in Minority Populations and Low-Income Populations, dated February 11, 1994. Project components are not located in close proximity to a minority or low-income community, and no impacts are expected to occur to any minority or low-income communities in the area.

5.0 Public Comment

Public Notices (CENAP-PL-E-09-01 and CENAP-PL-E-09-02 dated 17 December 2008 and 31 December 2008, respectively) solicited input from Federal and State resource agencies, environmental groups and the interested public. Notices were sent to the U.S. Environmental Protection Agency, the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, the National Park Service, the Delaware River Basin Commission, the Pennsylvania Department of Environmental Protection, the Pennsylvania Fish and Boat Commission, the New Jersey Department of Environmental Protection and the Delaware Department of Natural Resources and Environmental Control.

6.0 Evaluation of Section 404(b)(1) Guidelines

I. Project Description

A. Location: Delaware River and Bay from Philadelphia to the Sea, with dredging and confined, upland disposal sites in Delaware and New Jersey, and various placement locations in Delaware Bay for beneficial uses (See Figure 2-1).

B. General Description: The authorized project modifies the depth of the existing navigation channel from 40 to 45 feet at mean low water, with an allowable dredging overdepth of one foot. The modified channel would follow the existing channel alignment from Delaware Bay to Philadelphia Harbor and Beckett Street Terminal, Camden, New Jersey, with no change in channel widths. The plan also includes widening 12 of 16 existing channel bends, as well as partial deepening of the Marcus Hook Anchorage to 45 feet. Approximately 16 million cubic yards of material would be dredged for initial project construction. In addition, 77,000 cubic yards of rock would be removed by. The required maintenance dredging of the 45-foot channel will increase by 862,000 cubic yards per year (cy/yr) from the current 3,455,000 average cy/yr for the 40-foot channel for a total of 4,317,000 cy/yr. In the riverine portion of the project area,

dredged material would be placed in nine active, Federal, upland, dredged material disposal sites. In Delaware Bay, dredged material from initial project construction would be used for wetland restoration at Kelly Island, Delaware, and for beach nourishment work at Broadkill Beach, Delaware. All material that will be dredged from the Delaware Bay for channel maintenance will be deposited into the existing open water site at Buoy 10, as is the present practice.

C. Authority and Purpose: The Delaware River Main Stem and Channel Deepening Project, Pennsylvania, New Jersey, and Delaware, was authorized by Public Law 102-580, Section 101(6) of the Water Resources Development Act of 1992. The project was modified by Section 308 of the Water Resources Development Act of 1999, Public Law 106-53, and further modified by Section 306 of the Water Resources Development Act of 2000, Public Law 106-541.

D. General Description of Dredged or Fill Material

(1) General characteristics of Material: Rock, gravel, sand and silt.

(2) Quantity of Material (cubic yards): Approximately 16 million cubic yards of material would be dredged for initial project construction consisting of approximately 4 million cubic yards in Delaware Bay, and approximately 12 million cubic yards of in the riverine portion of the project. Most of the material dredged from Delaware Bay is sand. In addition, 77,000 cubic yards of rock would be removed from the channel in the vicinity of Marcus Hook, Pennsylvania. The required maintenance dredging of the 45-foot channel will increase by 862,000 cubic yards per year (cy/yr) from the current 3,455,000 average cy/yr for the 40-foot channel for a total of 4,317,000 cy/yr.

(3) Source of Material: Delaware River Navigation Channel from the Beckett Street Terminal, Camden, NJ to the mouth of Delaware Bay.

E. Description of the Proposed Discharge Sites

(1) Location (map): The locations of dredged material disposal sites are shown on Figure 2-1.

(2) Size (acres): Existing Federal, dredged material disposal sites: Reedy Point. - 255 ac. (2 sites); National Park - 120 ac.; Pedricktown North and South - 1089 ac. (2 sites); Oldmans – 189 ac; Penns Neck - 325 ac.; Killcohook - 1229 ac.; and Artificial Island - 305 ac.; Wetland Restoration: Kelly Island - 60 ac; and Beach Nourishment: Broadkill Beach - 69 ac. The open water disposal site at Buoy 10 is approximately 1000 acres in size.

(3) Type of Sites: Existing upland dredged material disposal sites adjacent to the Delaware River and open water sites in Delaware Bay.

(4) Types of Habitat: All of the confined dredged material disposal sites are active Federally owned sites. These areas are predominantly vegetated with common reed. The wetland restoration site and beach nourishment site are estuarine intertidal and subtidal habitats in Delaware Bay.

(5) Timing and Duration of Discharge: 5 year initial dredging duration; maintenance dredging will occur annually in selected reaches over a 50 year period.

F. Description of Disposal Method: Hydraulic pipeline dredge or hopper dredge with direct discharge to upland diked disposal areas or beneficial use sites (Kelly Island and Broadkill Beach) in Delaware Bay. Rock removal by blasting and excavator.

II. Factual Determination

A. Physical Substrate Determinations

(1) Substrate Elevation and Slope: Increase in surface elevations at the beneficial use sites and the upland dredged material disposal sites.

(2) Sediment Type: The material to be dredged from the navigation channel is similar in grain size to the existing sediment types at the beneficial use sites, and the existing confined dredged material disposal areas. The rock will be placed in the Fort Mifflin dredged material disposal site, and will be significantly larger in particle size than the sand and silt that exists on the site; however, there will be no significant adverse impact.

(3) Dredged/Fill Material Movement: Not significant. There will be temporary increases in turbidity at the discharge points for the confined dredged material disposal areas, and at the beneficial use and Buoy 10 open water discharge locations.

(4) Physical Effects on Benthos: Burial at beneficial use sites: Benthic evaluations have concluded that the existing benthic communities are neither significant nor unique.

(5) Action Taken to Minimize Impact: Effluent from diked upland disposal areas will be controlled by adjustable weirs. Also, standard construction practices to minimize turbidity and erosion would be employed.

B. Water Circulation, Fluctuation and Salinity Determinations

(1) Water. Consider effects on:

a. Salinity - No significant effect.

b. Water chemistry - No significant effect.

c. Clarity - Minor short-term increase in turbidity during construction at discharge sites.

d. Color - Minor short-term effect during construction.

e. Odor - No effect.

f. Taste - No effect.

g. Dissolved gas levels - No significant effect.

h. Nutrients - Minor effect.

i. Eutrophication - No effect.

j. Others as appropriate - None.

(2) Current patterns and circulation:

a. Current patterns and flow - No significant impact.

b. Velocity - No significant effects on tidal velocity and longshore current velocity regimes.

c. Stratification - Thermal stratification occurs beyond the mixing region created by the surf zone at the Kelly Island and Broadkill Beach sites. There is a potential for both winter and summer stratification. The normal pattern should continue post construction of the project.

d. Hydrologic regime - The regime is largely marine and estuarine. This will remain the case following construction of the project.

(3) Normal water level fluctuations - Construction of the work would not affect the tidal regime. The Kelly Island wetland restoration site is designed to permit regular tidal flushing.

(4) Salinity gradients - There should be no significant effect on existing salinity gradients.

(5) Actions that will be taken to minimize impacts – Use and monitoring of existing dredged material disposal area weirs for discharge of effluent to the Delaware River/Bay. Utilization of sand from a clean, high energy environment and excavation with a hydraulic dredge would also minimize water chemistry impacts at the open water beneficial use sites and Buoy 10 maintenance dredged material disposal area.

C. Suspended Particulate/Turbidity Determinations

(1) Expected Changes in Suspended Particulate and Turbidity Levels in the Vicinity of the Disposal Sites: All silty dredged material will be placed in confined dredged material disposal sites. There will be minimal increases in suspended particulate and turbidity from upland sites due to use of adjustable weirs. There would be a short-term elevation of suspended particulate concentrations during construction phases in the immediate vicinity of the dredging and the discharge at beneficial use sites.

(2) Effects (degree and duration) on Chemical and Physical Properties of the Water Column:

a. Light penetration - Short-term, limited reductions would be expected as a result of the discharge of effluent from confined dredged material disposal sites, and at the beneficial use sites and Buoy 10 from the deposition of sand material.

b. Dissolved oxygen - There is a potential for a decrease in dissolved oxygen levels at the beneficial use sites, but the anticipated low levels of organics in the dredged material should not generate a high, if any, oxygen demand. No significant effects anticipated as a result of the short-term discharge of effluent from confined dredged material disposal sites.



c. Toxic metals and organics - No significant impacts.

d. Pathogens - Pathogenic organisms are not expected to be a problem in the areas to be dredged or at the dredged material disposal areas.

e. Aesthetics - No significant impact.

(3) Effects on Biota:

a. Primary production, photosynthesis - Minor, short-term effects related to turbidity. Increase in productivity due to the Kelly Island wetland restoration.

b. Suspension/filter feeders - Minor, short-term effects related to suspended particulate outside the immediate deposition zone. Sessile organisms would be subject to burial within the deposition areas at the beneficial use sites.

c. 'Sight feeders - Minor, short-term effects related to turbidity.

d. Actions taken to minimize impacts include the use of confined upland disposal areas which will minimize release of suspended solids into receiving waters which are well mixed. Appropriate siting of beneficial use sites will minimize impacts to benthic resources. Standard construction practices will also be employed to minimize turbidity and erosion. Procedures for minimizing the impact of blasting for rock removal is discussed in Section 2.6.1 of this document.

D. Contaminant Determinations

The discharge of dredged material is not expected to introduce, relocate, or increase contaminant levels at either the confined upland dredged material disposal sites (including the water that will return to the Delaware River), or from the beneficial use sites in Delaware Bay

E. Aquatic Ecosystem and Organism Determinations

(1) Effects on Plankton: The effects on plankton should be minor and mostly related to light level reduction due to turbidity. Significant dissolved oxygen level reductions are not anticipated.

(2) Effects on Benthos: Benthic communities will be displaced at the beneficial use sites where subtidal habitat is changed into intertidal wetlands or beach. Recolonization is expected to occur in some areas through horizontal and in some cases vertical migrations of benthos. Impacts on benthic communities will not be significant.

(3) Effects on Nekton: Only a temporary displacement is expected as nekton would probably avoid active work areas.

(4) Effects on Aquatic Food Web: Only a minor, short-term impact on the food web is anticipated. This impact would extend beyond the construction period until recolonization of beneficial use sites occurred (estimated to be up to 18 months).

(5) Effect on Special Aquatic Sites: The overall impact will be positive with beneficial use of dredged material to restore and protect tidal wetlands at Kelly Island, DE, and the beachfront community of Broadkill Beach, DE.

(6) Threatened and Endangered Species: No significant impacts are expected. Section 7 consultation was performed with the U.S. Fish and Wildlife Service and the National Marine Fisheries Service during preparation of the Supplemental Environmental Impact Statement. An updated Section 7 consultation is underway with NMFS.

(7) Other Wildlife: No Significant Effect.

(8) Actions to minimize impacts: Recommended environmental windows will be observed to the extent possible to minimize impacts to aquatic resources. Construction techniques will be used to reduce the impacts of rock blasting on fish.

F. Proposed Disposal Site Determinations

(1) Mixing Zone Determination: The following factors have been considered in evaluating the disposal sites:

a. Depth of water at disposal locations.

b. Current velocity, direction, and variability at disposal locations.

c. Dredged material characteristics, constituents, amount, and type of material, and settling velocities.

d. Number of discharges per unit of time.

e. Use of confined upland disposal sites with controlled weirs.

An evaluation of the factors above indicates that the disposal sites and/or size of mixing zone are acceptable.

(2) Determination of compliance with applicable water quality standards: Extensive testing of water quality parameters has been completed. It is anticipated that the discharges from the upland dredged material disposal areas and at the beneficial use sites will be in compliance with all State and Federal water quality standards.

(3) Potential Effects on Human Use Characteristics:

a. Municipal and private water supply - No effect.

b. Recreational and commercial fisheries – No significant adverse impacts. The Kelly Island wetland restoration will benefit fisheries.

c. Water related recreation - No significant impacts.

d. Aesthetics - No significant impacts.

e. Parks, national and historic monuments, national seashores, wilderness areas, etc. - Wetland restoration at Kelly Island will benefit the Bombay Hook National Wildlife Refuge.

G. Determination of Cumulative Effects on the Aquatic Ecosystem - None anticipated.

H. Determination of Secondary Effects on the Aquatic Ecosystem - Any secondary effects would be minor.

III. Findings of Compliance or Non-Compliance with the Restrictions on Discharge

A. No significant adaptation of the Section 404(b)(l) Guidelines were made relative to this evaluation.

B. The alternative measures considered for accomplishing the project objectives are detailed in Section 3 of the Final Environmental Impact Statement, which was issued in February 1992 for which a 404(b)(l) analysis is a part.

C. It is not anticipated that the disposal of dredged material at the selected sites would violate any applicable state water quality standards. The disposal operation will not violate the Toxic Effluent Standards of Section 307 of the Clean Water Act. In order to implement the requirements of Section 404 of the Clean Water Act, an exemption was approved under Section 404 (r) as part of the Congressional authorization for this project, Public Law 102-580, Section 101 (6) of the Water Resources Development Act of 1992.

D. Use of the selected disposal sites is not expected to harm any endangered species or their critical habitat. Formal consultation was completed with the U.S. Fish and Wildlife Service and the National Marine Fisheries Service. An updated Section 7 consultation is underway with NMFS. There are no Marine Sanctuaries designated by the Marine Protection, Research, and Sanctuaries Act of 1972 in the project area.

E. The proposed disposal of dredged material will not result in significant adverse effects on human health and welfare, including municipal and private water supplies, recreation and commercial fishing, plankton, fish, shellfish, wildlife, and special aquatic sites. The life stages of aquatic life and other wildlife will not be adversely affected. Significant adverse effects on aquatic ecosystem diversity, productivity, and stability, and recreational, aesthetic and economic values will not occur. Restoration of wetlands in Delaware Bay using dredged

material, will result in increased fish and wildlife habitat, erosion control, and increased water quality.

F. Appropriate steps to minimize potential adverse impacts of the discharge on aquatic systems includes limiting suspended solids in the diked upland disposal area effluent through control of weir structures. Environmental windows will be observed to the extent possible to minimize impacts to aquatic resources. Construction techniques will be used to reduce the impacts of rock blasting on fish.

G. On the basis of the guidelines, the proposed disposal sites for the discharge of dredged material are specified as complying with the 404 (b)(1) guidelines with the inclusion of appropriate and practical conditions to minimize pollution or adverse effects to the aquatic ecosystem.

7.0 Conclusion and Findings

This Environmental Assessment (EA) has addressed changes to the authorized Delaware River Main Stem and Channel Deepening Project and changes to the affected environment since completion of the 1997 Supplemental Environmental Impact Statement (SEIS). This EA also updates the environmental analysis for the project by incorporating pertinent information collected since 1997. Based on the information contained in this EA and the referenced studies, I have concluded that relevant to environmental concerns addressed at 40 CFR 1502.9(c): 1) none of the changes to the proposed project are "substantial"; and 2) there are no new circumstances or information that can be considered "significant". Therefore, I have determined that the threshold for preparation of a Supplemental Environmental Impact Statement (SEIS) set forth at 40 CFR 1502.9(c) has not been met and that changes to the project or project conditions since the 1997 SEIS will not have a significant adverse effect on the human environment. I intend to adopt and implement all project-related recommendations that the NMFS will make in its Biological Opinion to minimize potential adverse effects on the shortnose sturgeon. Consequently, I find and conclude that no new Supplemental EIS is required prior to construction of the subject project.

3 April 2009

Date

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