

**DELAWARE RIVER MAIN CHANNEL DEEPENING PROJECT
(PENNSYLVANIA, NEW JERSEY, AND DELAWARE)**

COMPREHENSIVE ECONOMIC REANALYSIS REPORT



**U.S. Army Corps of Engineers, Philadelphia District
North Atlantic Division
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Table of Contents

1.	INTRODUCTION	1
1.1.	Background	1
1.1.1.	Feasibility Report	1
1.1.2.	Preconstruction, Engineering and Design.....	1
1.1.3.	Limited Reevaluation Report.....	1
1.2.	Purpose and Scope	2
1.3.	Study Area.....	2
1.4.	Quality Control Process	2
1.5.	Organization of the Report.....	4
2.	DESCRIPTION OF THE RECOMMENDED PROJECT	5
2.1.	Summary Description	5
2.2.	Dredging Quantities	5
2.3.	Disposal Plan.....	5
2.4.	Beneficial Uses of Dredged Material.....	6
2.5.	Real Estate Requirements	6
2.6.	Project Operation	6
3.	NATIONAL ECONOMIC DEVELOPMENT (NED) BENEFITS	8
3.1.	Categories of Benefits	9
3.1.1.	Vessel Efficiencies	9
3.1.2.	Operational Efficiencies.....	9
3.1.3.	Improved Safety.....	10
3.1.4.	Beneficial Uses of Dredged Material.....	10
3.2.	Quantified Benefits	12
3.3.	Average Annual Benefits.....	12
4.	NATIONAL ECONOMIC DEVELOPMENT (NED) COSTS	15
4.1.	Initial Construction Costs	15
4.1.1.	Dredging and Disposal Costs	15
4.1.2.	Real Estate Costs.....	15
4.1.3.	Navigation Aid Costs	16
4.2.	Associated Costs	16
4.3.	Summary of Initial Costs	17

4.4.	Operation and Maintenance Costs	18
4.4.1.	Federal Project	18
4.4.2.	Associated Costs	18
4.5.	Interest During Construction.....	19
4.6.	Average Annual Costs	20
5.	BENEFIT COST RATIO	21
6.	RISK AND UNCERTAINTY	22
6.1.	Guidance	22
6.2.	Definitions	22
6.3.	Uncertainties in the Estimation of Costs and Benefits.....	23
6.3.1.	Uncertainty in Benefit Estimation.....	23
6.3.2.	Uncertainty in the Estimation of Project Costs	26
7.	COST SHARING.....	29
7.1.	Non-Federal Cost Share	29
7.2.	Federal Cost Share	29
7.3.	Cost Apportionment	30
8.	RECOMMENDATION	31

List of Tables

Table 3-1	Average Annual Benefits by Commodity Type	13
Table 3-2	Average Annual Benefits by Facility	13
Table 4-1	Associated Facility Costs	17
Table 4-2	Project First Costs.....	17
Table 4-3	Associated Maintenance Dredging Volumes	18
Table 4-4	Annual First Cost Expenditures and Interest During Construction.....	19
Table 4-5	Average Annual Costs.....	20
Table 5-1	Average Annual Costs, Benefits and BCR.....	21
Table 6-1	Sensitivity Analysis on Project First Costs	27
Table 7-1	Cost Sharing Of Project Construction.....	30
Table 7-2	Cost Apportionment	30

List of Figures

Figure 1	Study Area	3
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1. INTRODUCTION

This report presents a comprehensive economic reanalysis of the Delaware River Main Channel Deepening Project.

1.1. Background

The history and background culminating in this comprehensive reanalysis is described below.

1.1.1. Feasibility Report

The Delaware River Comprehensive Navigation Study Main Channel Deepening Interim Feasibility Report and Environmental Impact Statement was completed in February 1992. The Division Engineer's Public Notice for that report was issued in February 1992. Thereafter, the report was reviewed by the Washington Level Review Center (WLRC), and the Board of Engineers for Rivers and Harbors (BERH). In June 1992, the WLRC concurred with the findings and recommendations of the reporting officers. Subsequently, the project was reviewed by the Office of Management and Budget. A Record of Decision (ROD) for the Final Environmental Impact Statement was completed in December 1992. Public Law 102-580, Section 101(6) of the Water Resources Development Act of 1992, authorized the recommended project for construction and was modified by Section 308 of the Water Resources Development Act of 1999 Public Law 106-53.

1.1.2. Preconstruction, Engineering and Design

In 1992, the Preconstruction, Engineering, and Design (PED) study was initiated. The objective of this study was to refine the recommended plan, respond to concerns raised by the WLRC review of the 1992 Interim Feasibility Report and to perform additional supplementary environmental analyses as recorded in the December 1992 Record of Decision for the Final Environmental Impact Statement. The Project Management Plan called for preparation of a Design Memorandum (DM) and an appropriate NEPA document.

With the completion of the DM and Supplemental Environmental Impact Statement as part of the PED study, the project design features for the proposed deepening to 45 feet of the Delaware River Main Channel were finalized.

In May 1996, the results of the PED study were documented in a DM which was approved by the District, as per guidance contained in CECW-EP Memorandum dated 31 May 1995, Subject: Engineering, Design and Dam Safety Guidance. In addition, a Draft Supplemental Environmental Impact Statement (SEIS) was prepared in December 1996 and made available to the public and agencies. The Final SEIS was filed with the U.S. Environmental Protection Agency in July 1997. The July 1997 Final SEIS re-affirmed the environmental impacts that were presented in the 1992 Interim Feasibility Report and Final Environmental Impact Statement. A Record of Decision (ROD) for the Final SEIS was completed in December 1998.

1.1.3. Limited Reevaluation Report

Since the date of the economic analysis exceeded the criteria for budgeting the project, a reevaluation of the project economics was required in order to budget for a new construction start in Fiscal Year 1999. A Limited Reevaluation Report was completed in February 1998 to

obtain approval to initiate construction, and to serve as the decision document for budgetary purposes, and the Project Cooperation Agreement.

1.2. Purpose and Scope

Due to delays in initiating construction in Fiscal Year 2002, the need for another economic reanalysis was dictated by guidance contained in Engineering Circular (EC) 11-2-183, entitled Corps of Engineers Civil Works Direct Program - Program Development Guidance - Fiscal Year 2004, dated 31 March 2002. Sub Appendix B-2, Construction - New and Continuing; Section B-2.6 Separable Elements of Ongoing Construction Projects, Resumptions, and Unstarted Projects Previously Funded for Construction requires that an economic analysis be performed, since the last approved economic analysis of this project occurred prior to Fiscal Year 1999.

In addition, the U.S. General Accounting Office, in its final June 2002 report on the Delaware River Main Channel Deepening Project, recommended that a comprehensive reanalysis be undertaken to address uncertainties about the project's economic analysis.

To assist the District in conducting the economic reanalysis, the Philadelphia District contracted with David Miller & Associates, Inc. (DMA) in April 2002 to prepare a reanalysis of the project benefits.

1.3. Study Area

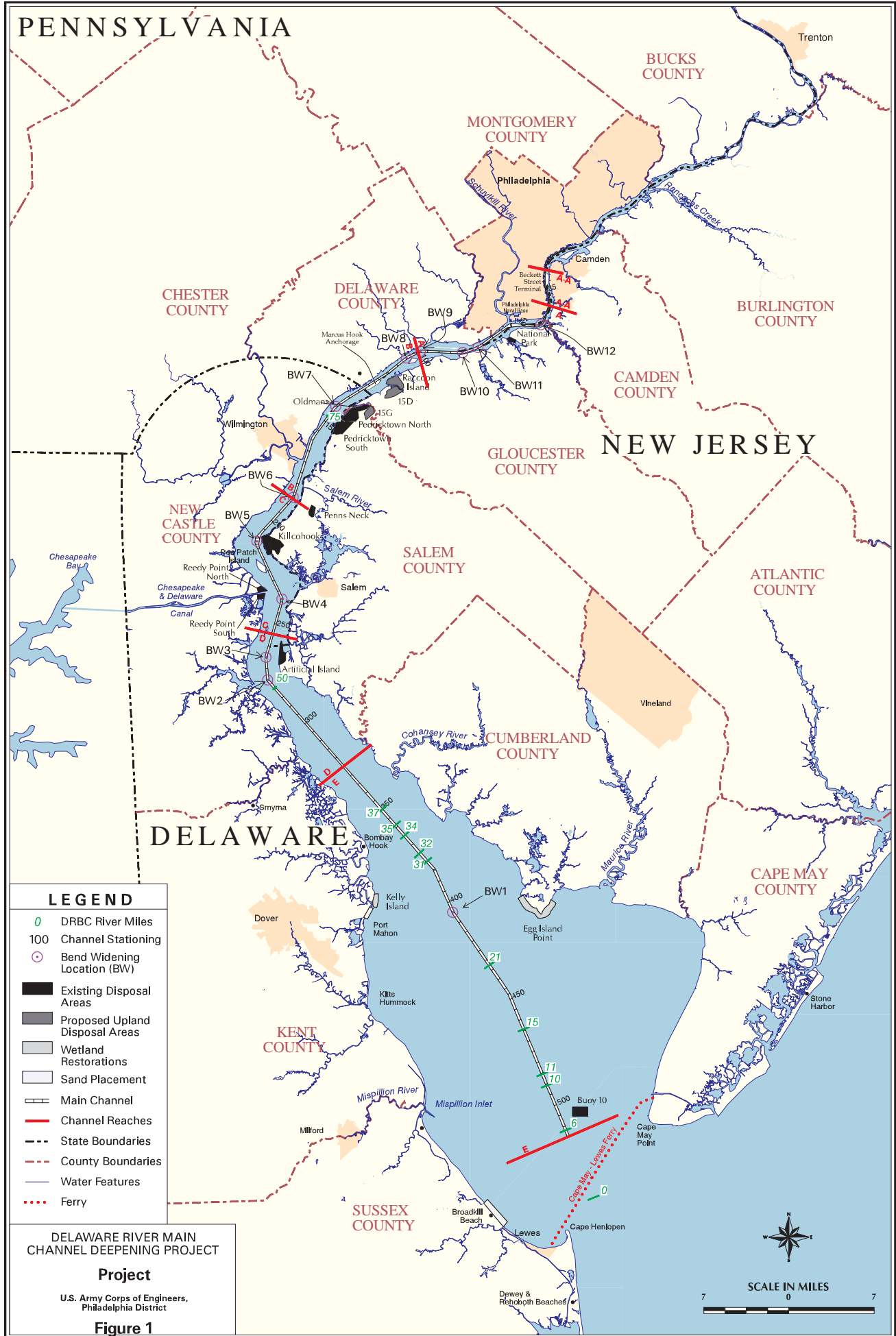
The study area is located along the northeastern coast of the United States. The Delaware River Port System is located in the center of the Eastern industrial corridor of the United States. The port complex is served by a highly efficient rail and highway network that brings some of the greatest centers of commerce within easy reach. The proposed 45-foot channel-deepening project is located within the Delaware River and Bay and the borders of the Commonwealth of Pennsylvania, and the States of New Jersey and Delaware. It extends over 100 river miles of the Delaware River and Bay, from Philadelphia, Pennsylvania to the mouth of Delaware Bay, following the alignment of the existing 40-foot Federal projects (see Figure 1).

1.4. Quality Control Process

Ongoing Quality Control reviews were performed throughout this reanalysis effort by Corps of Engineers elements. In addition, an independent technical review of project costs and benefits was arranged and conducted as part of DMA's contract.

A Quality Control Plan (QCP) was developed to guide efforts on the Comprehensive Economic Reanalysis Report. The QCP described the process used to review and validate the data, assumptions, models, analyses and documentation of the reanalysis effort. A Technical Review Team (TRT) was selected to conduct technical reviews of all elements of this report. The TRT consisted of senior personnel who were not directly involved in performing the technical analyses. The results of their efforts are documented in a Quality Control Report that is being submitted with this Comprehensive Economic Reanalysis Report for higher agency review.

A separate Independent Technical Review (ITR) was conducted by outside experts in navigation economics and engineering. Their results were submitted directly to the Corps North Atlantic Division, who will conduct a Quality Assurance (QA) review. The report and supporting QA/QC documentation will also be reviewed by HQUSACE to ensure that the Corps of Engineers' QA/QC requirements have been followed in the reanalysis effort.



LEGEND

- 0 DRBC River Miles
- 100 Channel Stationing
- Bend Widening Location (BW)
- Existing Disposal Areas
- Proposed Upland Disposal Areas
- Wetland Restorations
- Sand Placement
- Main Channel
- Channel Reaches
- - - State Boundaries
- - - County Boundaries
- Water Features
- ... Ferry

DELAWARE RIVER MAIN CHANNEL DEEPENING PROJECT

Project

U.S. Army Corps of Engineers,
Philadelphia District

Figure 1

SCALE IN MILES

7 0 7

1.5. Organization of the Report

This report consists of six major sections and three appendices.

Section 1 – Introduction

Section 2 – Description of the Recommended Project

Section 3 – National Economic Development (NED) Benefits

Section 4 – National Economic Development (NED) Costs

Section 5 – Benefit Cost Ratio

Section 6 – Risk and Uncertainty

Section 7 – Cost Sharing

Section 8 - Recommendation

Appendix A – Cost Estimate

Appendix B – Real Estate Plan

Appendix C – Benefit Analysis

2. DESCRIPTION OF THE RECOMMENDED PROJECT

2.1. Summary Description

The project as shown on Figure 1 consists of a navigation channel extending from deep water in the Delaware Bay to Philadelphia Harbor, Pennsylvania and to Beckett Street Terminal, Camden New Jersey, a distance of about 102.5 miles. The plan provides for modifying the existing Delaware River Federal Navigation Channel (Delaware River, Philadelphia to the Sea and Delaware River in the Vicinity of Camden) from 40 to 45 feet below Mean Low Water (MLW) with an allowable over depth dredging of one foot. The channel side slopes are 3 horizontal to 1 vertical.

The channel width remains the same as the existing 40-foot project, and would range from 400 feet in Philadelphia Harbor to 800 feet from Philadelphia Navy Yard to Bombay Hook and then 1,000 feet in Delaware Bay. The plan includes widening 12 of the 16 existing channel bends as well as provision of a two-space anchorage for safety purposes to a depth of 45 feet at Marcus Hook.

The existing turning basin adjacent to the Naval Shipyard will not be deepened as part of the 45-foot project. The project includes deepening of the existing 40-foot Federal project channel to a 45-foot depth to Beckett Street Terminal. The project also includes the acquisition of three new upland disposal sites (Raccoon Island, 15D, and 15G) and relocation of, and additions to, aids to navigation.

2.2. Dredging Quantities

For the initial deepening, 26,012,000 cubic yards of material would be removed using pipeline, clamshell and hopper dredges. Dredged material would be placed in confined upland disposal areas or placed for beneficial uses at various locations within Delaware Bay. About 77,000 cubic yards of rock would be removed in the vicinity of Marcus Hook, PA using a clamshell dredge after drilling and blasting operations are completed. The required maintenance dredging of the 45-foot channel will increase to 4,317,000 cubic yards (gross quantities) per year (cy/yr) from the current 3,455,000 cy/yr, for the 40-foot channel, resulting in a net increase of 862,000 cy/yr. Appendix A - Cost Estimate discusses the development of the estimated maintenance dredging quantities and costs.

2.3. Disposal Plan

The dredged material disposal plan was established using the most recent Delaware River channel examinations. The initial dredged material (18,684,000 million cubic yards) from the river portion of the project (Reaches AA-D) will be placed at six existing Federal upland sites (National Park, Pedricktown North, Pedricktown South, Killcohook, Reedy Point South and Artificial Island), and three new upland sites identified as Raccoon Island, 15D and 15G. The non-Federal sponsor, the Delaware River Port Authority (DRPA), will acquire the three new upland sites. Reedy Point South disposal area will only be used for disposal of dredged material from the initial construction. The maintenance quantities will be placed at five existing Federal upland sites (National Park, Pedricktown North, Pedricktown South, Killcohook, and Artificial Island) and at the three new upland sites.

The initial dredged material (7,328,000 million cubic yards) from Delaware Bay (Reach E) is comprised primarily of sand that will be used for wetland restoration at Egg Island Point, New Jersey and Kelly Island, Delaware; and for beach placement (Broadkill Beach) in the State of Delaware. The material from maintenance dredging will be disposed at an existing approved subaqueous site (Buoy 10).

The non-Federal sponsor, DRPA, will provide an equivalent amount of disposal capacity to the Federal Government from its three proposed sites. This will replace the loss of disposal capacity at the existing Federal sites incurred by the 45-foot deepening project (i.e., construction and subsequent 50-year incremental maintenance).

The management practices used at the existing Federal sites will be similar for the new proposed sites. Dikes will be raised at 10-foot increments and sluices will be replaced as part of a regular maintenance program. The new disposal areas will be developed initially with dikes and sluices. The costs of these features have been incorporated as part of the General Navigation Features account. With the addition of three new upland disposal areas, 50 years of disposal capacity will be available for maintenance of the 45-foot project.

2.4. Beneficial Uses of Dredged Material

In the lower portion of the project area, the dredged material from the deepening project primarily consists of clean sand. In coordination with Federal and State resource agencies, a plan was developed to use the material to stabilize and enhance the environment in the Delaware Bay. This plan entails using the dredged material to restore the eroding beaches, protect the tidal wetlands that are behind the beaches, enhance horseshoe crab and migratory bird habitat and to protect property from storm damage, respectively, at Kelly Island, Delaware and Egg Island Point, New Jersey; and Broadkill Beach in the State of Delaware.

2.5. Real Estate Requirements

The real estate required for the proposed project involves the acquisition of three new upland disposal areas (Raccoon Island, 15D, and 15G), acquisition of temporary work area easements, and licenses for initial sand placement at Broadkill Beach.

For the three upland disposal areas, this consists of fee title acquisition of approximately 1,295 acres of privately owned land and about 25 acres for temporary easements for sand placement at Broadkill Beach. The non-Federal sponsor, who is responsible for all Lands, Easements, Rights-of-Way, Real Estate, and Disposal areas (LERRD), will need to perform metes and bounds surveys for these sites.

There are no Public Law 91-646 relocations for this project. The non-Federal sponsor, DRPA, has sufficient experience and the ability to acquire the necessary real estate. The updated detailed Real Estate Plan (REP) is located in Appendix B.

2.6. Project Operation

The Philadelphia District, Corps of Engineers would maintain the Federal channel and anchorage in accordance with the project dimensions, providing advance maintenance in high shoaling areas as per existing practice. The Corps of Engineers will be responsible for operation and maintenance of the existing Federal sites, the new upland disposal areas and the wetland

restoration sites. Maintenance of navigation aids would continue to be performed by the U.S. Coast Guard. Local service facility berth dredging and maintenance would be accomplished by each facility.

3. NATIONAL ECONOMIC DEVELOPMENT (NED) BENEFITS

National Economic Development (NED) benefits were estimated for this Comprehensive Economic Reanalysis Report following 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 in this analysis 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.

The benefit estimation process described in this section relies on observed existing conditions and practices as a guide to developing future scenarios. There is a large degree of uncertainty in projecting future conditions and practices in the ocean shipping industry. Given this level of uncertainty, extreme assumptions are avoided and each step of the process must pass a test of reasonableness. As described below, types of economic benefits with high levels of uncertainty are identified but not quantified in this analysis. Therefore, the economic benefits quantified in this analysis represent the minimum value of NED benefits that would result from navigation improvements to the Delaware River Channel.

Benefits will result from the decrease in the cost per ton for shipping commodities into or out of the Delaware River Port System. While commodity movements will increase in the future as a function of regional demand, no induced tonnage (i.e., commodity shifts from other ports) is claimed from the project deepening. A deeper channel depth will allow some current vessels to carry more cargo as well as allow a fleet shift to larger vessels, thus more efficiently apportioning operating costs over a greater amount of tonnage. Other vessels, such as large crude oil vessels that currently lighter at Big Stone Anchorage in the naturally deep water of the lower Delaware Bay, will continue to carry equivalent tonnage but will be able to operate more efficiently with a deepened channel resulting in reduced lightering costs. Benefits are also claimed for a reduction in tidal delays. Finally, benefits are claimed for cost reductions resulting from beneficial reuse of dredged material at the authorized Broadkill Beach project.

Benefits are also expected to accrue from safety improvements and the use of dredged material for ecosystem restoration at Kelly Island and Egg Island Point. These last two categories of benefits are described in the analysis, but not quantified or included in the project benefit cost ratio.

The quantification of NED benefits involved computing and comparing total transportation costs under with and without project conditions for each pertinent vessel class, by trade route, by

commodity, and by terminal destination. Benefits have been estimated for liquid bulk (crude oil and petroleum product imports), dry bulk (including blast furnace slag and slab steel) and containerized reefer cargo (fruits, eggs and meat requiring refrigeration).

Vessel operating costs used in the analysis were taken from the tables and regressions provided in the most recent CECW-P Economic Guidance Memorandum 02-02, Deep Draft Vessel Operating Costs, 12 August 2002.

Economic benefits are calculated for the 50-year study period (2009 – 2058). In addition, some benefits would accrue prior to the base year; due to completion of the first four years of channel deepening that would provide 45-foot access to most terminals by 2008.

All project costs and benefits are computed in May 2002 Price Levels and are discounted at the Federal Fiscal Year 2003 discount rate of 5-7/8%

A detailed description of the benefit analysis assumptions, methodology and results is included in Appendix C – Benefit Analysis.

3.1. Categories of Benefits

Sources of benefits have been identified through analysis of vessel operations, port and terminal operations, vessel deployments, and project features. The categories of benefits include:

- Vessel efficiencies,
- Operational efficiencies,
- Improved safety, and
- Beneficial uses of dredged material.

3.1.1. 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.

3.1.2. 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.
- Reduced tidal delays: Operational safety practices in the harbor require vessels to maintain a minimum of 3 feet of underkeel clearance, limiting maximum unrestricted sailing drafts to 37 feet in the existing 40-foot channel. Many liquid bulk and some dry bulk vessels currently use tidal advantage to arrive at port with sailing drafts up to 40 feet. These vessels travel more slowly and “drift the tide” to maintain safe underkeel clearance. Deepening the Federal channels to -45 feet MLW would allow some of the vessels that currently take advantage of

high tides (i.e., those currently drafting greater than 37 to 42 feet) to access port facilities more quickly, reducing transportation time under with project conditions.

- Benefits during construction (pre-base year benefits): Benefits would accrue to facilities south of and including the Marcus Hook reach that will have access to the 45-foot project in the year 2008, one year prior to full completion of construction (2009). This includes the crude oil refineries and petroleum products terminal, but not the dry bulk and containerized vessel terminals.

3.1.3. Improved Safety

Benefits that would result from improved safety in the harbor include:

- Reduced natural resource injury: Deeper channels would reduce the overall number of vessel calls for future commodity movements, reduce congestion, reduce the practice of “drifting the tide”, and reduce lightering operations in the harbor. All other things being equal, reductions in each of these elements would reduce the probability of groundings, collisions, oil spills, or other contaminant spills that would injure natural resources in the harbor, thereby reducing the expected value of natural resource damages.
- Reduced disruptions of services: As described above, deeper channels would reduce the probability of oil spills or other contaminant spills in the harbor. Reducing the probability of such incidents would also reduce the probability of waterway closures and service disruptions that result from related clean-up, salvage, and restoration activities. The reduction in incident probability would reduce the expected value of damages related to disruptions of waterway services.

3.1.4. Beneficial Uses of Dredged Material

As described in Section 2, dredged material from Delaware Bay (Reach E) will be used to restore the eroding beaches, protect the tidal wetlands that are behind the beaches, enhance horseshoe crab and migratory bird habitat, and protect property from storm damage, respectively, at Kelly Island, Delaware and Egg Island Point, New Jersey; and Broadkill Beach in the State of Delaware.

Ecosystem Restoration at Kelly Island and Egg Island Point

Millions of migratory birds pass through Delaware Bay during spring and fall migrations. The beaches and adjacent intertidal wetlands are especially important as migratory stopover points for shorebirds. Delaware Bay ranks as the largest spring staging site for shorebirds in eastern North America. Staging sites, such as Kelly Island and Egg Island Point, serve to link wintering areas with breeding grounds, and are critical to the survival of hundreds of thousands of migrating shorebirds. 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 hundreds of thousands of shorebirds that migrate through Delaware Bay each spring. Wetland restoration will restore and enhance habitat for these species, as well as many other species that use these wetlands in Delaware Bay. In addition, wetland restoration and shoreline protection will protect many acres of wetlands that would otherwise be lost to continuing erosion. These tidal marshes are used by migratory shorebirds, waterfowl and wading birds, and provide nursery areas for many fish species.

At Kelly Island, approximately 60 acres of salt marsh will be restored and 80 acres of salt marsh will be protected from erosion over the life of the project (50 years). At Egg Island Point, approximately 135 acres of salt marsh will be restored and 110 acres will have reduced erosion over an estimated 25-year period.

The primary species of concern at Kelly Island under its present condition are the horseshoe crabs that spawn at nearby sand beaches, the migrating and feeding shorebirds, waterfowl, and waterbirds in general. Presently less than 50% of the shoreline of Kelly Island is suitable for horseshoe crab spawning (Weber, 2002)¹. Wetland restoration should more than double the available spawning habitat as well as add an additional 1,000 feet of sandy shoreline suitable for spawning. The wetland restoration will enhance habitat for all of these species, and in addition, will provide a sheltered intertidal area for juvenile fish species during certain times of the year. Wetland restoration at Egg Island Point will create a sandy beach about 700 feet long, suitable for horseshoe crab spawning.

There are a number of other species that will benefit from protection of the southeast Egg Island Point site, such as waterbirds, shorebirds, and juvenile fish. All of these species will use the low marsh and tidal pools. Overwash sandy areas would provide both additional crab-spawning areas along fringes and potential tern, gull, and other waterbird nesting areas.

Beach Renourishment at Broadkill Beach

The Corps of Engineers conducted studies along Delaware Bay to determine Federal involvement in providing shoreline and environmental projects for various communities. Authorization to undertake these studies was established in a resolution adopted in October 1986 by the Public Works and Transportation Committee, United States House of Representatives. Based on the results of these investigations, a Federal project was recommended at Broadkill Beach. Subsequently, a feasibility study was initiated in January 1993. This study was cost shared between the Federal Government and the State of Delaware, Department of Natural Resources and Environmental Control. In September 1996, a final Feasibility Report and Environmental Impact Statement was completed for Broadkill Beach. The project calls for beach nourishment utilizing sand obtained from offshore borrow areas to provide storm damage and erosion control protection. Beach nourishment will consist of a berm and dune restoration along 13,500 linear feet of the bay front.

The Broadkill Beach Project is a stand-alone project whose federal funding is separate from the Delaware River Main Channel Deepening Project. The Broadkill Beach Project has been authorized for construction and plans and specifications have been completed. When funding is provided, the Broadkill Beach Project will continue. Because of delays in construction funding, the project has exceeded criteria for dated economic data. In order to move forward, a limited economic analysis needs to be completed prior to budgeting for a “new start”.

¹ Weber, R. G. 2002. *Preconstruction Horseshoe Crab Egg Density Monitoring and Habitat Availability at Kelly Island, Port Mahon, and Broadkill Beach Study Areas, Delaware*. Report prepared for the Philadelphia District Corps of Engineers, February 2002.

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

Benefits would be realized due to cost savings resulting from “jointly” developing both projects rather than developing them independently. The Delaware River Main Channel Deepening Project has the primary requirement for disposing of associated dredged material and therefore is assigned the cost of placement. In doing so, the project also is assigned the NED cost savings from beneficial use of the disposal of material. The following approach was used in estimating potential NED cost savings.

Broadkill Beach Project: The currently identified sand source is an offshore borrow area. The estimated cost is \$9.7 million.

Delaware River Main Channel Disposal: Material that would be placed at Broadkill Beach would otherwise be placed at an existing upland, confined federally owned disposal facility at Artificial Island. The estimated cost is \$46.9 million.

Beneficial Use: The estimated cost of placement of material from the Delaware River Main Channel Deepening Project on Broadkill Beach is \$27 million. Thus, the least cost disposal option is established at Broadkill Beach.

Benefits: With the least cost option determined, the \$9.7 million in avoided borrow area sand source cost at Broadkill Beach is a benefit to the Delaware River project. On an average annual basis this is equal to \$604,698.

3.2. Quantified Benefits

Although each of the benefit categories identified above are reasonable, anticipated benefits of the deepening project, several of the benefit categories cannot be accurately quantified or are uncertain at this time. Therefore, only a sub-set of the previously described benefit categories is quantified in this analysis. Economic benefit calculations include only the transportation cost savings associated with vessel efficiencies and operational efficiencies, and beach renourishment at Broadkill Beach. Benefits will likely accrue due to improved safety and beneficial uses of dredged material at Kelly Island and Egg Island Point, but have not been quantified or included in the project justification.

3.3. Average Annual Benefits

The economic reanalysis estimated benefits that would result from deepening the Delaware River Main Channel from its current authorized and maintained project depth of 40 feet below MLW to the recommended depth of 45 feet below MLW. The average annual NED benefits of the 45-foot deepening plan are presented in May 2002 Price Levels at the prevailing Federal discount rate of 5-7/8 percent. Table 3-1 displays average annual benefits by commodity. Table 3-2 displays average annual benefits by facility.

A portion of the average annual benefits shown in Table 3-1 and Table 3-2 for crude oil and petroleum product imports are pre-base year benefits that will accrue in 2008, based on deepening prior to the base year of channel segments that will provide access to a subset of the benefiting facilities by that date. These pre-base year benefits are included in the total benefits

listed in Tables 3-1 and 3-2 and equal approximately \$853,000 in average annual benefits, or 3.5 percent of total transportation cost savings.

Table 3-1
Average Annual Benefits by Commodity Type

Benefit Type	Average Annual Benefits
Transportation Cost Savings	
Crude Oil (Imports)	\$14,798,714
Petroleum Products (Imports)	\$355,008
Containerized Cargo (Imports) (Vegetables, Fruit, Eggs, Meat requiring refrigeration)	\$3,490,717
Blast Furnace Slag (Imports)	\$1,811,496
Steel Slabs (Imports)	\$3,597,997
Subtotal Transportation Cost Savings	\$24,053,932
Beneficial Use Cost Savings at Broadkill Beach	\$604,698
Total	\$24,658,630

Table 3-2
Average Annual Benefits by Facility

Facility	Average Annual Benefits
Sunoco Facilities (Ft. Mifflin, Marcus Hook, Hog Island)	\$6,223,318
Valero	\$4,744,061
Phillips 66 (Tosco)	\$1,305,021
Coastal Eagle Point	\$1,789,715
Motiva	\$736,600
Subtotal Refineries	\$14,798,714
Beckett Street Terminal	\$1,811,496
Packer Ave. Terminal	\$7,088,714
Delaware Terminals	\$355,008
Total Facility Benefits	\$24,053,932
Beneficial Use Cost Savings at Broadkill Beach	\$604,698
Total All Benefits	\$24,658,630

Several other facilities in the port complex may also benefit from the deepening project. However, information was insufficient to calculate transportation cost savings for these facilities. The potential benefits for these facilities are described below.

Benefits from channel deepening may accrue to Gloucester Marine Terminals in Gloucester City, NJ. Currently, smaller vessels carrying steel imports from St. Petersburg, Russia call at Gloucester less than fully loaded. Vessels arrive about 12 to 14 times per year and also call at other ports such as Wilmington, Savannah, and New Haven. Each port receives a portion of the vessel's load. The current volume of steel imports at Gloucester is approximately 250,000 metric tons. If the channel were deepened to 45 feet, larger, more fully loaded vessels could potentially make Gloucester their first port of call.

Benefits may also accrue to Pier 122 in the Port of Philadelphia, PA. Koch Carbon, LLC shipped materials through Pier 122 several years ago when the depth at the Pier 122 berth was 38 feet. Since the depth at the berth has been reduced to 30 feet due to shoaling, the firm no longer uses Pier 122 on a regular basis. However, the DRPA has recently provided funding for restoring depths at Pier 122 to 38 feet, which could result in resumed shipments through Pier 122 under without project conditions. If the Delaware River Channel were deepened to 45 feet, Panamax size vessels carrying up to 70,000 tons could call at Pier 122. Potential commodities include slag, clinker, or cement from Europe or Asia. The final destination for these goods would be the Lehigh Valley or other regional markets.

The Port of Wilmington, Delaware, would also like to take advantage of main channel deepening. If the main channel were deepened to 45 feet, the Port of Wilmington has indicated their intention to deepen their berths to 42 feet and/or expand their facilities to the Delaware River. Deepening the Delaware River to 45 feet and the Christina River to 42 feet would immediately result in benefits from reduced lightloading of existing vessels and from use of larger and potentially fewer vessels carrying existing commodity volumes. Realization of these benefits would require modification of a separate Federal channel, the Christina River. This action would be subject to a separate benefit cost analysis and approval process. There is also significant potential for these navigation improvements to attract to the Port of Wilmington: (1) a greater volume of existing commodities (particularly dry bulk commodities such as steel) and (2) new types of cargo, consistent with their handling and storage capacity.

It is not possible to project future trade volumes or vessel fleets for Gloucester Marine Terminals, Pier 122, or The Port of Wilmington, based on the information available at this time. If additional information becomes available in the future, it may be possible to calculate transportation cost savings for these facilities.

4. NATIONAL ECONOMIC DEVELOPMENT (NED) COSTS

Section 4 of the report presents the current estimate (May 2002 Price Levels) of NED costs for the Delaware River Main Channel Deepening Project.

4.1. Initial Construction Costs

This section presents the initial construction costs for the Federal project. Section 4.2 presents the associated costs that would have to be incurred by non-Federal interests in order to accrue benefits from the Federal deepening project (e.g., berth deepening, dock modifications).

4.1.1. Dredging and Disposal Costs

Dredging quantities and cost estimates were prepared for the initial dredging of the Federal portions of the project. The cost estimate was developed assuming that dredging of the Federal and non-Federal associated portions of the project will be done independently.

The estimate for the Federal portion of the project assumes using pipeline, clamshell and hopper dredges. Due to the long pumping distances, Reaches AA/A and Reach D will be done using large size hopper dredges. Dredged material will be pumped into confined upland disposal facilities. For Reaches B and C, hydraulic pipeline dredges will be used and the dredged material will be pumped into confined upland disposal facilities. Rock excavation in Reach B will be dredged using a clamshell dredge after drilling and blasting operations are completed. Excavated material will be placed into a confined upland disposal facility. For Reach E, large size hopper dredges will be used to pump the dredged material to wetland restoration/protection areas (Kelly Island and Egg Island Point) and to the beach nourishment site at Broadkill Beach. Cost estimates developed for Reach E take into account environmental windows that may be encountered during dredging or placement of dredged material.

Cost estimates were also prepared for disposal area preparation. The disposal area work consists of site clearing, raising dikes and constructing sluices. Construction schedules, disposal areas use schedule and all quantities for initial and maintenance dredging cost estimates, including disposal area development were developed in estimating the cost of the project. The dredged material disposal plan was established utilizing the most recent Delaware River hydrographic survey channel examinations. Detailed dredging cost estimates were prepared using the Corps of Engineers' Dredge Estimating Programs (CEDEP). Non-dredging costs were prepared using the Corps of Engineers' Micro Computer-Aided Cost Engineering System (MCACES). Summary level CEDEP and MCACES estimates are presented in Appendix A – Cost Estimate. Due to the voluminous nature of the cost estimate, the full CEDEP and MCACES estimates are not included in this document, but are available at the Philadelphia District.

Due to the amount of material to be dredged (26 million cubic yards), disposal area capacity considerations and locations, construction is scheduled to take five years.

4.1.2. Real Estate Costs

Costs were estimated to acquire land for three upland disposal areas and temporary easements for sand placement. Real estate costs are shown in detail in Appendix B – Real Estate Plan.

4.1.3. Navigation Aid Costs

Costs were estimated by the U.S. Coast Guard to relocate and install aids to navigation.

4.2. Associated Costs

Associated costs are defined in the Planning Guidance Notebook, ER 1105-2-100, Appendix D. Economic and Social Considerations, D-3. NED Cost Evaluation Procedures, subparagraph f. Evaluation Procedure: Associated Costs.

“Associated costs are the costs of measures needed over and above project measures to achieve the benefits claimed during the period of analysis Base associated costs on the current market prices of goods and services required for the installation of measures needed over and above project measures (2) It is preferred that associated costs be explicitly treated as NED project related costs, and appear as costs in benefit-cost ratios.”

Associated costs for the Delaware River project consist of: a) any required initial construction and dredging costs necessary to achieve benefits from a deepened Federal channel, and b) any increase in the annual operations and maintenance costs of benefiting entities, in excess of those needed to maintain their facilities for the existing 40 foot project. This section discusses any required initial construction and dredging costs necessary to achieve benefits from a deepened Federal channel. Associated costs for annual operations and maintenance are discussed in paragraph 4.4.2 below.

Interviews were conducted with potentially benefiting facilities (users of the Delaware River Main Channel) to determine what type of incremental modifications, if any, would be necessary for them to accrue benefits from a deepened 45-foot Delaware River Main Channel. Interview results were documented and sent to the interviewees to ensure that the information collected was accurately recorded. From data collected during the interviews, the latest hydrographic survey data and existing facility drawings, estimates were prepared for both dredging of berthing areas and any required dockside infrastructure improvements. Associated cost written reports were prepared documenting information gathered regarding vessel berthing areas that could be modified due to the 45-foot Delaware River Main Channel Deepening. These reports include facility site map/aerial photo, summary of findings, and estimated costs.

It was assumed that any non-Federal dredging of the berthing areas will be done by a local dredging contractor who would haul the dredged material to a private disposal site, consistent with the long-term history of such work and the facility’s current permit requirements.

Based on Maritime Exchange data on ship movements within the harbor complex, work conducted during development of the 1998 LRR, and discussions with the non-Federal sponsor, a group of facilities were identified as potential beneficiaries and were interviewed to determine associated costs. The results of the interviews, combined with a facility-by-facility analysis of transportation cost savings and associated costs were used to determine whether a particular facility would benefit (and therefore would have their benefits and associated costs included in the final analysis of project benefits and costs).

Associated costs were determined to be required for the benefiting facilities shown in Table 4-1 and are included in the NED project cost estimate, per Corps guidance: Detail on associated costs, by facility, is presented in Appendix A – Cost Estimate.

Table 4-1
Associated Facility Costs
(May 2002 Price Level)

Facility	Berth or Storage Modification	Initial Dredging to 45+1 feet	Total Facility Cost
Beckett Street	\$2,050,000	\$702,000	\$2,752,000
Packer Avenue	\$0	\$719,000	\$719,000
Valero	\$5,000,000	\$1,109,000	\$6,109,000
SUNOCO Marcus Hook	\$1,800,000	\$5,898,000	\$7,698,000
SUNOCO Fort Mifflin / Hog Island	\$0	\$468,000	\$468,000
Phillips 66 (Tosco)	\$3,600,000	\$853,000	\$4,453,000
Coastal Eagle Point Oil Co.	\$0	\$362,000	\$362,000
Motiva	\$0	\$0	\$0
Delaware Terminals	\$0	\$0	\$0
Total	\$12,450,000	\$10,111,000	\$22,561,000

4.3. Summary of Initial Costs

Table 4-2 below displays the initial project costs for all cost categories discussed above. All costs are presented in May 2002 Price Levels. Costs in Table 4-2 are shown both including and excluding sunk Preconstruction, Engineering and Design (PED) costs.

Table 4-2
Project First Costs
(May 2002 Price Level)

Account	Item	Cost (Including PED)	Cost (Excluding PED)
01	Lands, Easements-Rights of Way	\$10,703,000	\$10,703,000
02	Relocations	\$0	\$0
12	Navigation, Ports and Harbors	\$185,371,592	\$185,371,592
12a	Navigation Aids	\$322,000	\$322,000
18	Cultural Mitigation	\$0	\$0
30	Engineering and Design	\$11,629,800	\$11,629,800
	Preconstruction Engineering and Design (PED)	\$10,025,000	\$0
31	Construction Management	\$11,420,338	\$11,420,338
	Subtotal Project First Cost	\$229,471,730	\$219,446,730
	Associated First Cost	\$22,561,000	\$22,561,000
	Total Project First Cost	\$252,032,730	\$242,007,730

4.4. Operation and Maintenance Costs

4.4.1. Federal Project

Estimates were prepared for maintenance dredging of the Federal portions of the project. These costs were estimated at May 2002 price levels. Disposal area cost estimates were developed to account for the miscellaneous dike raising during the life of the project. Annual costs for maintenance of aids to navigation were estimated by the U.S. Coast Guard.

Costs were prepared for channel maintenance dredging, operation and maintenance of upland disposal areas including dike raisings, and operation and maintenance of wetland restoration beneficial use sites during the 50-year life of the 45-foot channel deepening project. The incremental maintenance costs for the 45-foot channel-deepening project (i.e., the difference between the maintenance costs of the proposed 45-foot and existing 40-foot project) is included in the estimate. These costs are discussed in greater detail in Appendix A – Cost Estimate.

4.4.2. Associated Costs

Associated costs for operations and maintenance include any increase in the annual operations and maintenance costs of benefiting entities, in excess of those needed to maintain their facilities for the existing 40 foot project. The incremental maintenance costs for maintaining the 45-foot depth at the berthing area (s) (i.e., the difference between the maintenance costs of the 45 and 40foot depths) is included in the estimate. Incremental maintenance dredging costs are presented in Table 4-3 below.

Table 4-3
Associated Maintenance Dredging Costs

Facility	Incremental Annual Maintenance Dredging Costs
Beckett Street	\$1,552
Packer Avenue	\$55,181
Valero	\$0
SUNOCO – Marcus Hook	\$59,062
SUNOCO – Fort Mifflin / Hog Island	\$0
Phillips 66 (Tosco)	\$21,699
Coastal Eagle Point Oil Co.	\$0
Delaware Terminals	\$0
Total	\$137,493

4.5. Interest During Construction

Interest During Construction (IDC) is an economic cost of the project and is therefore included in the NED cost estimate. ER 1105-2-100, paragraph 2-4.k.(3), defines Interest During Construction:

“Other direct costs are the costs of resources directly required for a project or a plan but for which no implementation outlays are made. Examples of these costs are interest during construction...”

The Planning Guidance Notebook, ER 1105-2-100, Appendix D. Economic and Social Considerations, D-3. NED Cost Evaluation Procedures, subparagraph D. (10) states:

“Interest During Construction. This represents the opportunity cost of capital incurred during the construction period. The cost of a project to be amortized is the investment incurred up to the beginning of the period of analysis. The investment cost at that time is the sum of construction and other initial cost plus interest during construction. Cost incurred during the construction period should be increased by adding compound interest at the applicable project discount rate from the date the expenditures are incurred to the beginning of the period of analysis. This is comparable to the treatment of benefits that accrue during the construction period (see paragraph D-4c) and is performed to insure costs and benefits are evaluated on a[n] equivalent time basis.”

Interest During Construction (IDC) has been calculated for the five-year construction period. Cost items included all of the cost items listed in Table 4-1 above. IDC is computed from the mid-point of the period, using the time weighted present worth (PW) factor that corresponds to the prevailing annual Federal discount rate of 5-7/8 percent. The schedule of project expenditures and interest during construction over the five-year construction period is shown in Table 4-4 below.

**Table 4-4
Annual First Cost Expenditures and Interest During Construction**

Construction Year	Description	Cost	PW Factor*	IDC Cost (Including PED)	IDC Cost (Excluding PED)
1	Contracts 1, 2 & 3 – Dredging / Disposal Development	\$57,321,761	0.292916	\$16,790,477	\$16,790,477
2	Contracts 4 & 5 - Dredging/Rock Blasting	\$42,423,277	0.221172	\$9,382,858	\$9,382,858
3	Contract 6 – Dredging	\$27,016,432	0.153410	\$4,144,580	\$4,144,580
4	Contract 7 & 8 – Dredging	\$51,347,253	0.089407	\$4,590,800	\$4,590,800
5	Contract 9 – Dredging	\$30,313,007	0.028956	\$877,737	\$877,737
1.5	Real Estate	\$10,703,000	0.256532	\$2,745,666	\$2,745,666
5	Navigation Aids	\$322,000	0.028956	\$9,324	\$9,324
0	PED Costs	\$10,025,000	0.330354	\$3,311,796	\$0
	Total	\$229,471,730		\$41,853,238	\$38,541,442

* Present Worth Factors have been truncated for presentation purposes.

Interest during construction was also calculated for associated costs. For facilities that would incur pre-base year benefits, IDC was calculated assuming the work would be completed 12 months prior to the base year. For all other facilities, it was assumed that associated cost work would be scheduled to coincide with the completion date of the deepening project.

4.6. Average Annual Costs

Average annual costs (AACs) have been calculated based on May 2002 Price Levels and the Federal Fiscal Year 2003 discount rate of 5-7/8 percent. The project base year is 2009. Average annual costs are presented in Table 4-5.

**Table 4-5
Average Annual Costs**

Cost Item	Cost (Including PED)	Cost (Excluding PED)
Financial First Costs	\$229,471,730	\$219,446,730
Interest During Construction (Financial First Costs)	\$41,853,238	\$38,541,442
Associated First Costs	\$22,561,000	\$22,561,000
Interest During Construction (Associated Cost)	\$1,530,101	\$1,530,101
Total Economic First Costs	\$295,416,069	\$282,079,273
Average Annual Economic First Costs	\$18,416,241	\$17,584,825
Annual Operations and Maintenance – Project	\$3,041,712	\$3,041,712
Annual Operations and Maintenance – Associated	\$137,493	\$137,493
Annual Operations and Maintenance – Navigation Aids	\$93,000	\$93,000
Total Average Annual Costs	\$21,688,446	\$20,857,030

5. BENEFIT COST RATIO

This section of the Comprehensive Reanalysis Report compares the National Economic Development (NED) benefits presented in Section 3 to the NED costs presented in Section 4 and computes the benefit-cost ratio for the Delaware River Main Channel Deepening Project.

All project costs and benefits are computed in May 2002 Price Levels and are discounted at the current prevailing Federal Fiscal Year 2003 discount rate of 5-7/8%. The project life is 50 years and the period of analysis is 2009 – 2058.

A detailed description of the benefit analysis assumptions, methodology and results is included in Appendix C – Benefit Analysis. Detail on project costs is provided in Appendix B – Costs. Table 5-1 below presents a summary of the costs, benefits, benefit-cost ratio (BCR), and net annual benefits for the project. In accordance with ER 1105-2-100, expended PED costs are considered sunk, therefore the final benefit-cost ratio is 1.18 with net benefits of \$3,802,000.

Table 5-1
Average Annual Costs, Benefits and BCR¹

Item	Amount (Including PED)	Amount (Excluding PED)
NED Costs		
Financial First Costs	\$229,472,000	\$219,447,000
Interest During Construction (Financial First Costs)	\$41,853,000	\$38,541,000
Associated First Costs	\$22,561,000	\$22,561,000
Interest During Construction (Associated Cost)	\$1,530,000	\$1,530,000
Total Economic First Costs	\$295,416,000	\$282,079,000
Average Annual Economic First Costs	\$18,416,000	\$17,585,000
Annual Operations and Maintenance – Project	\$3,042,000	\$3,042,000
Annual Operations and Maintenance – Associated	\$137,000	\$137,000
Annual Operations and Maintenance – Navigation Aids	\$93,000	\$93,000
Total Average Annual Costs	\$21,688,000	\$20,857,000
NED Benefits		
Average Annual Transportation Cost Savings	\$24,054,000	\$24,054,000
Average Annual Beneficial Reuse Cost Savings	\$605,000	\$605,000
Total Average Annual Benefits	\$24,659,000	\$24,659,000
Benefit-Cost Ratio	1.14	1.18
Average Annual Net Benefits	\$2,970,000	\$3,802,000

¹ Costs and benefits rounded to nearest \$1,000.

6. RISK AND UNCERTAINTY

This section of the report describes the risks and uncertainties inherent in estimating the benefits and costs of the deepening project, and how the sources of risk and uncertainty were addressed in the reanalysis effort. Several potential sources of uncertainty in estimating the cost and benefits of the deepening project have also been addressed through sensitivity analysis. Sensitivity analyses on project costs and benefits are contained in Appendix A – Cost Estimate and Appendix C – Benefit Analysis, respectively.

6.1. Guidance

The Economic and Environmental Principles for Water and Related Land Resources Implementation Studies, February 3, 1983 (P&G); and the Planning Guidance Notebook, ER 1105-2-100, 22 April 2000; discuss the role of risk and uncertainty analysis in Corps of Engineers civil works projects (P&G, Paragraph 10):

“Planners shall identify areas of risk and uncertainty in their analysis and describe them clearly, so that decisions can be made with knowledge of the degree of reliability of the estimated benefits and costs and of the effectiveness of alternative plans.”

Planning Guidance Notebook (ER 1105-2-100), 2-4. Principles of Analysis. g. Risk and Uncertainty:

“The P&G state that planners shall characterize, to the extent possible, the different degrees of risk and uncertainty inherent in water resources planning and to describe them clearly so decisions can be based on the best available information. Risk-based analysis is defined as an approach to evaluation and decision making that explicitly, and to the extent practical, analytically incorporates considerations of risk and uncertainty. Risk-based analysis shall be used to compare plans in terms of the likelihood and variability of their physical performance, economic success and residual risks. A risk-based approach to water resources planning captures and quantifies the extent of risk and uncertainty in the various planning and design components of an investment project. The total effect of risk and uncertainty on the project’s design and viability can be examined and conscious decisions made reflecting an explicit trade-off between risk and costs.”

6.2. Definitions

There is extensive public and academic literature devoted to the area of risk and uncertainty and yet there is still considerable confusion regarding what the terms mean. ‘Risk’ can generally be defined as the possibility that various outcomes, events or actions can occur, at least some of which could be undesirable. ‘Uncertainty’ describes a situation where a number of possibilities exist and which of them will occur is unknown. In navigation projects, risk most often refers to the potential for events with adverse physical consequences, for example, groundings, collisions, or environmental damage, such as oil spills. Uncertainty in the costs and benefits of navigation projects can result from many factors, including: fleet composition; commodity movements; transportation costs; dredge material composition, quantities, quality, and disposal locations; and many others.

This analysis is intended to deal with uncertainty in the estimation of the benefits and costs of the Delaware River Main Channel Deepening project. There are some issues of risk as well, as briefly described in Section 3.1.3, Improved Safety. However, inadequate information is available to quantitatively assess the impacts of the deepening project on risk issues in the port complex. Also, as a general rule, experts in Delaware River navigation issues (including pilots, terminal operators, and shipping lines) did not indicate that navigation safety was a significant problem at present, and was not a primary impetus for the deepening project. Safety issues related to the potential for environmental damage resulting from the deepening project were analyzed extensively and discussed in the Final Supplemental Environmental Impact Statement that was filed with U.S. Environmental Protection Agency in July 1997.

6.3. *Uncertainties in the Estimation of Costs and Benefits*

As stated previously, there are many sources of potential uncertainty in estimating the costs and benefits of navigation projects. The major sources of uncertainty relate to the characterization of existing conditions and projections of what will happen in the future, under both without-project conditions (continued operation of the 40-foot project) and with-project conditions (project deepening to 45 feet).

One of the primary goals in any navigation analysis is to first identify the major sources of uncertainty and then attempt to reduce them through collection and analysis of additional information. Attempts to reduce uncertainty during the reanalysis effort included extensive interviews and follow-ups with port representatives, shipping lines, terminal operators, refineries, pilots, and other knowledgeable individuals. Information provided by interviewees was also checked against shipping data for verification, and any discrepancies were noted. Sources of uncertainty that have been addressed during this reanalysis effort are described in detail in Appendix C – Benefit Analysis and are summarized below.

6.3.1. Uncertainty in Benefit Estimation

Several potential sources of remaining uncertainty in benefit estimation have been identified and were addressed through sensitivity analysis. These are listed below, with the affected benefit category shown in parentheses:

- Commodity growth rates (all benefiting commodities);
- Cost and price of lightering operations (crude oil benefits);
- Containership operating costs (container benefits)
- Dry bulk with project condition fleet shift (steel slab and furnace slag benefits)
- Timing of refinery responses to project deepening (crude oil benefits).

Sensitivity analyses were conducted to analyze the effects of uncertainty on project benefits. This information is provided so that an informed investment decision can be made, recognizing that inevitable uncertainties exist in estimating the future benefits of any deep draft navigation project. There are a nearly limitless number of sensitivity analyses that could be performed on the myriad of assumptions, data sources, methodologies, and analytical estimates that were used to calculate benefits for the deepening project. The final set of sensitivity analyses were selected based on several factors, including: analyst judgment regarding the degree of uncertainty in each of the key input parameters; the potential impact (i.e., significance) of changes in key variables

on final benefit results; and the inevitable uncertainty associated with benefits that rely to some extent on assumptions regarding the future behavior of others, and future economic conditions. Because of these uncertainties, the sensitivity analyses show the impact on project benefits of alternative scenarios, but cannot quantitatively estimate the probability of such scenarios.

Commodity Growth Rate Sensitivity Analyses

Sensitivity analyses were conducted for alternative growth rate scenarios for all benefiting commodity groups, including: crude oil, petroleum products, containerized goods, steel slabs, and blast furnace slag. Each of the alternative growth rates examined in the sensitivity analyses were applied to the most recent year's data for each commodity group (either 2000 or 2001, depending on the commodity), then projected to the base year (2009) and throughout the planning period (2009 to 2058). Four alternative growth rate scenarios were evaluated for each commodity, including: 1) negative of base case growth rate (e.g., the compound annual base case growth rate for crude oil was 0.2 percent, so in this case –0.2 percent was used); 2) zero growth from the most recent year of actual data (either 2000 or 2001, depending on the commodity); 3) zero growth beyond the base year (2009); and 4) a higher than base case growth rate, specifically selected for each commodity based on national or regional trends.

In all cases, the project benefit cost ratio remains above unity, regardless of the change in any individual commodity's growth rate. A further analysis was performed combining zero growth rates from 2000/2001, zero to the base year (2009) growth rates, and higher growth rates, for all commodities. The results of this sensitivity analysis indicated that the project benefit cost ratio would range from 0.95 (zero growth rate beyond 2000/2001) to 1.32 (higher growth rate). The BCRs for these two scenarios, excluding PED costs, are 0.99 and 1.37, respectively.

Cost of Lightering Operations: Vessel Fleet Operating Costs

Reductions in the costs of lightering operations are a significant percentage of crude oil benefits. Lightering costs are based in large part on the cost of owning and operating the lightering fleet. Vessel operating costs for the Maritrans fleet were estimated using data and information obtained from the Corps of Engineers Institute for Water Resources' ongoing vessel cost information programs, supplemented by maritime industry sources and Maritrans fleet information. Key areas of uncertainty in the lightering fleet vessel cost estimates include costs for crew, lubes, stores, maintenance and repairs. A lower cost scenario and higher cost scenario for crew, lubes, stores, maintenance and repairs were developed to compute project benefits. The benefit cost ratio for the deepening project remains above unity in both of these alternative cost of lightering operations scenarios (1.09 and 1.16, respectively; or 1.14 and 1.21 with no PED costs).

Sensitivity Analysis: Cost of Lightering Operations - Lightering Fleet Configuration

In the most likely base case scenario, it is assumed that the lightering company will respond to reduced lightering volumes (and revenues) under with project conditions in an economically rational manner, by reducing lightering resources and re-assigning one of their lightering vessels to other productive uses (i.e., non-anchorage area lightering operations). This assumed fleet shift reduces the overall cost of the lightering fleet by reducing the fleet size needed to service anchorage area lightering activities from three vessels to two vessels. A sensitivity analysis was

conducted to assess what effects alternative lightering fleet configurations would have on project benefits. These alternative scenarios would be less economically efficient than the most likely scenario, but are included here because they were identified by the lightering company as potential responses to channel deepening.

The first lightering fleet sensitivity analysis evaluated whether the choice of the vessel removed from service would impact project justification. The benefit cost ratio for the deepening project is marginally unjustified at 0.99, if the less costly of the two smaller lightering vessels with the same capacity is eliminated. Excluding PED costs, the BCR is marginally justified at 1.03.

A second alternative lightering fleet scenario assumed that the fleet size would not change and all three vessels (the without project fleet) would continue to be used under with project conditions to service the reduced lightering volumes (31 percent lower in base year). The benefit cost ratio for the deepening project falls to 0.79 in this scenario, or 0.82 with no PED costs. Both of these two scenarios are considered to be unlikely. In the first scenario, since the two smaller lightering vessels have the same capacity, but one costs more to own and operate, the lightering company would be choosing to remove a more efficient vessel in lieu of a less efficient one, increasing the average and marginal costs of their lightering operations.

The second scenario is considered to be even more unlikely. Lightering customers are charged on a per barrel basis. Therefore, the lightering company would need to raise the rates they charge for lightering services significantly to recover the costs of owning and operating their existing fleet across a significantly (31 percent) reduced lightering volume. It is unlikely that the lightering company has the pricing power necessary to impose a rate increase of this magnitude. Therefore, maintaining the existing lightering fleet in the face of declining revenues would result in a significance decrease in profits to the firm.

A third alternative fleet configuration consists of a three vessel with project fleet that replaces the relatively high cost third vessel with a smaller, lower cost vessel. In this case, benefits would fall between the base case estimate and the existing fleet scenario described above.

Sensitivity Analysis: Lightering Rate Change

Although benefits calculated throughout this analysis are based on the cost of lightering operations, a sensitivity analysis was conducted to assess the impact of a potential lightering rate increase under with project conditions. Two alternative scenarios were evaluated, one in which the representative lightering rate charged consumers stayed the same under with project conditions, and the second in which the lightering charge was increased by 15 percent under with project conditions (to partially offset the loss in revenues from reduced lightering volumes. The benefit cost ratio for the deepening project remains above unity in both of these alternative rate change scenarios at 1.22 and 1.11, respectively (1.27 and 1.15 with no PED costs).

Sensitivity Analysis: Containership Capital Costs

The containerships to be deployed on the benefiting liner service consist of 4100+ TEU containerships containing 1300 reefer slots. These are all new vessels constructed in 2001 and 2002. The standard IWR vessel operating costs category for these vessels (4,000 TEU foreign flag containerships) are based upon a methodology the uses a ten-year moving average of vessel construction costs. A ten-year moving average is used to balance the impact of short-term

fluctuations in the ship construction market, and minimize variations in vessel costs due to the year vessels were built, shipyard locations, and other factors.

Given the recent short-term trend towards lower containership construction costs, the ten-year moving average is higher than current containership construction costs. Since the fleet employed on the benefiting Australia/New Zealand to U.S. East Coast liner service is new, it can be expected to cost less than the 10-year moving average. Therefore, a sensitivity analysis was conducted using the estimated construction cost of the new vessel fleet in lieu of the capital costs included in the standard IWR vessel operating cost calculations. The benefit cost ratio for the deepening project remains above unity in this alternative containership capital cost scenario at 1.13 (1.17 with no PED costs).

Sensitivity Analysis: Alternative Bulker Fleet – Steel Slabs

Three alternative fleet configurations for steel slab imports under with project conditions were assessed in the sensitivity analysis. The alternative fleet configurations include: deployment of the without project fleet under with project conditions, deployment of larger vessels under with project conditions (design drafts two feet greater than base case fleet), and deployment of smaller vessels under the with project condition (design drafts two feet less than base case fleet). The benefit cost ratio for the deepening project is marginally unjustified at 0.99 if the steel slab fleet remains the same under with project conditions. With no PED costs, the BCR is marginally justified under this scenario at 1.03. The benefit cost ratio for the deepening project remains above unity in each of 2 foot above and 2 foot below design draft alternative steel slab bulker fleet scenarios (1.14 and 1.12, respectively; or 1.19 and 1.17 with no PED costs).

Sensitivity Analysis: Alternative Bulker Fleet – Blast Furnace Slag

Three alternative fleet configurations for blast furnace slag imports under with project conditions were assessed in the sensitivity analysis. The alternative fleet configurations include: no change in the existing fleet under with project conditions, deployment of larger vessels under with project conditions (design drafts two feet greater than base case fleet), and deployment of smaller vessels under the with project condition (design drafts two feet less than base case fleet). The benefit cost ratio for the deepening project remains above unity in each of these alternative furnace slag bulker fleet scenarios at 1.08 for existing fleet, 1.14 for two feet greater design drafts, and 1.10 for two feet less design drafts (or 1.13, 1.19, and 1.14 with no PED costs).

Sensitivity Analysis: Refinery Berth Improvements

Interviews with refinery personnel indicate that two of the refineries may choose to delay initiating construction of berth improvements until the main channel has been deepened. This “wait and see” approach could delay the realization of benefits related to these two facilities. A sensitivity analysis was conducted under the assumption that benefits at these two facilities would not commence until 2010 (the base case is 2008). The benefit cost ratio for the deepening project remains above unity in this scenario at 1.12 (or 1.17 with no PED costs).

6.3.2. Uncertainty in the Estimation of Project Costs

Two sensitivity analyses were conducted to analyze the effects of uncertainty on the project first costs (which include construction costs, engineering and design, and construction management).

The first sensitivity analysis considered potential impacts on the federal dredging cost estimate from differing assumptions concerning dredging efficiency, dredge selection, and material composition. The second sensitivity analysis addressed alternative levels of contingencies in the project cost estimate.

Dredging Efficiency, Dredge Selection, And Material Composition

The sensitivity analyses conducted for this analysis include the following:

Sensitivity Test #1 - an increase in the effective hopper capacity of hopper dredges for no overflow conditions from roughly 25% of hopper volume to 35% of hopper volume;

Sensitivity Test #2 - economic loading allowing for overflow;

Sensitivity Test #3 - excavation of potentially pre-blasted/fractured rock with a cutter suction pipeline dredge; and

Sensitivity Test #4 - a 25% increase in the volume of rock quantity.

The results of the sensitivity analyses are shown in Table 6-1 below and are described in greater detail in Appendix A – Cost Estimate.

Table 6-1
Sensitivity Analyses on Project First Costs
(\$ Millions)

Sensitivity Analyses	First Cost	Change from Base Estimate	Percent Change from Base Estimate
Base Estimate	\$208.4	\$0.0	0%
Test # 1	\$190.3	-\$18.1	-9%
Test # 2	\$180.0	-\$28.4	-14%
Test # 3	\$199.1	-\$9.3	-4%
Test # 4	\$211.6	\$3.2	2%

Tests #1, #2 and #3 act to reduce the cost compared to the base cost, Test #4 results in a cost increase. Test #1 is plausible inasmuch as existing field data support the increased hopper load for no overflow. Test #2 can only be achieved with hopper overflow, but there are good reasons to consider overflow as existing field data show that overflow in the Delaware would not adversely impact the physical environment. Test #3 considers the possibility that some previously blasted rock could be removed with another dredged type. Test #3 can be verified through further study. Test #4 is more hypothetical as the rock quantities are based on detailed geotechnical and survey information. The project benefit cost ratio remains above unity in each of these four test cases.

Contingency Estimates

In comments received during quality control and external independent technical reviews, it was suggested that a sensitivity analysis be conducted to support the contingency factors used in the project cost estimate.

In order to address this concern, simulation analyses have been performed for two representative dredging cases: the hydraulic pipeline dredge estimate for Reach C in Contract Number 1, and the hopper dredge estimate for Broadkill Beach in Contract Number 6. The rock dredging in Contract Number 5 already includes a high (20.3%) contingency factor, so further analysis of this contract estimate was unwarranted.

The pipeline dredge estimate was computed using a simulation analysis that included statistical distributions for dredge material factors for mud and silt as well as loose sand. The project cost estimate uses a factor of either 2.5 or 2.0 for mud and silt, a factor of 1.1 for loose sand. The risk analysis was prepared assuming a triangular distribution with minimum, most-likely and maximum factors of 2, 2.5 and 3.0 for mud and silt. Similarly, a triangular distribution (minimum = 1, most likely = 1.1 and maximum = 1.1) was used for loose sand.

Results of the risk analysis produced unit costs ranging from \$1.82 to \$2.55 as compared to the presently reported value of \$2.26. The contingency used for Contract 1 was 6.6%, which applied to the \$2.26 value, corresponds to a unit cost of \$2.41. The risk analysis indicates this contingency corresponds to a 92% confidence level that the estimated cost with contingency is not exceeded.

The hopper dredge estimate was also evaluated using a simulation analysis that included statistical distributions for: (1) effective hopper size, (2) hopper pump-out rate, and (3) turn time. The fixed value of 1,900 cubic yards (cy) for hopper size was replaced by a triangular distribution with minimum, most-likely and maximum values of 1,600 cubic yards, 1,900 cubic yards, and 2,800 cubic yards, respectively. These values are based on estimates for existing dredges rather than a generic average dredge. The 4,200-cy/hour hopper pump-out rate was replaced with a triangular distribution characterized by a minimum of 4,200 cy/hour, a likely value of 4,200 cy/hour and a maximum of 4,500 cy/hour. Again this distribution is based on the characteristics of actual dredges rather than the generic average. Finally, the estimated turn around time of 10 minutes was characterized by a triangular distribution of 5 minutes minimum, 10 minutes most likely, and 10 minutes maximum. These numbers are based on records for other hopper dredging projects that indicate the 10-minute turn is conservative.

Results of the risk analysis produce unit costs ranging from \$6.65 to \$9.04 per cy and can be compared to the current estimate of \$8.25. A contingency of 7.4% has been used in the current estimate and, applied to \$8.25, gives \$8.86. According to the risk analysis, there is a 96% level of confidence that the actual cost will be less than the fixed cost plus the contingency included in the project cost estimate.

These results indicate that the selected contingency levels are reasonable and indicative of the fact that contract bids received for past dredging operations in the Delaware River have been consistent with the contingency factors used in the project cost estimate. Furthermore, it should be noted that it is significant that the hopper dredge estimate is conservative inasmuch as the largest project costs are associated with hopper dredging.

7. COST SHARING

Public Law 99-662, the Water Resource Development Act of 1986, as amended by the Water Resources Development Act of 1996, has established the basis for Federal and non-Federal cost sharing and responsibilities in the construction, and operation and maintenance of Federal water resources projects. In addition, the sponsor could receive credits towards the non-Federal cost share as dictated by Section 308 of the Water Resources Development Act of 1999, Public Law 106-53; and Section 306 of the Water Resources Development Act of 2000, Public Law 106-541.

7.1. Non-Federal Cost Share

The non-Federal sponsor will pay at the outset of construction, 25 percent of the total costs of all General Navigation Features (GNF), which consist of the Federal navigation channel, the anchorage area, and construction of dredged material disposal areas. In addition, the non-Federal sponsor will provide all lands, easements, and rights-of-way, including lands for dredged material disposal facilities that are necessary for the construction, operation or maintenance of the GNF. Finally, the non-Federal sponsor will perform all relocations that are necessary for the construction, operation or maintenance of the GNF.

The sponsor is also responsible for an additional 10 percent of the cost of GNF, less the value of lands, easements, rights-of-way, relocations, and deep draft utility relocations, including those lands necessary for dredged or excavated material facilities. These costs may be repaid with interest over a period not to exceed 30 years.

Associated costs are described in Section 4 and are also a non-Federal responsibility. Associated costs are the costs that must be expended by local service facilities in order to benefit from the deepening project. These include costs to dredge berthing facilities and any structural modifications to dockside facilities.

7.2. Federal Cost Share

The Federal government is responsible for 75 percent of the cost of GNF as well as the cost of navigation aids. Operation and maintenance costs for the Federal navigation channel project, disposal areas and navigation aids are a Federal cost. Sunk PED costs of \$10,025,000 are included in the project cost sharing.

Cost sharing arrangements for the 45-foot project are displayed in Table 7-1. The Federal Government is responsible for 75% of the costs for GNF features. The sponsor is responsible for 25% of the costs for GNF and the full costs of lands, easements, rights-of-way and relocations. In addition the sponsor is also responsible for an additional 10% of the GNF less credit for lands, easements, rights-of-way and relocations. Since the 10 percent of the GNF exceeds the cost of lands, easements, rights-of-way and relocations by \$11,141,673, the sponsor must pay this difference following construction, or over a 30-year period at the Federal discount rate.

Table 7-1
Cost Sharing of Project Construction
(May 2002 Price Level)

Item	Cost
General Navigation Features (GNF)	\$218,446,730
Aids To Navigation	\$322,000
Lands, Easements, Rights-of-Way, Relocations	\$10,703,000
Total Project Cost	\$229,471,730

7.3. Cost Apportionment

Table 7-2 displays the apportionment of costs between Federal and Non-Federal interests.

Table 7-2
Cost Apportionment
(May 2002 Price Level)

	Federal	Non-Federal	Total
General Navigation Features (GNF)	(75% x A) \$163,835,048	(25% x A) \$54,611,682	\$218,446,730
Long term repayment	(-10% x A) -\$21,844,673	(+10% x A) +\$21,844,673	\$0
Aids To Navigation	\$322,000	N/A	\$322,000
Lands, Easements, Rights-of-Way, Relocations	N/A	\$10,703,000	\$10,703,000
Credit of Lands, Easements, Rights-of-Way, Relocations	\$10,703,000	-\$10,703,000	\$0
Total Project Cost	\$152,693,375	\$76,456,355	\$229,471,730

A = Total cost of General Navigation Features

8. RECOMMENDATION

As recommended by the U.S. General Accounting Office in its final June 2002 report on the Delaware River Main Channel Deepening Project, a comprehensive reanalysis was undertaken to address uncertainties about the project's economic analysis. The reanalysis presented in this report concludes that the project is economically justified.

It is recommended that work proceed on the project related to processing of the Project Cooperation Agreement, completion of plans and specifications, and advertising the project for construction.



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