US Army Corps
of Engineers
Philadelphia District

Delaware River Comprehensive Navigation Study Main Channel Deepening

FINAL

INTERIM FEASIBILITY REPORT

FEBRUARY 1992

DELAWARE RIVER
COMPREHENSIVE NAVIGATION STUDY

MAIN CHANNEL DEEPENING

FINAL INTERIM FEASIBILITY STUDY
AND ENVIRONMENTAL IMPACT STATEMENT

DEPARTMENT OF THE ARMY
PHILADELPHIA DISTRICT, CORPS OF ENGINEERS
FEBRUARY 1992

SYLLABUS

This report is an interim feasibility study and is a partial response to a resolution adopted by the House Committee on Public Works authorizing the Delaware River Comprehensive Navigation Study (2 December 1970) as well as the 1 March 1954 resolution by the Committee on Public Works of the United States Senate regarding channel dimensions of the Delaware River, Philadelphia to the Sea project. In addition, the study responds to September 20, 1974 resolution by the Senate Committee on Public Works to develop a regional dredging disposal plan for the tidal Delaware River and its tributaries. The existing Delaware River, Philadelphia to the Sea project was adopted in 1910 and modified in 1930, 1935, 1938, 1954, and 1958. The project extends from Allegheny Avenue in Philadelphia to deep water in Delaware Bay. The channel widths range from 400 feet in Philadelphia Harbor to 1,000 feet in the bay. Through Philadelphia Harbor the channel is 40 feet deep on the west side and 37 feet deep on the east side. The project also provides for widening at critical bends. There are nineteen anchorages on the Delaware River; six are authorized under the Philadelphia to the Sea project (Mantua Creek, Marcus Hook, Deepwater Point, Reedy Point, Gloucester and Port Richmond) and the remaining thirteen are natural deep-water anchorages. The disposal of dredged material is a Federal responsibility. The project includes twelve training dikes to reduce shoaling in the channel and anchorages or minimize dredging and disposal costs.

Channel depths ranging up to 50' and channel widths to accommodate one-way and two-way traffic are analyzed in this feasibility study. In addition it examines anchorages and needs certain of tributary projects. Based on the findings of this study, the recommended plan of improvement includes a two-way full width channel of variable width and a depth of 45 feet from deep water in Delaware Bay into Philadelphia Harbor, bend widening, partial deepening of the Marcus Hook Anchorage, disposal areas, and navigation aids.

The ultimate cost of the project is $278,293,000 of which $184,456,000 is Federal and $93,837,000 is non-Federal. These figures are based on 75% Federal and 25% non-Federal cost sharing for the general navigation features (channel and anchorage) and provision of lands, easements, rights-of-way, relocations, and dredged material disposal areas by the non-Federal sponsor. Navigation aid costs of $856,000 are a Federal responsibility. Associated costs of $23,205,000 for berth dredging and bulkhead modifications are a non-Federal responsibility. The non-Federal sponsor is also responsible for an additional 10% of the GNF ($24,480,000) less credit for LERRD, however since LERRD exceeds 10% of the GNF, there is no additional contribution required. Based on the average annual project investment costs of $32,113,000 and average annual benefits of $42,776,000 the benefit cost ratio is 1.33 to 1. All operation and maintenance costs, exclusive of berth area dredging would be borne by the Federal government.

The requirements of Section 404(r) of Public Law 92-500, as amended, have been met.

DELAWARE RIVER
COMPREHENSIVE NAVIGATION STUDY
MAIN CHANNEL DEEPENING
FEASIBILITY REPORT

TABLE OF CONTENTS

ITEM	PAGE
INTRODUCTION	1
STUDY AUTHORITY	1
STUDY AREA	3
STUDY OBJECTIVES	3
PRIOR REPORTS AND STUDIES	5
EXISTING PROJECTS	8
REPORT AND STUDY PROGRESS	11
EXISTING CONDITIONS	16
NATURAL RESOURCES	16
HUMAN RESOURCES	28
DEVELOPMENT AND ECONOMY	30
WATERWAYS AND DISPOSAL AREAS	30
HISTORIC WATERBORNE COMMERCE	36
WORLD SHIPPING/VESSEL USAGE	41
NAVIGATION PRACTICES	43
FACILITIES/CAPACITY ANALYSIS	45
TRADE ROUTES	54
LANDSIDE TRANSPORTATION SYSTEMS	55
EXISTING INSTITUTIONS	62
PROBLEM IDENTIFICATION	67
MEANS BY WHICH PROBLEMS WERE IDENTIFIED	67
CONDITION IF NO FEDERAL ACTION IS TAKEN (WITHOUT PROJECT PROFILE)	68
PROBLEMS, NEEDS, AND OPPORTUNITIES	92
PLAN FORMULATION	102
PLANNING OBJECTIVES	102
PLANNING CONSTRAINTS	102
ECONOMIC CONSTRAINTS	103
ENVIRONMENTAL CONSTRAINTS	103
PLAN FORMULATION RATIONALE	104
MANAGEMENT MEASURES	104
FORMULATION AND EVALUATION CRITERIA	105
PRELIMINARY SCREENING OF ALTERNATIVE MEASURES	108
CYCLE 1 - GENERAL SCREENING FOR DISPOSAL AREA POLYGONS	119
CYCLE 2 - MANUAL SCREENING OF POLYGONS FOR DISPOSAL AREAS	141
CYCLE 3 - INSTITUTIONAL/ENVIRONMENTAL SCREENING OF DISPOSAL AREAS	141
CYCLE 4 - INITIAL CHANNEL DEEPENING ANALYSIS	162
CYCLE 5 - NAVIGATION SYSTEM ANALYSIS	163

TABLE OF CONTENTS (CONT'D)

ITEM	PAGE
CYCLE 6 - DISPOSAL COST AND IMPACT ASSESSMENT	181
CYCLE 7 - DISPOSAL AREA SCHEME SELECTION	187
CYCLE 8 - ASSESSMENT AND EVALUATION OF DETAILED PLANS	207
TRADE OFF ANALYSIS	240
RATIONALE FOR SELECTED PLAN	240
RISK AND UNCERTAINTY ANALYSIS	240
COORDINATION	260
SELECTED PLAN	261
PROJECT DESCRIPTION	261
PROJECT COSTS	263
PROJECT OPERATION	273
PLAN ACCOMPLISHMENTS	274
PROJECT EFFECTS	275
RELATIONSHIP TO ENVIRONMENTAL STATUTES	281
ECONOMIC EVALUATION	283
COST APPORTIONMENT	284
LOCAL COOPERATION	287
PLAN IMPLEMENTATION	289
EIS	290
CONCLUSIONS	291
RECOMMENDATIONS	292

LIST OF TABLES

NO.	TITLE	PAGE
1	Population of Study Area by Counties	29
2	Employment and Income by County	31
3	Tonnage and Distribution of Waterborne Imports by Major Commodity on the Delaware River: Trenton, New Jersey to the Sea, 1973-1989	37
4	Tonnage and Distribution of Waterborne Exports by Major Commodity on the Delaware River: Trenton, New Jersey to the Sea, 1973-1989	38
5	Coastal Waterborne Commerce on the Delaware River: Tonnage and Distribution of Coastal Receipts and Shipments by Commodity Groups: Trenton, New Jersey to the Sea, 1973-1989	40
6	Tonnage and Distribution of Internal Waterborne Commerce on the Delaware River: Trenton, New Jersey to the Sea, 1973-1989	42
7	Inventory of Deep-Draft Facilities for Crude Oil/Petroleum Products/Petrochemicals and Chemicals	47
8	Disposal Area Maintenance Requirements for Full Width 40 Ft. Channel During the 50 Year Study Period	70
9	Comparison of Fleet Mix for 1983 and 1986	73
10	Projected Growth in Crude Oil Coming into the Port of Philadelphia	85
11	Projected Growth in Coal Leaving the Port of Phila. by Trade Routes	89
12	Projected Growth in Iron Ore Coming into Port of Philadelphia	90
13	Projected Container Cargo North Atlantic Ports	91
14	Major Oil Spills in the Delaware River, 1973-1989	100

TABLES (CONT'D)

NO.	TITLE	PAGE
15	Scale of Acceptability for Weighing Potential Disposal Sites	122
16	Disposal Site Selection Based on Varying Index Values	130
17	Disposal Polygon Output	132
18	Disposal Options for Delaware Bay	133
19	Institutional and Environmental Screening	143
20	Institutional and Environmental Screening for Delaware Bay	155
21	Cycle 4, Formulation, Main Channel Deepening, Delaware River, Philadelphia to the Sea	164
22	Minimum Vertical Clearances at Delaware River Bridge Crossings	166
23	Cycle 5, Analysis of Realignment of 40' Channel at Benjamin Franklin Bridge	170
24	Cycle 5, Analysis of Realignment of Delaware River Channel, Realignment of Marcus Hook	172
25	Economic Analysis of Marcus Hook Anchorage Improvements	176
26	Cycle 5, Channel Deepening Dredged Material Quantities (Total)	178
27	Cycle 6, Screening of Disposal Areas	189
28	Cycle 7 - Disposal Area Scheme Selection	200
29	Option 2 Summary of Avg. Ann. Benefits	220
30	Option 3 Summary of Avg. Ann. Benefits	223
31	Annualization Benefits for Option 1	228
32	Annualization of Costs and Economic Optimization	229
33	Incremental Optimization of Asymmetric Channels	232

TABLES (CONT'D)

ITEM	TITLE	PAGE
34	Optimization of Outbound Lane	233
35	Option 1 (Without Beckett Street) Annualization of Costs and Economic Optimization	234
36	Option 1 (With Beckett Street) Annualization of Costs and Economic Optimization	235
36A	Option 2 Annualization of Cost and Economic Optimization	236
37	Optimization of Beckett Reach	237
38	Length Optimization-Dredging only to Coastal Refinery	238
39	Length Optimization-Segment between Northern most Refinery & Walt Whitman Bridge	239
40	Full Width Channel Benefits Sensitivity to Discount Rates	241
41	Full Width Channel Optimization at 8 5/8% Discount Rate	242
42	Full Width Channel Optimization	243
43	Full Width Channel at 10% Discount Rate	244
44	Full Width Channel Optimistic Scenario Benefits	246
45	Full Width Channel Pessimistic Scenario Benefits	247
46	Full Width Channel Optimization for Optimistic Scenario Benefits	248
47	Full Width Channel Optimization for Pessimistic Scenario Benefits	249
48	Full Width Channel Base Year Tonnage Benefits	250
49	Full Width Channel Optimization with base year Tonnage Benefits	251
50	Full Width Channel Optimization with study year Tonnage Benefits	252

TABLES (CONT'D)

ITEM	TITLE	PAGE
51	Full Width Channel Optimization with Study year Tonnage Benefits	253
52	Full Width Channel Benefits with Average Size Refinery Closed	254
53	Full Width Channel Optimization with Average Sized Refinery Closed	255
54	Full Width Channel Benefits with Coal Moved to Baltimore	256
55	Full Width Channel Optimization with Coal	257
56	Optimization of Outbound Lane moved to Baltimore	258
57	Disposal Quantities	262
58	Initial Dredging	265
59	Initial Disposal Areas	266
60	Utility Relocations	267
61	Navigation Aids	268
62	Associated Costs	269
63	Maintenance 45' Full Width Channel	270
64	Maintenance Existing 40' Channel	271
65	Comparison of Benefits and Costs for Selected Plan	284
66	Cost Sharing for the NED Plan	286

LIST OF FIGURES

NO.	TITLE	PAGE
1	Comprehensive Navigation Study Area Map	4
2	Delaware River, Philadelphia to the Sea Penn., NJ & DEL. 40-foot Channel	9
3	Delaware River, Philadelphia to the Sea Penn., NJ & DEL. 40-foot Channel	10
4	Delaware River, Phila., PA to Trenton, NJ	12
5	Delaware River in the Vicinity of Camden, NJ	13
6	Schuylkill River, PA, Mouth to University Avenue	14
7	Wilmington Harbor, Christina River, DE	15
8	Delaware River Comprehensive Navigation Study Highway Network	56
9	Delaware River Comprehensive Navigation Study Rail Network	57
10	Delaware River Comprehensive Navigation Study Pipeline Network	59
11	Schematic of Attractiveness Modeling	121
12	Channel Realignment Under Ben Franklin Bridge	167
13	Marcus Hook Anchorage and Delaware River Channel Proposed Realignment	171
14	Marcus Hook Anchorage Deepening of Entire Anchorage	174
15	Marcus Hook Anchorage Deepening for Two Vessel Capacity	175

FIGURES (CONT'D)

TITLE

16	Del. R., Phila. to the Sea, Bend Widening 1 of 2	179
17	Del. R., Phila. to the Sea, Bend Widening 2 of 2	180
18	Disposal Analysis Reaches	184
19	Cycle 8 - Minimum Width Asymmetric Channel	211
20	Cycle 8 - More Efficient Asymmetric Channel	215
21	Cycle 8 - Full Width Channel	218

LIST OF PLATES

TITLE	NUMBER
Tentatively Selected Plan	1
Bend Widening Locations	2
Bend Widening Locations	3

LIST OF APPENDICES

A - Coordination

B - Comments and Responses to EIS Coordination

DELAWARE RIVER COMPREHENSIVE NAVIGATION STUDY
MAIN CHANNEL INTERIM

INTRODUCTION

1. The Delaware River navigation system serves the Middle Atlantic region by providing a series of navigation channels maintained by the U.S. Army Corps of Engineers. The Delaware River Comprehensive Navigation Study is analyzing the ability of the various channels to respond to the demands of present and prospective waterborne commerce. This Interim Feasibility Report has been prepared to document the economic, environmental, social, institutional, and engineering feasibility of improving the main Delaware River channel for commercial navigation and to consider improvement of tributary channel projects as a result of main channel deepening.

STUDY AUTHORITY

2. STUDY RESOLUTIONS. This study is being conducted in partial response to a resolution by the Committee on Public Works of the United States Senate, dated 1 March 1954. The resolution reads as follows:

> "Resolved by the Committee on Public Works of the United States Senate, That the Board of Engineers for Rivers and Harbors, created under Section 3 of the River and Harbor Act, approved June 13, 1902, be, and is hereby, requested to review the reports on the Delaware River between Philadelphia and the Sea, submitted in House Document Numbered 340, Seventy-seventh Congress, First Session, and previous reports, with a view to determining whether any modification in the existing channel dimensions and anchorage areas is advisable at this time."

3. In addition, the study is addressing in part a resolution passed by the House Committee on Public Works on December 2, 1970 which is much more comprehensive and reads as follows:

> "Resolved by the Committee on Public Works of the House of Representatives, United States, that the Board of Engineers for River Harbors is hereby requested to review the reports on the Delaware River from Trenton, New Jersey, to the sea, contained in House Document Number 358, 83rd Congress and other reports with a view to promoting and encouraging the efficient, economic and logical development of the Delaware River Ports. The scope of such review shall encompass investigation of current shipping problems, adequacy of facilities, delays in intermodal transfers, channel dimensions, storage locations and capacities, and other physical aspects of affecting waterborne commerce, including the conduct of such model studies as may be necessary to establish an efficient layout of the port complex and the

design of navigation facilities. Such investigation shall also include, but not be limited to, the impact of waterborne commerce in the Delaware River region on the local, national and international economies, and its relation thereto: research into current and future markets for the import and export commerce of the region; evaluation of regional integrated approaches toward the opportunities and problems engendered thereby; an inventory of regional shipping facilities, capacity, and operating entities and evaluation thereof: a study of industrial and trade trends owing to new and improved technological advances, methods, improved vessel design, cargo handling facilities, extension of automation, and other cargo, vessels, and operating concepts; relationship of waterborne shipping to other modes of transportation with particular reference to intermodal transfer and facilitation of through shipments; comparison of the status and future of Delaware River ports and terminals with other national and international harbor complexes; recommendations for types, sizes, and locations of future facilities, and improvements and expansions of existing facilities,including deep-draft navigation channels; recommendations for improvements in port and industrial operations and development through improved coordination and programming, and long-term planning; determination of the adequacy of the region's shipping capacity in terms of its role and function of the port complex in Delaware River Basin development; presentation of guidelines for regional development to the extent required by navigational uses and potentials; determination of bulk movement projections, including estimated raw material requirements of the regional and national economy possible of shipment through the Delaware river ports, with particular reference to economies afforded by use of supersized bulk transport vessels and tankers; effects on the regional and national economy of new and expanded heavy industry and ancillary industries dependent thereon as a result of improved navigation and more efficient port operations; and desirability and extent of Federal participation in securing adequate bases for expansions and improvement of shipping facilities and further integration of regional planning for waterborne commerce. In carrying out this study the Secretary of the Army and the Chief of Engineers shall cooperate with and coordinate their efforts with all affected Federal departments, agencies and instrumentalities and all other interested parties, public and private."

4. OTHER RESOLUTIONS. It was determined during the course of the reconnaissance study that one other outstanding resolution could be addressed while responding to the two primary study resolutions. This is the resolution regarding dredged material disposal adopted by the U.S. Senate Committee on Public Works which was adopted on September 20, 1974 and reads as follows:

"Resolved by the Committee on Public Works of the United States Senate, That the Board of Engineers for Rivers and Harbors, created under the provisions of Section 3 of the River and Harbor Act approved June 13, 1902, be, and is hereby requested to review the report of the Chief of Engineers on the Delaware River between Philadelphia, Pennsylvania and Trenton, New Jersey, and Philadelphia to the Sea, printed as House Document 358, 83rd Congress, 2nd Session, and other reports with a view to developing a regional dredging spoil disposal plan for the tidal Delaware River, its tidal tributaries, and Delaware Bay."

STUDY AREA

5. The Delaware River Comprehensive Navigation Study is addressing the navigation related problems of all waterways which support commercial activity along the Delaware River and tributaries from Trenton, New Jersey to the Sea. Figure 1 shows the limitations of commercial navigation channels tributary to the Delaware River. This Interim study concerns itself only with navigation along the Delaware River and certain tributary projects which may be constrained by the main channel depth.

STUDY OBJECTIVES

6. The purpose of the interim study is to address and evaluate current problems, such as adequacy of facilities, delays in intermodel transfers, channel dimensions, storage locations and capacities, and other physical factors affecting waterborne commerce on the Delaware River and its deep draft tributaries. The goal is to determine an appropriate plan for the efficient use and development of the Delaware River channel system.

7. The study made the maximum use of previously developed data to evaluate and recommend measures for which there is Federal interest and local support.

8. THE REPORT AND THE PLANNING PROCESS. This report is organized into a main report, an environmental impact statement, an amendment to the environmental impact statement, a Correspondence Appendix, and an appendix evaluating the effects of dredged or fill material according to Section 404(b)(1) of the Clean Water Act. The main report explains the study methodology, accomplishments, conclusions and recommendations.

9. The main report proceeds from a profile of the natural, human, and economic resources through a description of the problems and needs of the study area to a discussion of the plan formulation process. Details of the alternative plans are then highlighted in a separate section. The main report ends with rationale and description for the recommended plan, study conclusions, and recommendations. The environmental impact statement is a self

TRENTON
RM 134
Bordentown
Burlington
Norristown
PENNSYLVANIA
PHILADELPHIA
CAMDEN
Chester
WILMINGTON
Christiana
New Castle
Salem
RM 70
Delaware City
St. George
Chesapeake City
C&D Canal
CHESAPEAKE BAY
NEW JERSEY
ATLANTIC CITY
RM 40
MARYLAND
DELAWARE BAY
Cape May
ATLANTIC OCEAN
Harbor of Refuge
Cape Henlopen
RM 0
Lewes
Lewes Rehoboth Canal
DELAWARE
DELAWARE
MARYLAND
N
SCALE IN MILES
10 0 10
DELAWARE RIVER
COMPREHENSIVE NAVIGATION STUDY
MAIN CHANNEL DEEPENING
STUDY AREA
PHILADELPHIA DISTRICT, CORPS OF ENGINEERS

FIGURE 1

supporting document which informs decision-makers and the public of project alternatives and their environmental effects. It analyzes measures which would avoid or minimize adverse impacts or enhance the quality of the human environment.

10. The planning process used in completing this report is a systematic, multi-objective procedure for analyzing problems and opportunities and culminates in the selection of a recommended plan of action. The process provides decision-makers and the interested public with information on the basic assumptions employed, the data and information analyzed, the areas of risk and uncertainty, the reasons and rationale used, and the significant implications of each alternative plan.

PRIOR REPORTS AND STUDIES

11. FEDERAL STUDIES. The following studies and reports completed by the Corps are related to waterborne transportation on the Delaware River. They represent only the most pertinent reports.

12. Delaware River Channel Dimensions Study. This study, initiated by the Corps of Engineers in response to the 1954 Resolution, analyzed existing channel dimensions in the Delaware River to determine the advisability of modifying existing channel dimensions and providing additional and improved anchorage facilities.

13. In 1964, a draft report on the existing channel dimensions was completed, which analyzed the feasibility of deepening the existing channel from Philadelphia to the Sea to 50 feet and widening it to 2000 feet. The study indicated that these modifications were feasible and that further detailed studies were warranted, however, these studies were deferred pending resolution of issues related to potential development of deepwater port facilities.

14. Long Range Spoil Disposal Study. This study program was conducted in response to the realization of the diminishing availability of suitable riparian land for use as disposal sites for Delaware River navigation projects. The study was completed in 1969. The goal of the study was to locate and obtain disposal areas which were within efficient pumping distance of the shoal areas for the Philadelphia to the Sea project. Achievement of these study goals, however, was limited by various physical, environmental and institutional constraints on location of the sites.

15. As a result of the study potential sites were identified, each with its own constraint or limitation, for disposal of material. The study also concluded that maintenance of the Delaware River channel from Philadelphia to the Sea would be possible for at least twenty years with existing disposal areas. If new disposal sites were not developed, any new work would shorten the life span of

existing disposal sites. Subsequent to completion of the study, new policies, such as the National Environmental Policy Act were enacted which invalidated the rationale used for identification of new disposal sites. However, the study remains an excellent technical reference on many aspects of dredging and disposal operations.

16. Atlantic Coast Deepwater Port Facilities Study. Completed in June 1973, the purpose of the study was to determine the most economic, efficient and logical means for developing facilities for handling dry and liquid bulk carriers, and consider methods to govern, finance and maintain these facilities while protecting and/or enhancing environmental values of the affected areas. The study was conducted by the Philadelphia District in cooperation with the Baltimore, Norfolk and New York Districts and New England Division.

17. In response to the purposes outlined, the study evaluated numerous candidate sites along the Atlantic Coast as well as several types of deepwater port facilities. These included local and regional islands both with and without on site storage as well as various types of mooring systems. Facilities to handle crude oil as well as grain, coal and iron ore were considered. The preliminary studies found that several sites were economically feasible for handling both dry and liquid bulk commodities, however a multi-purpose deepwater port was less attractive for dry bulk movements than channel deepening. Detailed studies found that the most economic locations for crude oil facilities were in the Atlantic Ocean off of New Jersey and off of Big Stone Beach in Delaware Bay. Institutionally, however, there was no single site which was not strongly opposed at the time by local interests and government officials. Therefore no recommendations were made for further studies of a deepwater port facility. Several of the economic assumptions underlying the study findings are no longer valid.

18. Delaware Estuary Salinity Intrusion Study. The Philadelphia District completed this study with the Division Engineer's Notice issued in January 1983. The study determined the probability for advance or retreat of salinity in the Delaware Estuary and the quantity of fresh water inflow needed to protect the various water users along the estuary.

19. Delaware River Shallows Study. This study, completed in March of 1979, was concerned with evaluating the shallow water resources of the Upper Delaware Estuary, from Reedy Point, Delaware to Trenton, New Jersey. Shallow water areas are defined as those areas from the mean low water line to the -10 foot mean low water contour. The study defined these areas, and developed a system by which their ecological value to the estuary can be evaluated. Such evaluations have assisted personnel of the Philadelphia District in processing permit applications involving encroachments within the

study area and provide a good reference for consideration of aquatic disposal.

20. Environmental Impact Statements (EIS). An EIS for project maintenance of the Delaware River, Trenton to the Sea, (including the Delaware River, Philadelphia to Sea; Delaware River, Philadelphia to Trenton; and Delaware River at Camden Projects) was prepared by the District in 1975.

21. Delaware River Dredging Disposal Study. The study was initiated in February 1978. The purposes of the study were to develop a regional dredging plan for the Delaware River and its tributaries, Delaware Bay, and Indian River Inlet and Bay for both Federal and private sectors; and to identify specific short and long term disposal sites, which minimize degradation of the natural environment.

22. Prior to consolidation into the Delaware River Comprehensive Navigation study, it defined the current and future needs for existing projects and private dredging. For such projects no new authorizations appear to be needed and an information report was issued in June 1984. For the alternative plans under consideration in the Comprehensive Navigation Study, additional demand for sites to dispose dredged material will be generated. In these cases, the identification and formulation of potential disposal sites required the input of data specific to each proposed new project. Therefore, the balance of the study is being completed as part of the Delaware River Comprehensive Navigation Study.

23. Interim Feasibility Report, Delaware River from Philadelphia to Wilmington: Delaware River Comprehensive Navigation Study. This study was completed in December 1984 as an interim feasibility study to the Delaware River Comprehensive Navigation Study Authority. It addressed current and potential future navigation problems of Federal interest at waterways tributaries to and constrained by the 40 foot main channel of the Delaware River.

24. The interim project areas included the lower Schuylkill River; a proposed auto terminal at Hog Island and Tioga Marine Terminals in Philadelphia; the Broadway/Holt and Beckett Street Terminals in Camden; and Wilmington Harbor in Delaware. This study recommended improvements at the lower Schuylkill River, and Beckett Street Terminals that were environmentally acceptable and technically and economically feasible. Based on the costs related to the Wilmington Harbor project, that plan was pursued under the Continuing Authorities Program. The recommended plans of improvement included deepening the existing Federal projects, in the Lower Schuylkill River from 33 foot to 40 foot, and at the Delaware River in the Vicinity of Camden, NJ (Beckett Street Terminal) from the authorized 37 foot project to 40 foot. The Chief of Engineers Report, dated 15 June 1986, was forwarded by the Assistant Secretary of the Army on 28 August 1987 for inclusion in

the Administration's 1988 legislative proposal. The projects contained in this report were authorized by Section (3a) of the Water Resources Development Act of 1988.

EXISTING PROJECTS

25. The Delaware River system includes six deep draft projects and 16 shallow draft projects which are Federally maintained. The deep draft projects are Delaware River, Philadelphia to the Sea; Delaware River in the Vicinity of Camden (Beckett St. Terminal); Delaware River, Philadelphia to Trenton; Wilmington Harbor (Christina River), Inland Waterway - Delaware River to Chesapeake Bay (C&D Canal); and Schuylkill River. The main Delaware River channel (Phila to the Sea) and the deep draft tributary channels which are the subject of this specific study are described in the following paragraphs.

26. DELAWARE RIVER, PHILADELPHIA TO THE SEA. The Philadelphia to the Sea project (adopted in 1910 and modified in 1930, '35, '38, '45, '54 and '58) provides for a 40 foot deep channel from Allegheny Avenue in Philadelphia to deep water in Delaware Bay. The channel widths range from 400 feet in Philadelphia Harbor to 1,000 feet in the bay. Through Philadelphia Harbor the channel is 40 feet deep on the west side and 37 feet deep on the east side. The project also provides for widening at critical bends. There are nineteen anchorages on the Delaware River; six are authorized under the Philadelphia to the Sea project (Mantua Creek, Marcus Hook, Deepwater Point, Reedy Point, Gloucester and Port Richmond) and the remaining thirteen are natural deep-water anchorages. The disposal of dredged material is solely a Federal responsibility. A number of training dikes were also constructed to reduce shoaling in the channel or anchorages, or to shift the shoaling from areas where disposal is expensive to areas where disposal areas are more readily available. Refer to Figures 2 and 3 for details.

27. DELAWARE RIVER, PHILADELPHIA TO TRENTON. The Philadelphia to Trenton project (adopted in 1930 and modified in 1935, '37, '46, '54, and '76) provides for a 40 foot deep, 400 foot wide channel from Allegheny Avenue, Philadelphia, to the upstream end of Newbold Island (a distance of 23.5 miles), a 35 foot deep channel from the upstream end of Newbold Island to the (former) Trenton Marine Terminal and a 12-foot deep channel upstream to the Penn Central Railroad bridge in Trenton. The total project length is 30.5 miles.

28. The project which was authorized in 1954, was completed in 1964 except for a 5.5 mile long segment dredged only to 35 feet between Newbold Island and the former Trenton Marine Terminal, a 1.5 mile segment along Trenton dredged only to 12 feet, and widening the turning basin at the Trenton Marine terminal. A modification at Tioga Marine Terminal, authorized in 1976, provides for dredging a turning area to a depth of 36 feet adjacent to the

FIGURE 2

DELAWARE RIVER
COMPREHENSIVE NAVIGATION STUDY
MAIN CHANNEL DEEPENING

DELAWARE RIVER
PHILADELPHIA TO THE SEA

PHILADELPHIA DISTRICT, CORPS OF ENGINEERS

CORPS OF ENGINEERS

U.S. ARMY

AREA WHERE NEW WORK REMAINS TO BE DONE, SHOWN THUS: ////////////

THE CHANNEL FROM ALLEGHENY AVENUE TO THE PHILADELPHIA HARBOR BASIN, INCLUDING PORT RICHMOND ANCHORAGE HAS BEEN DREDGED TO A DEPTH OF 40 FEET.

CHANNEL DIMENSIONS		
LOCATION	DEPTH	WIDTH
A-B WEST BASIN	40 FT	400'-500'
A-B EAST BASIN	37 FT	500'-600'
B-C	40 FT	800'
C-D	40 FT	1000'

DELAWARE RIVER
COMPREHENSIVE NAVIGATION STUDY
MAIN CHANNEL DEEPENING

FIGURE 3

DELAWARE RIVER
PHILADELPHIA TO THE SEA
PENNA., N. J. & DEL.

40-FOOT CHANNEL
REVISED 30 SEPT 1984

SCALE OF MILES

U.S. ARMY ENGINEER DISTRICT, PHILA.

existing Delaware River channel and maintenance dredging of a non-Federally constructed maneuvering area and the turning basin. Recently completed Preconstruction Engineering and Design (PED) studies have found no navigation problems presently exist which would require construction of the 1976 modification.

29. DELAWARE RIVER IN THE VICINITY OF CAMDEN. The Delaware River in the Vicinity of Camden project (adopted in 1919 and modified in 1930 and 1945) provides for a 30-foot-deep channel from Newton Creek at the Broadway terminal to Beckett Street Terminal and an 18 foot deep channel extending from Beckett Street terminal to Cooper Point. Also, the project provides for a depth of 37 feet in front of the Beckett Street terminal which was constructed in 1988. The project length is about four miles. The Water Resources Development Act of 1988 authorized deepening the access to berths 3 and 4 of Beckett Street terminal to 40 foot. A General Design Memorandum for the 40 foot project was completed in January 1990. Construction funds were appropriated in Fiscal Year 1991. Construction of this project is pending execution of the Local Cooperation Agreement. See Figure 5.

30. SCHUYLKILL RIVER. The Schuylkill River project provides for a channel from its confluence with the Delaware River upstream to University Avenue. The project (adopted in 1917 and modified in 1930 and 1946) has depths ranging from 33 to 22 feet. The project length is six miles. Disposal for the existing project is a Federal responsibility. The Water Resources Development Act of 1988 authorized deepening the lower Schuylkill River from 33' to 40'. Refer to Figure 6.

31. WILMINGTON HARBOR, CHRISTINA RIVER, DELAWARE. The Wilmington Harbor project (adopted in 1896 and modified in 1899, 1922, '30, '35, '40, '60 and '87) provides for a channel in the Christina River with depths of 38, 21, 10, and 7 feet from the Delaware River to Newport, Delaware, as shown in Figure 7. The project also provides for a turning basin opposite the Wilmington Marine Terminal, along with jetties at the mouths of the Christina and Brandywine Rivers. The project length is about 10 miles from the Delaware channel upstream to Newport. Deepening the lower 4240' of channel and widening the turning basin to 38' was completed in 1988 under the Corps of Engineers Continuing Authorities (Section 107) Program.

REPORT AND STUDY PROGRESS

32. This final interim report presents the results of feasibility studies for deepening the main channel of the Delaware River from 40' to 45'. After review and approval by Corps of Engineers Higher Authority it will be sent to Congress. Prior to construction, Preconstruction Engineering and Design Studies which includes initial Plans and Specifications will be necessary.

CHANNEL DIMENSIONS		
LOCATION	DEPTH	WIDTH
A-B	40 FT	400 FT
B-C	35 FT	300 FT
C-D	12 FT	200 FT
E-F	20 FT	200 FT
G-H	8 FT	400 FT

FIGURE 4

DELAWARE RIVER
COMPREHENSIVE NAVIGATION STUDY
MAIN CHANNEL DEEPENING

DELAWARE RIVER
PHILADELPHIA, PA TO TRENTON, NJ

PHILADELPHIA DISTRICT, CORPS OF ENGINEERS

EXISTING PROJECT 37'
(CONSTRUCTION COMPLETED IN 1988)

FIGURE 5

DELAWARE RIVER
COMPREHENSIVE NAVIGATION STUDY
MAIN CHANNEL DEEPENING

DELAWARE RIVER IN THE VICINITY OF CAMDEN, NJ

PHILADELPHIA DISTRICT, CORPS OF ENGINEERS

CHANNEL DIMENSIONS		
LOCATION	DEPTH	WIDTH
A - B	33 FT.	400 FT.
B - C	33 FT.	300 FT.
C - D	26 FT.	200 FT.
D - E	22 FT.	200 FT.

FIGURE 6

DELAWARE RIVER
COMPREHENSIVE NAVIGATION STUDY
MAIN CHANNEL DEEPENING

SCHUYLKILL RIVER, PA.
MOUTH TO UNIVERSITY AVE.
REVISED 30 SEPTEMBER 1984

SCALE OF FEET
1000 0 1 2 3 4 5000

U.S. ARMY ENGINEER DISTRICT, PHILA.

N9

CHANNEL DIMENSIONS		
LOCATION	DEPTH	WIDTH
A - B	38 FT	340 FT
B - C	35 FT.	400 FT.
C - D	21 FT.	250 FT.
D - E	21 FT	200 FT.
E - F	10 FT	200 FT.
F - G	7 FT	100 FT

FIGURE 7

WILMINGTON HARBOR
CHRISTINA RIVER, DELAWARE

REVISED 30 SEPTEMBER 1968

SCALE OF FEET

U.S. ARMY ENGINEER DISTRICT, PHILA.

EXISTING CONDITIONS

33. In seeking a solution to navigation and related problems of the study area, it is first necessary to understand the existing conditions along the waterway and the surrounding land area. It is important to examine the socio-economic and environmental parameters, that might impact or be impacted by the study. By then projecting these existing conditions into the future it is possible to identify future problems, needs and opportunities and to formulate planning objectives and planning constraints.

34. The Delaware River Basin contains an area of 12,757 square miles. Fifty percent of the basin lies in Pennsylvania, twenty three percent in New Jersey, nineteen percent in New York, and eight percent in Delaware. The Delaware River begins as two streams, the East and West Branches, on the western slopes of the Catskill Mountains. These branches meet at Hancock, New York, then flow in a general southward direction for 326 miles to the sea. In this distance the river acts as a boundary, first dividing New York from Pennsylvania, and finally New Jersey from Delaware and Pennsylvania.

NATURAL RESOURCES

35. LAND USE. The study area includes every classifiable type of land use, ranging from the highly urbanized metropolitan areas to highly rural areas. Inbetween are large suburban areas and extensive farmlands. Urban land uses, including residential, commercial, and industrial uses, are concentrated in the major cities and their suburbs and along the major ground transportation routes. Urbanization is continuing within the fringes of the urban areas and along the transportation routes.

36. The Philadelphia, Wilmington, Trenton Consolidated Metropolitan Statistical Area occupies the lower Delaware River Basin. It had the fifth largest population in the United States. Even so only about a third of the landmass was developed in 1970. Between 1970 and 1980 another 3% was subject to suburban and exurban development, a trend continuing in the 1980's.

37. CLIMATE. 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. The yearly mean temperature is about 54 degrees F. Temperatures of 100 degrees or higher are comparatively rare. Readings 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. The normal annual precipitation is about 43 inches; rainfall is well distributed throughout the year with generally more than three inches per month. Temporary

droughts or periods of subnormal rainfall, however, are not uncommon for the area.

38. Light, southerly winds blowing up the Delaware Bay favor the formation of fog which occurs relatively frequently, especially from December to February when it often lasts two or three days. Such fog occurs about 50 days annually. Fog occurrence along the Delaware River itself happens less often. It averages roughly 30 times a year, though heavier fog occurs only about 7 days annually. Light north-northeasterly winds also bring in smoke from Philadelphia and the heavy industrial area located along the Delaware River north of Wilmington.

39. HYDROLOGY. The total drainage area tributary to the Delaware River estuary is 12,767 square miles, excluding 782 square miles of water surface in the estuary. The total average annual inflow of fresh water, head of tide to the mouth, is 20,000 cfs. Most of the fresh water inflow (88.9%) enters the estuary in its upper 70 miles. The discharge per square mile is greatest from that part of the watershed located above the head of tide at Trenton. There are substantial variations of the mean monthly discharges. The most discharge occurs in April, due to high precipitation and snow melt, and the least occurs in September, due to low precipitation and high evapotranspiration.

40. TIDAL HYDRAULICS. The tides of the Delaware Estuary are semidiurnal; there are two nearly equal high waters and two nearly equal low waters per lunar day. The mean range is about 4.2 feet at the mouth where the variation of elevation with time is approximately sinusoidal. As the tidal undulation propagates up the estuary, the tide range increases with the distance above the mouth, so that the mean range at the mouth of the Christina River is 5.6 feet, at the mouth of the Schuylkill River, 5.7 feet, and at the Benjamin Franklin Bridge in Philadelphia, 6.2 feet. Variations in water level are also highly dependent on wind speed and direction.

41. Based on tidal current charts compiled by the National Ocean Survey, maximum spring ebb and flood current velocities in the Delaware Bay range from 0.8 to 2.7 knots and from 0.9 to 2.4 knots, respectively depending on location. The Delaware River opposite Wilmington has peak tidal currents of 1.4 knots while 2.4 knots at Philadelphia opposite the Navy Yard is the highest predicted on the Delaware River below Trenton.

42. SALINITY. The salinity of the Delaware River is a function of freshwater outflow (from Delaware River headwaters, tributaries, runoff, and groundwater seepage) and saltwater inflow from the sea. Freshwater outflow varies with the seasons. Generally, it is greatest in March to April and least from June to October. The March to April discharge pushes saltwater seaward, and low flows from June to October allow saltwater to advance.

43. The Delaware River has an average freshwater discharge of about 12,000 cfs at Trenton, which increases to about 15,000 cfs at Artificial Island, New Jersey. Tidal flow, ranging from 448,000 to 472,000 cfs, at Artificial Island is far greater than freshwater discharge. During average weather and river flow conditions, tidal currents are the primary currents in the lower estuary and for the most part, determine normal estuarine circulation. Nontidal features such as freshwater runoff, weather and salinity gradients also effect currents.

44. Salinity in the Delaware estuary forms a gradient from less than 0.5 ppt in the tidal river to about 32 ppt at the mouth of the Delaware Bay. The estuary is generally polyhaline (18-30 ppt) from the mouth up to the vicinity of the Leipsic River, mesohaline (5-18 ppt) from the Leipsic River to around the Smyrna River, oligohaline (0.5-5 ppt) from the Smyrna River to around Marcus Hook, and fresh (0.0-0.5 ppt) from about Marcus Hook to Trenton. These zones are not static, but move in different directions depending upon freshwater outflow, tidal height and stage, weather conditions and morphologic alterations.

45. Delaware River salinity levels vary vertically as well as horizontally. For example, between Philadelphia and Reedy Point, Delaware, salinity is usually greater near the bottom than at the surface; however, the difference between surface and bottom is usually slight. Tide-induced mixing minimizes salinity stratification but generally, an essentially homogeneous vertical salinity profile is the case. Occasionally, gradients as high as 2 ppt per meter occur. The degree of stratification in the estuary is dependent on both location and tidal stage. The Delaware Bay is strongly stratified in winter and spring during high freshwater outflow, and well mixed in summer due to low outflow.

46. Saltwater inflow is associated with sea level (which rises with tidal stage), tidal elevation and seasons of the year. In a tidal cycle, salinity is at a maximum level near high slack water, and at a minimum level near low slack water. A small tidal range produces a small range in salinity and a large tidal range results in a greater range in salinity. Sea level is lower in December, January and February, and higher in August, September and October. Changing sea level favors upstream movement of saltwater most in summer and least in winter; the most favorable period for saltwater intrusion is from August to October when freshwater outflow is lowest and sea level is highest.

47. 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 are progressively deeper toward the Atlantic Ocean. Rock outcrops are located in the River Channel in the vicinity of Marcus Hook. The unconsolidated sediments consist of pervious and impervious layers which form a series of aquifers and aquicludes.

48. The primary aquifer units along the Delaware River are the Potomac-Raritan-Magothy formations and the Cape May and Columbia formations. The Potomac-Raritan-Magothy 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 municipal water wells in southern New Jersey generally withdrawal their water from the Potomac-Raritan-Magothy formation. It is considered the sole source aquifer for the region and will be evaluated as such in determining the effects of any plans under consideration.

49. The Potomac-Raritan-Magothy formation contains the most important and productive aquifers in southern New Jersey and is referred to as the region's sole source aquifer. The thickness of the combined formations is as much as 500 feet. Many industries and public water companies in the region obtain groundwater from this formation. There are four major aquifers within the formation.

50. Groundwater flow is generally toward the main river in a typical river basin. However, the groundwater regime in the project area, specifically the New Jersey side of the river, has been disturbed by urbanization. This information has been documented in numerous reports. The U.S.G.S. Atlas HA-697 dated 1986 estimates a leakage of 70 MGD from the Delaware River into the Potomac-Raritan-Magothy aquifer system in the project area. A reversal of the natural groundwater flow due to overpumping of the aquifer has occurred. Prior to municipal and industrial pumping, water flow in the aquifer was towards the river. Where large groundwater withdrawals have locally reversed the original aquifer flow patterns, aquifer recharge by river water results. 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. Although a large volume of river water is presently infiltrating the aquifer from the river, no contamination or salinity problems have been reported.

51. The groundwater regime in northern Delaware, as documented by the U.S. Geological Survey Water Resources Investigation Report 87-4185, is very similar to the situation in New Jersey. Brackish water is infiltrating the underlying Potomac Aquifers in the Cretaceous Potomac Formation in northern Delaware. The potential for infiltration of river water into the aquifers is suggested by

groundwater levels below sea level and removal by erosion of confining units overlying the aquifers near the river. Pumping from wells has lowered heads in the Potomac aquifers below sea level, which has created a hydraulic gradient from the Delaware River towards the underlying aquifers. There is a direct correlation between the rate of infiltration of river water and the total well-field pumpage. Evidence that infiltration is actually occurring in Delaware includes chloride concentrations in the aquifers that are above ambient levels and chemical characteristics of ground water and river water that are similar. The amount is controlled by the rate of pumping from municipal and private wells.

52. DELAWARE RIVER SUBSURFACE SEDIMENT CHARACTERISTICS. In order to better determine the type of material to be dredged from the channel and bends of the Delaware River, a series of 57 vibracore holes were recently taken throughout the project limits. Twenty foot of penetration was required at all locations, however the actual depth of penetration and amount of recovery varied. The 57 vibracore holes were spread throughout the project. Of the 29 holes taken in the channel, 16 were located in Reach E which is located in Delaware Bay. The remaining 28 holes were concentrated in the channel bends, where widening is planned.

53. Based on the findings of the vibracore explorations, bay sediments were divided into four subreaches. Reach E-1 and E-3 consist of fine-grained sediments; reaches E-2 and E-4 are predominantly coarse grained.

54. The gradation analysis of the channel bend sediments indicate predominantly fine grained characteristics. The materials consist of organic clays and silts with some fine sand layers. At bends H, PQ and S, (refer to Plate 2) the fine-grained sediments are underlain by coarser materials.

55. The channel vibracore samples contain varying amounts of sandy materials. The majority of reaches A and A-A (see Plate 1) contain sand and gravel with pockets of fine-grained materials. Rock was encountered in DRV 4, 5 and 7 at elevations -48.5, -50.6, -47.7 respectively (COE MLW datum), all below the maximum project depth. As previously mentioned, Reaches B, C, and D, predominantly consist of fine-grained silts and clays, with small pockets of sandy materials.

56. WATER AND SEDIMENT QUALITY. The water quality in the estuary is linked to the volume of flow. The Delaware is unable to assimilate as large a pollution load when flow is reduced as it can at normal volume. Even under normal flow conditions, water quality is degraded between Philadelphia and Wilmington. Dissolved oxygen and fecal coliform standards have been repeatedly violated, limiting use of the river for human contact and healthy aquatic communities.

57. Historically the Delaware Estuary has been one of the more polluted rivers in the world. Almost one hundred municipal and industrial discharges exist on or near the river. In addition, the river is subjected to pollution from tributaries, non-point sources, over 300 combined sewer overflows and other sources. Major water quality improvement has occurred as the result of a forty year cleanup program and the river currently has better water quality than any time in this century. In spite of this improvement, dissolved oxygen concentrations in the summer of 1987 were below 3 mg/1 in a portion of the estuary. Although dissolved oxygen and fecal coliform standards have been nearly attained as the result of federal, state and Delaware River Basin Commission abatement programs, the water quality reflected in these standards do not meet the fishable and swimmable goals of the Federal Clean Water Act.

58. A sediment testing program was conducted during the summer of 1991 to characterize the chemical quality of sediments in the existing, Philadelphia to the sea navigation channel. Chemical analyses were conducted on 18 sediment cores collected in the channel and 28 sediment cores collected in channel bend locations. Sediment samples were analyzed using both bulk and elutriate analysis procedures. Chemical parameters included metals, pesticides, polychlorinated biphenyls (PCB's) and polynuclear aromatic hydrocarbons (PAH's). Four sediment cores, collected in locations considered to have the greatest potential for contamination, were also tested for volatile organics, acid extractable organics and additional base neutral organics.

59. In order to evaluate the results of the chemical analyses, two sets of sediment criteria were considered. These criteria are currently used by the State of New Jersey, Department of Environmental Protection (NJDEP) to evaluate the potential hazard of soil contamination at project sites within New Jersey. It is recognized that these criteria have no regulatory authority behind them, and may not be used by other agencies for similar evaluations. The first set of criteria are Interim NJDEP Soil Action Levels. These criteria are not necessarily cleanup objectives, higher concentrations may be allowed at certain sites. The second set of criteria used by the NJDEP were initially developed to classify dredged sediments from the Great Lakes. The criteria provide non-polluted, moderately polluted and heavily polluted concentration ranges for various contaminants. The NJDEP uses these ranges to consider if special handling requirements are necessary for the disposal of sediments.

60. Two types of chemical quality concerns can be raised with respect to dredging and dredged material disposal operations. The first is potential water quality degradation arising from disturbance of bottom sediments, and ensuing impacts to aquatic biota. The second is long-term contamination problems associated with the dredged material disposal site. The sediment quality data

collected during the 1991 testing program do no indicate any significant problems relative to these concerns. Organic contaminants were found in few samples, at low concentrations. Bulk analyses of 46 sediment cores detected PCB's in one sample at a concentration of 1.72 parts per million (ppm), and pesticides in two samples at concentrations below 1 ppm. PCB's were not detected in any sediment elutriates, while pesticides were detected in only three elutriates at concentrations ranging between 0.0026 and 0.0063 ppm. All of these samples were collected in the river between Philadelphia, PA and Wilmington, DE. PAH's were detected in several channel bends throughout the project area. Concentrations were generally low, with only one reading above the Interim NJDEP Soil Action Level of 10 ppm. PAH's were detected at a concentration of 12.23 ppm at one sample located in the vicinity of Philadelphia, PA. This reading was from the upper 1.25 feet of the sediment core, with no PAH's detected below this strata. PAH's were only detected in one sediment elutriate at a concentration of 0.013 ppm. This sample was collected in Delaware Bay. Methylene chloride and phthalates were the only additional organic contaminants detected in cores analyzed for the full chemical parameter list. These contaminants were found in both bulk and elutriate samples at low concentrations. Based on these data it is concluded that organic contaminants would not degrade water quality during dredging operations, or cause long-term contamination problems at dredged material disposal sites.

61. Metals were found in channel sediments. While Interim NJDEP Soil Action Levels were exceeded for some metals, the overall metal content of channel sediments was within reasonable limits. The metal content of sediment elutriates was low throughout the project area. Concentrations of metals that were found were generally below 0.1 ppm. These observed concentrations suggest that the presence of metals in channel sediments would not significantly affect water quality during the dredging or disposal process. Total sediment concentrations of arsenic, cadmium, chromium and mercury each exceeded Soil Action Levels at one location throughout the project area. Zinc exceeded the Soil Action Level at two locations. All of these values, except arsenic, were found at the surface of sediment cores. Lower metal concentrations were found below the top strata. One channel bend sample had an arsenic concentration of 26.6 ppm, which was above the Soil Action Level of 20 ppm. There was no stratification in this sediment core, consequently no additional data is available. These few spot occurrences do not demonstrate contamination trends, and are not considered significant relative to the overall quality of channel sediments. Antimony, beryllium and thallium were not present in sediment elutriates. Beryllium was found in three elutriates at a concentration of 0.01 ppm in each. These metals would not cause water quality problems during the dredging process, or create hazardous conditions with disposal at confined, upland sites. Some sediment samples had metal concentrations within the moderately to heavily polluted range, relative to the sediment criteria utilized

by the NJDEP. As previously stated, the NJDEP use these classifications to determine disposal requirements. Disposal at confined, upland dredged material disposal sites, as is proposed for this project, is the preferred disposal alternative for this type of sediment. In the Delaware Bay, the sediments were found to be clean. There were no metals present above Soil Action Levels, or within the heavily polluted category. A more detailed discussion of the 1991 sediment testing program is provided in the Environmental Impact Statement.

62. FISH AND WILDLIFE RESOURCES. The ecological boundary of the study area consists of both banks of the Delaware River, its associated shallows and shoreline habitats, and the adjacent upland areas of potential dredged material disposal sites. The estuary is a dynamic mixing zone of fresh and salt water, the productivity of which is influenced by tidal action, water quality and temperature. Habitats are diverse and inter-dependent. Water depth is a major factor in productivity where the absence of sunlight and possibly oxygen is restrictive to abundant species populations.

63. The primary characteristics of the study area are its physical heterogeneity and its formerly degraded but greatly improved water quality. Variations exist in the quantity and types of wetlands associated with shallow water areas, the amounts of shoreline modification, the composition of the bottom sediments, and the sizes of the shallows. Each of the areas is, therefore, somewhat different from all others within the study area. Such differences are important because they affect the degree to which each area may be utilized by common basin species.

64. Since the physical characteristics vary throughout the study area, it follows that biological potentials also vary greatly. Any habitat, however, may support fewer organisms than its biological potential would indicate. This situation appears to occur frequently within the upper Delaware Estuary. While most sections of the study area are utilized by a variety of organisms, the data indicate that all sections could be utilized more intensely in the future with further improvements to water quality. This contention is based on the fact that suboptimal water quality exists within most of the study area. Much of the problem arises from the large amounts of organic material that are discharged into the estuary. This organic load results in the creation and maintenance of low dissolved oxygen levels in the upper portion of the study area.

65. Estuarine Habitats. Habitats in the study area are widely variable and diversified according to water depths, salinity, type of substrate and water quality fluctuations. Benthic diversity is greatest in Delaware Bay and diminishes upstream in the Delaware River. Most of the commercial fishery focuses on the bay where lobster, clams, crabs, weakfish, bluefish and menhaden populations are significant. The anadromous fishery, striped bass, shad and

shortnose sturgeon primarily, move to upstream fresh water areas to spawn.

66. Intertidal and Wetlands Habitats. Extensive wetland areas border Delaware Bay and, to a lesser and more intermittent extent, river edges from the bay to south of Philadelphia. The wetlands serve as valuable contributors to the food-web, as nurseries and spawning areas for the fisheries, and as a critical shallows/terrestrial interface for aquatic fowl and mammals. Intertidal habitats are abundant in both the bay and riverine environments. Aquatic vegetation is present on many bay and riverine shallows. Many saltwater, brackish water and fresh water plant species are represented and provide valuable fishery nursery and food-web sources. The bay and riverine system is utilized extensively for fish passage or habitat access. Anadromous species frequently use deep channels for access upstream or into major tributaries. Other species inhabit shallower waters and extensively use intertidal and wetland habitat areas.

67. Terrestrial Habitats. Upland vegetation ranges from extensively forested stands to grassy meadows and farm fields. This prolific and varied cover provides habitats supporting a great number of game and non-game species of mammals, waterfowl, terrestrial birds, rodents and insects. Even populated areas display a diversified number of smaller mammals and numerous birds. Downstream from Philadelphia to the bay mouth, both shorelines display extensive vegetation cover extending deep inland. Grassy fields, shrub-scrub, emerging forests and maturing forest habitats are represented.

68. Fisheries. An important aspect of the Delaware River estuary ecology is its capability to support a commercial and recreational fishery. The environment has been improved as a result of the implementation and enforcement of regulations by Federal and State agencies. The estuary fishery is slowly beginning to return to pre-industrialization levels. These efforts directly relate to primary jobs in fishing, processing and distribution, and secondary jobs in retail product sales, advertising, shipping and sales of complimentary items. The primary shellfish harvested are the oyster, hard clam and blue crab. The menhaden, weakfish, and blue fish are the predominant finfish caught in the bay. Over 250 species of finfish have been identified in the estuary including American shad, striped bass, bluefish, flounder, weakfish, sturgeon and menhaden.

69. The anadromous fishery is of particular importance as it reflects upon both fishing and dredging industries. The spring upriver shad spawning run is popular with recreational fishermen. These fish migrations are particularly sensitive to turbid water conditions during both spring and fall seasons of passage. This sensitivity is reflected in a bucket dredging and aquatic dredged material deposition moratorium during heavy fish migrations from

March through May and September through October. Overboard deposition is also environmentally unacceptable in the vicinity of turbidity-vulnerable oyster beds and in crab overwintering sites.

70. Recreational fishing in the bay and river is extremely popular, supporting numerous boats for hire and privately-owned craft. Associated services, usually dispensed from marina complexes, include provision of bait and tackle, food and beverage, petroleum products and ramp or other service fees. Clothing and boat sales, sightseeing and hotel rentals are also associated with these activities.

71. THREATENED AND ENDANGERED SPECIES. The Delaware estuary is within the range of 17 Federally designated threatened or endanged species. These include area transients such as sperm, fin, humpback, blue, sei and black right whales; and green loggerhead, Hawksbill, and Kemps Ridley leatherback turtles. Inhabitants under protection include the bald eagle, American peregrine falcon, Arctic peregrine falcon and the shortnose sturgeon. The American bald eagle has been successfully introduced to the New Jersey shore and is establishing itself in a preserve extending from Cape May along the New Jersey marshes westward.

72. CULTURAL RESOURCES. Much of the present topography of the Delaware Valley was formed during and after the last glacial advance. As the ice melted, large amounts of debris were washed downstream and out over the coastal plains of New Jersey and the Delmarva Peninsula. By 10,000 years ago, the estuary mouth was still some 10-40 miles offshore, and sea level was still rising at a rate of up to 6 feet every 100 years. It was sometime during this period that humans first entered the Delaware Valley. With the continued rise in sea level, the Delaware River and Bay eventually evolved into the present drowned estuary system.

73. The archaeological record of the prehistoric occupation of the Delaware Valley conforms to the generalized patterns of cultural development for the Middle Atlantic States. Three major periods are recognized: Paleoindian (15,000 years Before Present (B.P.) - 8,500 B.P.), Archaic (8,500 B.P. - 5,000 B.P.), and Woodland (5,000 B.P. - 400 B.P.). Few Paleoindian period sites have been found in the Delaware Valley, especially in the lower portion of the valley covered by the Philadelphia to the Sea project partly as a result of the low population density and nomadic lifestyle of the peoples from the period, and partly due to the inundation of sites by sea level rise, and the burial of sites under thick layers of alluvium and cultural deposits. Archaic period sites are known for the Upper Delaware but the lack of information from the lower estuary reflects site inundation and destruction due to flooding. Archaeological investigations have traditionally focused on Woodland period sites. Sites from the Woodland period are typically found in estuarine settings. By the 1600's, the Delaware Basin had been settled by the Lenape Indians.

Several National Register listed prehistoric sites have been found in the Delaware River and Bay area within one mile of shore.

74. European exploration of the Delaware Bay area began with Henry Hudson's voyage in 1609, for the Dutch East India Company. By the 1640s both the Dutch and the Swedes had established settlements as far upriver as Trenton, and battled each other for supremacy in the Delaware Valley. In 1654 the Dutch captured all Swedish posts, only to be conquered by an armed British fleet in 1664. By 1674, the British controlled all of the Dutch North American colonies, including Delaware Bay. In 1675, a settlement was established at Salem, New Jersey, which quickly became the center of government along the eastern banks of the Delaware. With the chartering of the Colony of Pennsylvania in the 1680's, and the establishment of Philadelphia as the colony's capital, development along the Delaware Estuary grew rapidly. Philadelphia soon became the principal port city on the Atlantic Coast, due in large measure to the region's rich grain harvest, ample water power for mills to convert the grain to flour, and quickly developing towns and roads to support the port city. The English maintained control of the region until the Revolutionary War. Several naval engagements between the British and the revolutionary forces took place along the Delaware River south of Philadelphia.

75. As the new country entered the nineteenth century, new commercial activities developed in the Delaware Valley. The thriving timber and tannery enterprises, and the mining and processing of rich mineral deposits in the region led to the creation of turnpikes, canals, and railroads throughout the area. In the lower estuary commercial fishing continued to thrive, as did agriculture. By the late nineteenth century, industrial development in the Delaware Valley was in full swing. Steel mills, locomotive works, canneries, chemical plants, and oil refineries dotted the shorelines. One Delaware Valley industry that deserves special mention is ship building. Shipbuilding has been one of the most important and most famous industries along the Delaware River for more than three centuries. During the Revolution, Philadelphia took the lead away from Boston as the shipbuilding capital of the colonies. Shipyards sprang up all along the Delaware River. John Fitch successfully operated the world's first steamboat along the Delaware River shoreline in the 1780's. In south Camden, the New York Shipbuilding Corporation's yard was the largest self-contained shipbuilding plant in the world in 1919, and the Philadelphia Navy Yard had become the largest navy yard with the largest drydock in the world. By World War I, Hog Island was the site of the largest shipbuilding plant in the world.

76. Ship building originally started along the Delaware River to enhance trade. Because the Delaware River/Bay is situated roughly halfway between New York Bay and the mouth of the Chesapeake Bay, and provides the only break in a dangerous 295 mile stretch of the Atlantic Coast, it was a natural site for port development. By the

colonial period, Delaware Valley port cities were engaged in trade with other colonies, Europe, and the Caribbean. Maritime commerce to and from the port cities along the Delaware River played a major role in the economic development of the entire Delaware Valley. The volume of shipping in this region, aggravated by the navigational hazards in the waterway, inevitably led to shipwrecks. Although the total number of wrecks will never be known, more than 145 documented shipwrecks have occurred in the Delaware River/Bay over the past three centuries. Most wrecks occurred in the first two centuries, before the development of regularly maintained channels, navigation aids, and harbor improvements.

77. Philadelphia District has undertaken several investigations of cultural resources within the project area. The Cultural Resources Overview and Sensitivity Analysis for the Delaware River and Shoreline (Gilbert/Commonwealth 1979) collected data for shoreline areas to assist in the development of suitable dredged material disposal areas. The study identified 162 historic sites and districts within one mile of the Delaware River and Bay area shoreline from Trenton, New Jersey to Lewes, Delaware. The Delaware River Comprehensive Navigation Study (Interim): Cultural Resources Sensitivity Reconnaissance (GAI 1983) assessed the potential for containing significant cultural resources of several proposed dredging and disposal sites between Wilmington and north of Philadelphia. This study added 30 new historic sites to the 1979 inventory. A Sensitivity Level Investigation of Cultural Resources in the Vicinity of the Main Navigational Channel, Delaware River, Wilmington to the Sea, and a Proposed Deepwater Port (Cox 1986) assigned cultural resource sensitivity designations of high, medium, or low to three segments of the waterway from Wilmington to the sea, to facilitate plans for deepening or widening the existing navigation channels and anchorages and creating a deepwater port. A "Preliminary Cultural Resource Reconnaissance Investigation of Thirteen Disposal Areas" (Heite and Heite 1986) assessed the potential for significant prehistoric or historic resources at thirteen proposed disposal areas along the Delaware River in New Jersey and Delaware. Finally, "Submerged Cultural Resources Investigations, Delaware River Main Navigational Channel, Philadelphia, PA to Artificial Island, NJ" (Cox 1988) presents the results of magnetometer and side scan sonar survey at fourteen locations, all found at the inside portion of the intersection of two ranges along the main channel, and each proposed for bend widening. This report documents sixty-six remotely sensed targets, six of which may represent potentially significant submerged cultural resources. The results of this report, and the others discussed above, are presented in greater detail, as appropriate, in the EIS.

HUMAN RESOURCES

78. There are 13 counties in the study area with a 1990 total population of 5,092,800. Information was extracted from Pennsylvania Facts and New Jersey Facts both from Clements Research Inc. plus Statistical Abstract of the U.S. Bureau of the Census. County totals range from the heavily urbanized 1,585,900 population in Philadelphia County to 65,300 in Salem County, New Jersey. Philadelphia, the major metropolitan center, is the most densely populated with 11,745 persons per square mile while Sussex County, Delaware has the least density with 121 persons per square mile (see Table 1).

79. The most heavily populated reach of the lower Delaware River Basin is the area bordering the estuary from Trenton, New Jersey, to Wilmington, Delaware. The principal municipalities are: Trenton, New Jersey; Camden, New Jersey; Philadelphia, Pennsylvania; Chester, Pennsylvania; and Wilmington, Delaware.

80. An extensive complex of industrial plants line both sides of the Delaware River. Industries produce goods such as chemicals and allied products, petroleum, primary metals, paper and allied products, processed foods, and electric power. The most heavily industrialized area is located in the Camden-Philadelphia-Chester reach of the river. In 1980 and beyond, the economic sector employing the most people in the area of consideration is the service industry followed by manufacturing. This is the reverse of the situation in 1970. Wholesale and retail trade remained a strong third throughout both 1970 and 1980.

81. The Ports of Philadelphia are a significant part of the regional economy. There are approximately 100,000 port related jobs in the Delaware Valley which generate one billion dollars of income annually. State and local taxes including income, profits and sale taxes, amounted to about 100 million dollars a year.

82. EMPLOYMENT. As shown in Table 2, the 1970 unemployment rates ranged from 2.1% in Chester County, Pennsylvania, to 6.5% in Cape May County, New Jersey. The 1980 figures show a dramatic increase throughout the study area ranging from 5.5% in Bucks County, Pennsylvania to 13.6% in Cape May County while 1990 figures are somewhat less. Per capita income approximately doubled in the 13 county study region from 1970-1980. The largest growth occurred in Kent County, Delaware and the smallest in Philadelphia County, Pennsylvania. Unemployment figures for 1991 range from 5.6% to 9.1%.

TABLE 1
POPULATION OF STUDY AREA BY COUNTIES
1970-1990 1/

COUNTY	1970	1980	1985	1990	1990 land area sq. mile	1990 density (per sq. mi.)
NEW JERSEY						
BURLINGTON	323,100	376,700	380,100	395,066	805	491
CAMDEN	456,400	483,200	488,100	502,824	222	2,265
CAPE MAY	59,600	85,900	90,600	95,089	255	373
CUMBERLAND	121,400	135,100	134,900	138,053	489	282
GLOUCESTER	172,700	201,300	207,100	230,082	325	708
MERCER	304,100	323,500	317,700	325,824	226	1,442
SALEM	60,300	62,900	65,200	65,294	338	193
PENNSYLVANIA						
BUCKS	416,700	453,000	512,700	541,174	608	890
DELAWARE	603,500	586,100	557,200	547,651	184	2,976
PHILA	1,950,000	1,876,500	1,637,400	1,585,877	135	11,745
DELAWARE						
KENT	81,900	98,700	101,200	110,993	591	188
NEW CASTLE	385,900	398,100	402,100	441,946	426	1,037
SUSSEX	80,400	93,900	103,800	113,229	938	121
STUDY AREA TOTAL	5,016,000	5,174,900	4,998,100	5,092,802	5542	1,747 (average)

1/ Bureau of Census

chemicals to other facilities in the region or domestic ports. Major dry and liquid bulk facilities are also found along the Delaware River at Wilmington, Delaware; Port Richmond in Northeast Philadelphia; Paulsboro, New Jersey; Greenwich Point in South Philadelphia; and along the Schuylkill River in Philadelphia. Development of an intermodal rail yard in south Philadelphia connected to the Packer Ave is underway. The numerous tributaries to the Delaware River support a variety of industries and the waterways are used primarily for delivery of fuel oils and raw materials or shipment of products.

WATERWAYS AND DISPOSAL AREAS

84. Six deep draft projects and 16 shallow draft projects serve commercial navigation in the Delaware River system. The following paragraphs discuss the existing conditions and disposal of dredged material for the five major deep draft, commercial channels which presently exist on the Delaware River or its tributaries and which could be impacted by the deepening of the Delaware River.

85. DELAWARE RIVER, PHILADELPHIA TO THE SEA. The 40 foot channel, Philadelphia Naval Base to the Sea and Philadelphia Naval Base to Allegheny Avenue, was completed in 1942 and 1962, respectively, and is maintained to authorized dimensions. 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 Philadelphia Naval Base, 40 feet deep and 800 feet wide, with 1,200-foot width at Bulkhead Bar and 1,000-foot width at other 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 width of 600 feet. All depths refer to mean low water. The project also provides for construction of dikes and training works for regulation and control of tidal flow to reduce dredging. The 40-foot channel from the Naval Base to the Sea was completed in 1942. The dredging of the channel from the Naval Base to Allegheny Avenue to a 40 foot depth was completed in 1962. The enlarging of the anchorage at Marcus Hook was completed in 1967. Authorized but unconstructed features include constructing the new anchorages at Reedy Point and Deepwater Point, enlarging the Mantua Creek Anchorage, and deepening the Port Richmond Anchorage to 37 feet (see Figures 2 and 3). The authorized anchorage dimensions are:

TABLE 2

Employment and Income by County

	Total Employed			Total Unemployed			%Unemployed			Per Capital Income	
	1970	1980	1991	1970	1980	1991	1970	1980	1991	1970	1980
DELAWARE											
Kent	27,233	38,744	47,828	1,200	3,356	4,123	4.2	8.0	7.9	2,582	6,126
New Castle	151,125	181,132	226,116	6,097	11,525	14,398	3.9	6.0	6.0	3,557	8,067
Sussex	32,569	41,933	62,404	931	2,747	3,724	2.8	6.1	5.6	2,649	6,262
PENNSYLVANIA											
Bucks	164,602	223,939	281,286	5,090	12,993	18,596	3.0	5.5	6.2	3,417	8,048
Delaware	238,264	247,016	274,427	6,813	15,602	15,256	2.8	5.9	5.3	3,735	8,044
Phila.	763,520	624,706	674,861	26,806	80,599	59,764	4.6	11.4	8.1	3,041	6,053
NEW JERSEY											
Burlington	106,838	153,295	180,799	4,342	11,413	10,025	3.9	6.9	5.3	3,298	7,671
Camden	175,971	197,470	225,724	7,318	17,369	15,563	4.0	8.1	6.4	3,347	7,278
Cape May	18,667	28,561	47,827	1,288	4,484	2,795	6.5	13.6	5.5	3,157	7,079
Cumberland	46,942	52,866	56,967	2,831	5,522	5,730	5.7	9.5	9.1	2,902	6,032
Gloucester	64,034	84,758	99,903	2,661	6,935	7,179	4.0	7.6	6.7	3,032	6,939
Mercer	127,472	142,808	47,499	4,635	8,803	2,091	3.5	5.8	4.2	3,631	8,095
Salem	23,203	25,315	29,904	901	2,515	1,793	3.7	9.0	5.7	3,102	6,714

Source: U.S. Dept. of Labor, Bureau of Labor Statistics, LABSTAT Series Report, Local Area Employment and Unemployment Statistics.

Project	Authorized Dimensions
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 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'

86. 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 (35' MLW).

87. There are wide variations in the amount of dredging required to maintain the Philadelphia to the Sea project, depending on the ranges discussed; some are nearly self maintaining and others experience rapid shoaling. The 40 foot channel section requires annual maintenance dredging in the amount of 5,400,000 cubic yards including advance maintenance of 2 to 4 feet in rapid shoaling areas. Of this amount, the majority is required in the Marcus Hook Range (34%), Deepwater Point Range (26%), and New Castle Range (23%). The remaining 17 percent of the dredging is spread through the other 37 ranges. The historic annual maintenance dredging rates for the Marcus Hook and Mantua Creek Anchorages are 487,000 and 157,000 cubic yards, respectively.

88. During the 1970's vessel traffic patterns in the Delaware River moved toward utilization by deeper draft vessels, in order to maximize the utilization of the 40' channel. Vessel operations allowed ships to navigate the channel with drafts approaching the authorized depth provided that utilization of tide stages was maximized. Commitantly, shoaling began to increase within certain ranges to the point that controlling depths began to decrease. Subsequently, draft limitations were imposed since depths near the authorized depth could not be adequately maintained. During the six week period around September 1979 a loss of approximately $830,000 (September 1979 P.L.) in lightering costs were reported for 69 oil tankers. This figure did not include costs attributable to lost ship time, or additional fuel, pilotage or tug costs necessitated by the draft reduction. Accordingly, authorization for advance maintenance dredging was granted in June 1981 which stated that: "authority is granted to perform up to 4 foot overdepth dredging in the Delaware River, Philadelphia to the Sea project in those reaches which demonstrate an economic advantage to do so, as well as sufficient user need to maintain the authorized depth at all times". The "4 foot overdepth dredging" refers to

advance maintenance dredging rather than routine allowable overdepth dredging which is used to maintain a certain tolerance.

89. The Federal government has the sole responsibility for providing the necessary disposal areas and embankments for material dredged from this project. The disposal areas are listed below along with the acreage and ownership. In addition, a disposal site exists at Penns Grove, New Jersey. However, since Congress limited this site to a height of 10 feet in the Water Resources Development Act of 1986, and required approvals have not been obtained from the New Jersey Department of Environmental Protection, this site has not been utilized for disposal.

Name	Banked Area (acres)	Ownership
Artificial Island	305	Federal
Killcohook	1,229	Federal
Penns Neck	325	Federal
Pedricktown	1,089	Federal
National Park	120	Federal
Oldmans	270	Leased
Buoy 10	(subaqueous)	

90. DELAWARE RIVER, PHILADELPHIA, PA. TO TRENTON, N.J.. The existing 40' channel was completed in 1964 for a length of 23.5 miles. Uncompleted work includes dredging the 35-foot deep channel from Newbold Island to the former Trenton Marine Terminal and widening the turning basin at the terminal.

91. The historical dredging requirements for the project are as follows:

Channel Section (cy/yr)	Ranges	Historical Rate (cy/yr)	Rate to Maintain Authorized Project
40' x 400'	Harbor to Newbold Is.	518,300	518,300
35' x 400'	Blake to Trenton South	31,000	518,000
12' x 200'	Trenton North to Bridge	-	-
	Total	549,300	1,036,300

The Federal government has required the states of New Jersey and Pennsylvania to provide the necessary disposal areas and embankments for the disposal of material dredged from the channel. Current areas include:

#2 (Camden Site), Camden County, NJ
#4 (Palmyra Site), Burlington County, NJ
#12A (Hawk Island Site), Burlington County, NJ
#14 (Beverly Site), Burlington County, NJ

#20 (Tenneco Site), Burlington County, NJ
#22 (Burlington Island Site), Burlington County, NJ
*#28A (Former U.S. Steel Site), Bucks County, PA
*#28 (Biles Island Site), Bucks County, PA
* (Money Island Site), Bucks County, PA

* The State of PA is currently negotiating with Waste Management of North America to lease these sites for future Corps maintenance dredging activities.

92. DELAWARE RIVER IN THE VICINITY OF CAMDEN, NEW JERSEY. The 18 foot channel from Cooper Point to Kaighn Point and the 30 foot channel from Kaighn Point to Newton Creek were completed in 1924. Under the 1930 modification, the 30 foot channel was extended from Kaighn Point to the Camden Marine Terminal at Berkley Street.

93. In 1945, Congress recommended modification of the existing navigation project at Camden by dredging the channel in the vicinity of the Camden Marine Terminal to a depth of 37 feet. This new construction project was dredged during 1987 and 1988, excavating approximately 500,000 cubic yards. In the Water Resources Development Act of 1988, Congress authorized deepening of portions of the project adjacent to Beckett Street Terminal to a depth of 40 feet. Generally, the project area requires relatively little maintenance dredging with the last maintenance occurring in 1962; the annual volume is about 10,000 c.y. Any future disposal requirements are to be handled at a nearby Federal disposal area which is part of the Philadelphia to the Sea project. Disposal area costs were a non-Federal responsibility for the 37' access to the Beckett Street Terminal and would also be a local responsibility for any deepening project.

94. SCHUYLKILL RIVER. This project was initially authorized in 1917 and modified in 1930, 1946, and 1988. It provides for a navigation channel 33 feet deep with a 400 foot width near the mouth to 29th Street (see Figure 6). At this point the project narrows to 300 feet in the second reach to Passyunk Ave. Bridge. In the third reach from Passyunk Ave. to Gibson Point (approximately one mile) the dimensions are decreased to 26 by 200 feet. The last portion, from Gibson Pt. to University Ave. Bridge, has authorized dimensions of 22 by 200 feet.

95. Along the lower portion of the Schuylkill River (Reaches 1,2,&3) from the mouth to the Passyunk Ave. Bridge, the existing channel is currently maintained at 33 feet MLW. The third reach of the river, from Passyunk Ave. to Gibson Point is currently maintained at 26 feet MLW. The 22 foot depth portion of the project, from Gibson Point to University Ave. is not maintained to authorized depth and has not been dredged since before 1960. This section is currently at about natural depth.

96. Maintenance dredging and provision of disposal areas is a Federal responsibility. Currently, the 33 and 26 foot depth portions of the project are maintained by hydraulic pipeline dredge, with material being disposed at Fort Mifflin. The Fort Mifflin disposal area located at the confluence of the Schuylkill with the Delaware River is a 298 acre, Federally-owned disposal area.

97. The 33' deep section is dredged generally every two years. The 26' deep section is dredged generally every three years. Removal rates are as follows:

Reach	Historical Average Annual Removal Rate (1960 - Present)*	Average Annual Removal Rate to Authorized Depth*
1. Mouth to 29th St.	85,500	85,500
2. 29th to Passyunk	133,600	133,600
3. Passyunk to Gibson Pt.	90,000	90,500
4. Gibson Pt. to Univ. Ave.	0	86,000
Total	309,100	395,600

* gross place yardage

98. The Delaware River, Philadelphia to Wilmington Interim Feasibility report recommended deepening the lower reach (Penrose Avenue to the Delaware River) from 33' to 40' which was subsequently authorized in the Water Resources Development Act of 1988.

99. WILMINGTON HARBOR CHRISTINA RIVER. The existing project provides for a channel with depths of 38, 35, 21, 10, and 7 feet from the Delaware River to Newport. A turning basin is located opposite Wilmington Marine Terminal and jetties are provided at the mouths of the Christina and Brandywide Rivers. Channel widths vary from 400 feet to 100 feet, and the project extends a length of about 9.9 miles.

100. Until 1982 the reach accessing the Port of Wilmington had historically been maintenance dredged annually. However, due to the rapid shoaling rate at Wilmington Harbor, this cycle was changed to twice annually. Annual dredged quantities are similar under current dredging practice to those historically removed, approximately 1,108,000 cubic yards annually. It is estimated that the dredging rate to maintain authorized dimensions above the Wilmington Terminal would be about 88,700 cubic yards annually,

however these project reaches have historically not been maintenance dredged.

101. Under the Corps Continuing Authorities Program, a portion of the channel with a depth of 35 foot was deepened to 38 foot and a wider turning basin has been constructed to service the bulk berths at the Wilmington Terminal. It required initial disposal of 795,000 cubic yards but no measurable additional maintenance.

102. The Edgemore disposal area is being turned over to Delaware Solid Waste Authority. It is no longer available for dredged material disposal. Two Corps maintained upland disposal areas in the vicinity are available; Wilmington Harbor and Wilmington Harbor South. Wilmington Harbor is an existing site and Wilmington Harbor South is a new site recently constructed to provide additional disposal capacity.

103. OTHER WATERWAYS AND DISPOSAL AREAS. In addition to these major deep-draft projects the Federal government operates the Chesapeake and Delaware Canal, a 35' deep and 450' wide waterway which connects the Delaware and Chesapeake Bays. This project provides a valuable link which shortens the trip and travel time for vessels transiting between the Ports of Philadelphia and Baltimore and other Chesapeake Bay ports via connecting channels in upper Chesapeake Bay. Upland disposal areas line much of the Canal's length in Delaware, and two of these areas, Reedy Point North and South, are located at the eastern end of the Canal as it enters the Delaware River. Two disposal areas, Pierce Creek and Courthouse Point, are located in Maryland in the Upper Chesapeake Bay.

104. In this general vicinity near Delaware City, Delaware the Texaco Oil Refinery (formerly Getty) maintains a private 35 foot deep access channel for access of oil tankers and vessels to its refinery piers and berths. Material from this channel is dredged and disposed into a private disposal area adjacent to the refinery.

105. Much of the remainder of the non-Federal dredging at facilities and piers is done by private contract, who places this material at its upland contained disposal area.

HISTORIC WATERBORNE COMMERCE

106. Historic Commodity Movements. Over the past decade, traffic on the Delaware River has been dominated by liquid bulk commodities. As can be seen in Tables 3 and 4, import levels have historically comprised over 90% of foreign trade in the basin. Crude oil imports have particularly shown an increase, in tonnage terms, in 1985-1989. This dominance has caused changes in total tonnage to almost totally reflect changes in the petroleum market, which has masked some trends in tonnage levels for other commodities.

TABLE 3

TONNAGE AND DISTRIBUTION OF WATERBORNE IMPORTS BY MAJOR COMMODITY ON THE DELAWARE RIVER: TRENTON, NEW JERSEY TO THE SEA, 1973-1989

(thousands of short tons)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Total	69,253 100.00%	69,340 100.00%	68,275 100.00%	67,969 100.00%	70,160 100.00%	67,122 100.00%	70,784 100.00%	56,039 100.00%	56,433 100.00%	49,546 100.00%	46,490 100.00%	52,458 100.00%	53,841 100.00%	59,989 100.00%	61,728 100.00%	64,046 100.00%	64,093 100.00%
Crude Oil	43,091 62.00%	41,068 59.00%	43,298 63.00%	49,865 73.00%	52,270 75.00%	51,060 76.00%	54,602 77.00%	42,859 76.00%	42,297 75.00%	40,187 81.00%	37,152 80.00%	41,334 79.00%	42,475 79.00%	48,143 80.00%	47,696 77.00%	47,476 74.00%	49,125 77.00%
Iron Ore	13,135 19.00%	14,617 21.00%	15,037 25.00%	10,789 16.00%	7,335 10.00%	6,833 10.00%	6,760 10.00%	6,715 12.00%	7,934 14.00%	3,833 8.00%	2,818 6.00%	3,646 7.00%	3,574 7.00%	3,574 6.00%	3,824 6.00%	5,116 7.80%	4,396 6.90%
Petroleum Products 1]	7,679 11.00%	6,889 10.00%	5,271 5.00%	2,917 4.00%	4,347 6.00%	5,071 8.00%	4,561 6.00%	2,766 5.00%	2,678 5.00%	2,799 6.00%	2,898 6.00%	2,471 5.00%	1,881 3.00%	3,138 5.00%	4,489 7.00%	5,358 8.40%	4,396 6.90%
(Residual Fuel Oil) 2]	(6,589) (10.00%)	(4,727) (7.00%)	(2,194) (3.00%)	(2,793) (4.00%)	(3,433) (5.00%)	(3,628) (6.00%)	(2,803) (4.00%)	(2,120) (4.00%)	(1,746) (3.00%)	(1,635) (3.00%)	(2,103) (5.00%)	(1,748) (3.00%)	(1,186) (2.00%)	(2,129) (4.00%)	(2,777) (4.00%)	(2,819) (4.40%)	(2,673) (4.20%)
Iron & Steel Products 3]	1,470 2.00%	2,672 4.00%	1,803 3.00%	1,229 2.00%	2,060 3.00%	1,507 2.00%	1,220 2.00%	714 1.00%	773 1.00%	642 1.00%	835 2.00%	1,307 2.00%	1,217 2.00%	1,092 2.00%	932 2.00%	1,139 1.80%	906 1.40%
Sugar	1,089 2.00%	952 1.00%	730 1.00%	654 1.00%	1,272 2.00%	472 1.00%	950 1.00%	697 1.00%	670 1.00%	122 0.00%	0 0.00%	9 0.00%	20 0.00%	8 0.00%	0 0.00%	0 0.00%	0 0.00%
Limestone & Non-Ferrous Minerals	638 1.00%	794 1.00%	650 1.00%	521 1.00%	719 1.00%	255 0.00%	563 1.00%	658 400.00%	498 1.00%	550 1.00%	703 2.00%	581 1.00%	568 1.00%	726 1.00%	1 0.00%	0 0.00%	0 0.00%
Other Commodities 4]	1,951 3.00%	2,128 3.00%	1,466 2.00%	1,794 3.00%	2,157 3.00%	1,924 3.00%	1,928 3.00%	1,630 3.00%	1,583 3.00%	1,415 3.00%	2,086 4.00%	3,110 6.00%	4,106 8.00%	3,300 6.00%	2,010 3.00%	4,957 7.70%	5,267 8.20%

TABLE 4

TONNAGE AND DISTRIBUTION OF WATERBORNE EXPORTS BY MAJOR COMMODITY ON THE DELAWARE RIVER: TRENTON, NEW JERSEY TO THE SEA, 1973-1989

(thousands of short tons)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Total	4,205	5,822	4,151	3,541	2,471	4,034	4,975	6,684	5,604	4,117	3,108	2,661	6,047	5,758	3,766	4,676	5,226
Coal	602	1,947	1,197	812	576	772	1,133	2,875	3,314	2,077	1,282	1,153	4,390	3,978	1,939	2,328	2,458
	14.00%	33.00%	30.00%	23.00%	23.00%	19.00%	23.00%	43.00%	59.00%	50.00%	41.00%	43.00%	73.00%	6.00%	51.00%	50.00%	47.00%
Iron Ore & Steel Scrap	494	278	404	377	249	384	550	573	301	349	413	538	265	734	836	85	469
	13.00%	5.00%	10.00%	11.00%	10.00%	10.00%	11.00%	9.00%	5.00%	8.00%	13.00%	20.00%	4.00%	13.00%	22.00%	0.00%	0.00%
Corn	1058	1147	625	559	268	775	1303	1274	585	567	260	5	1	2	0	284	31
	25.00%	20.00%	15.00%	16.00%	11.00%	19.00%	25.00%	19.00%	10.00%	14.00%	9.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Wheat	133	186	631	130	0	269	4	254	70	22	0	1	0	0	0	0	0
	3.00%	3.00%	9.00%	4.00%	0.00%	7.00%	3.00%	4.00%	1.00%	1.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Soybeans	165	279	112	112	113	422	219	125	229	29	0	1	8	45	0	0	0
	4.00%	5.00%	3.00%	3.00%	5.00%	10.00%	4.00%	2.00%	4.00%	1.00%	0.00%	0.00%	0.00%	1.00%	0.00%	0.00%	0.00%
Chemicals 1]	325	289	212	223	181	280	271	240	232	227	213	259	203	221	251	406	486
	8.00%	5.00%	5.00%	6.00%	7.00%	7.00%	5.00%	4.00%	4.00%	6.00%	7.00%	10.00%	3.00%	4.00%	7.00%	8.00%	9.00%
Motor Vehicles, Parts and Equipment	45	159	279	172	120	155	160	167	178	125	71	64	28	6	19	29	28
	1.00%	3.00%	7.00%	5.00%	5.00%	4.00%	3.00%	2.00%	3.00%	3.00%	2.00%	2.00%	1.00%	0.00%	0.00%	0.62%	0.54%
Coke, Petroleum Coke	0	0	0	0	0	276	423	455	35	27	81	26	239	190	149	235	165
	0.00%	0.00%	0.00%	0.00%	0.00%	7.00%	9.00%	7.00%	1.00%	1.00%	3.00%	1.00%	4.00%	3.00%	4.00%	5.00%	3.20%
Other Commodities 2]	1,383	1,537	961	1,156	964	701	768	721	560	694	779	614	913	582	582	1,677	2,087
	33.00%	26.00%	23.00%	33.00%	39.00%	17.00%	15.00%	11.00%	10.00%	17.00%	25.00%	23.00%	15.00%	10.00%	15.00%	35.00%	40.00%

1] Chemicals includes all listings 2800-2899, mainly benzene and sodium hydroxide

2] Other Commodities includes remaining commodities such as Foodstuffs, Ores, Petroleum Products, and General Manufactured Items.

107. For imports, tonnage levels of iron ore have fallen from the 1975 high of 15 million tons to a 1989 level of 4.4 million tons. Associated with this decline has been a sharp drop in iron and steel imports to less than one-half of 1973 levels. Both of these declines reflect the depressed state of the U.S. steel industry. For exports, coal and grain have historically dominated traffic. Coal exports exhibited a general upward trend until 1982 when they declined by almost 40%, a reflection of the depressed international economy. However, the 1973-1989 period contains two trends. During the early and mid-70's, exports were primarily metallurgical coal. Export levels, during this period, exhibited large fluctuations, probably as a result of changes in the world economy. In 1979, steam coal exports began to dominate coal exports resulting in an upward trend. The 1985-1986 increase was principally due to rising shipments from Pier 124, which had undertaken significant capital investment to increase capacity. A dropoff in tonnage occurred in 1987, but a partial recovery was seen in 1988-1989. Also, scrap exports and containers have shown promising growth in recent years.

108. Shipments of grain, the other major export commodity, varied considerably during the 1973-1989 period. There were a variety of market factors that contributed to this fluctuation, such as the grain embargo in the late 70's, and the variation in world supply from year to year affecting the magnitude of U.S. export movements. A review of U.S. grain export levels and discussion with knowledgeable sources indicated that this variability also reflected that the Delaware River grain facilities were basically operating as a marginal port versus more successful ports. Of major importance, the export of significant grain movements essentially ceased in the port with the closing of the Tidewater Grain facility on the Schuylkill River in early 1986. No change is expected for the foreseeable future.

109. For the remaining imports and exports, coastal traffic (Table 5) and internal traffic (Table 6), there has been a general downward trend over the 1973-1989 time period. For example, the depressed state of the U.S. steel industry has influenced not only iron and steel imports, but also coastal movements of iron ore, iron and steel products, and various metallic and non-metallic ores. In combination with the generally depressed state of the world economy in the early-80's, this may have distorted the longer term growth trends for many commodities.

TABLE 5

COASTAL RECEIPTS AND SHIPMENTS BY MAJOR COMMONDITY GROUPS: TRENTON, NEW JERSEY TO THE SEA, 1973-1969

(thousands of short tons)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Total, Coastal Receipts	17,491	16,883	12,713	11,923	10438	10,352	11,567	10,646	9,423	7,841	7,725	6,649	5,716	5,205	4,720	5,430	4,800
Crude Petroleum	6,395	5,808	3,161	2,064	2,171	3,206	3,793	2,469	1,857	2,233	3,597	2,325	2,541	1,874	994	1,470	1,051
	37.00%	34.00%	25.00%	17.00%	21.00%	31.00%	33.00%	23.00%	20.00%	29.00%	47.00%	35.00%	44.00%	36.00%	21.00%	27.00%	21.90%
Chemicals & Plastics 1]	1,069	1,075	916	1,152	934	764	614	670	737	573	494	510	550	494	509	565	372
	5.00%	5.00%	7.00%	10.00%	9.00%	7.00%	7.00%	6.00%	8.00%	7.00%	6.00%	8.00%	10.00%	9.00%	11.00%	10.40%	7.70%
Petroleum Products 2]	9,558	9,513	8,440	8,506	7,198	6,266	6,870	7,487	6,661	4,746	3,527	3,746	2,565	2,724	3,082	3,305	3,213
	55.00%	55.00%	66.00%	71.00%	69.00%	61.00%	59.00%	69.00%	71.00%	62.00%	46.00%	56.00%	45.00%	52.00%	65.00%	60.00%	66.00%
All Other Commodities 3]	469	1,387	196	199	135	114	90	242	146	69	107	68	62	113	135	91	164
	3.00%	8.00%	2.00%	2.00%	1.00%	1.00%	1.00%	2.00%	2.00%	1.00%	1.00%	1.00%	1.00%	2.00%	3.00%	1.60%	3.40%
Total, Coastal Shipments	8,405	6,939	6,830	10,297	9,726	9,509	10,718	9,095	6,734	6,621	7,723	7,545	6,209	6,454	6,820	8,055	7,593
Crude Petroleum	73	208	417	334	9	74	356	243	129	60	59	9	49	76	327	566	645
	1.00%	2.00%	5.00%	3.00%	0.09%	1.00%	3.00%	3.00%	1.00%	1.00%	1.00%	0.00%	1.00%	1.00%	5.00%	7.00%	8.50%
Chemicals & Plastics 1]	169	220	169	177	217	156	131	144	155	77	100	189	136	159	126	159	151
	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	1.00%	2.00%	2.00%	1.00%	1.00%	3.00%	2.00%	2.00%	2.00%	1.90%	2.00%
Petroleum Products 2]	7,926	6,261	6,113	9,657	9,471	9,197	10,201	8,641	6,434	6,377	7,141	6,422	5,126	5,579	5,917	6,958	6,229
	94.00%	92.00%	92.00%	94.00%	97.00%	97.00%	95.00%	95.00%	97.00%	97.00%	92.00%	85.00%	83.00%	86.00%	87.00%	86.00%	82.00%
All Other Commodities 3]	237	250	131	129	29	60	30	67	16	107	423	925	896	636	448	370	567
	3.00%	3.00%	2.00%	1.00%	1.00%	1.00%	0.00%	1.00%	1.00%	1.00%	5.00%	12.00%	14.00%	10.00%	7.00%	4.60%	7.40%
Total, Coastal Traffic	25,896	25,822	21,543	22,220	20,164	19,861	22,285	19,943	16,157	16,262	15,448	14,194	11,927	11,659	115,540	13,485	12,394
Receipts as a Percent of Total	58.00%	65.00%	59.00%	53.00%	52.00%	51.00%	52.00%	54.00%	52.00%	47.00%	50.00%	47.00%	48.00%	45.00%	41.00%	40.00%	39.00%
Shipments as a Percent of Total	32.00%	35.00%	41.00%	46.00%	48.00%	49.00%	48.00%	46.00%	48.00%	53.00%	50.00%	53.00%	52.00%	55.00%	59.00%	60.00%	61.00%

1] Chemicals & Plastics includes all listings 2600-2699, mainly benzene and sodium hydroxide.

2] Petroleum Products includes all listings 2900-2999, mainly residual fuel oil and gasoline.

3] All other commodities includes remaining commodities such as Cereals and Grains, Foodstuffs, Ores and General Manufactured Items.

WORLD SHIPPING TRENDS/VESSEL USAGE.

110. A breakdown of vessels of the world fleet by draft was obtained using MARDATA Ship Library for dry bulk carriers, freighters, tankers, combination (oil, bulk ore) vessels and container vessels. The percent of fleet capacity (in deadweight tons) associated with design drafts in excess of 40 feet, 50 feet and 70 feet is as follows:

Percent of Fleet Capacity

Vessel Type	Draft 40' or more	Draft 50'	Draft 70'	No. of Vessels
Bulk Carriers	42.9	14.8	0.0	4,535
Freighters	0.3	0.1	0.0	13,103
Tankers	75.4	60.6	18.3	5,007
Combination Vessels	97.7	68.2	2.2	461
Container Vessels	9.9	0.0	0.0	1,104

111. U.S. FLEET. According to the July 1, 1983, inventory of the U.S. flag merchant fleet compiled by the Maritime Administration, the U.S. flag fleet consisted of 571 privately owned vessels of 22.0 million deadweight tons and 255 government owned vessels of 2.7 million deadweight. A detailed breakdown of the U.S. flag fleet by draft and deadweight was also complied by the Maritime Administration.

112. Dry Bulk Carriers. U.S. merchant-type dry bulk carriers are all privately owned. They all fit in the 20,000 to 30,000 DWT category, with drafts ranging from 30 to 36 feet, except for 2 vessels in the 80,000 to 90,000 DWT category (46 foot draft), and 1 vessel in the 30,000 to 40,000 DWT category (35 foot draft). The average draft for the entire fleet is 35 feet.

113. Tankers. Over 90 percent of U.S. flag tankers are privately owned. Fifty percent of the vessels concentrate in the 20,000 to 40,000 DWT category, with drafts ranging from 30 to 40 feet. Nearly 80 percent of the vessels have a draft lower than 40 feet. All government tankers are in the "under 20,000 DWT" category, with drafts ranging from 19 to 32 feet.

114. Freighters. There are about as many U.S. government owned freighters as there are privately owned freighters. However, the distribution of those vessels by draft and deadweight is different. About 65 percent of all government owned vessels fit in the 11,000 to 13,000 DWT category and all have a draft of 29 feet. Nearly 50 percent of the private fleet is composed of vessels of DWT exceeding 15,000 tons. The deepest draft for all U.S. flag freighters is 39 feet.

TABLE 6

TONNAGE AND DISTRIBUTION OF INTERNAL WATERBORNE COMMERCE ON THE DELAWARE RIVER:
TRENTON, NEW JERSEY TO THE SEA, 1973-1987

(thousands of short tons)

Commodity	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Total, Freight	29,219	31,432	28,862	29,185	29,693	30,303	31,218	25,403	22,647	19,052	17,430	19,780	20,472	22,421	23,913
Coal	1,736	1,708	1,525	949	843	755	845	964	1,014	1,130	1,219	1,201	1,068	781	772
	6%	5%	5%	3%	3%	2%	3%	4%	4%	6%	7%	6%	5%	3%	3%
Crude Petroleum	6,796	9,069	9,993	9,847	11,045	11,822	12,318	8,053	4,542	6,115	4,809	6,552	8,932	9,695	10,876
	23%	29%	35%	34%	37%	39%	39%	32%	20%	32%	28%	33%	44%	43%	45%
Chemicals & Fertilizers1	1,258	1,089	744	981	858	866	967	938	933	479	550	642	952	1,091	1,084
	4%	3%	3%	3%	3%	3%	3%	4%	4%	3%	3%	3%	5%	5%	5%
Gasoline	2,977	3,030	2,329	2,376	1,946	1,804	2,192	1,749	1,411	1,287	991	1,026	1,694	1,847	1,802
	10%	10%	8%	8%	7%	6%	7%	7%	6%	7%	6%	5%	8%	8%	8%
Distillate Fuel Oil	3,873	4,815	4,121	3,342	3,445	3,621	3,611	3,971	3,726	2,692	2,337	2,517	1,928	1,975	2,008
	13%	15%	14%	11%	12%	12%	12%	16%	16%	14%	13%	13%	9%	9%	8%
Residual Fuel Oil	7,709	7,263	6,442	8,635	8,579	9,153	9,183	8,010	9,556	5,920	5,945	5,959	4,393	5,313	5,302
	26%	23%	22%	30%	29%	30%	29%	32%	42%	31%	34%	30%	21%	24%	22%
Other Petroleum Products2	1,149	1,845	1,265	1,211	1,457	1,473	1,502	1,281	1,058	963	1,093	1,442	1,344	1,197	1,658
	4%	6%	4%	4%	5%	5%	5%	5%	5%	5%	6%	7%	7%	5%	7%
Other Commodities3	3,727	2,613	2,443	1,844	1,520	809	600	437	407	466	485	441	161	522	2,211
	13%	8%	8%	6%	5%	3%	2%	2%	2%	2%	3%	2%	1%	2%	9%

1 Chemicals & Fertilizers includes all listings 2800-2899, mainly benzene and sodium hydroxide.
2 Other Petroleum Products includes all 2900's listings except 2911, 2914, and 2915, mainly liquified gases and kerosene.
3 Other commodities includes remaining commodities such as Cereals and Grains, Foodstuffs, and General Manufactured Items.

SOURCE: Waterborne Commerce of the United States, Volume I, U.S. Amry Corps of Engineers.

115. REGIONAL FLEET. The regional fleet is defined as that portion of the world fleet servicing a particular coastal region of the United States. The most detailed information which includes the Port of Philadelphia comes from information about the Atlantic Coast region. The latest available document concerning the fleet servicing the Atlantic Coast is a 1978 Maritime Administrative report entitled, "Merchant Fleet Forecast of Vessels in U.S.-Foreign Trade." Based on this report, it is possible to compare the world, regional and U.S. flag fleets broken down by deadweight for dry bulk vessels, tankers and freighters.

116. Dry Bulk Carriers. The distribution of the regional and the world fleets is nearly identical for vessels of up to 60,000 DWT, composing 70 percent of the capacity of both fleets. Above 60,000 DWT, the regional fleet is much smaller than the world fleet as evidenced by the following breakdown:

DWT Range	Typ. Draft (ft.)	Percent of Fleet Capacity	
		World	Region
0 - 60,000	-	65	67
60,000 - 80,000	42	11	25
80,000 - 125,000	46	16	6
125,000 - above	58	8	2

117. Tankers. Major differences are observed between the world fleet and the part of the world fleet serving the Atlantic Coast. The composition of the regional fleet is extremely biased toward the 20,000 to 125,000 DWT range where over 90 percent of the fleet capacity can be found, evenly distributed inside this interval. Conversely, over 50 percent of the world fleet capacity is found in vessels of DWT higher than 125,000 tons. The composition of the world fleet is evenly distributed between 1,000 and 300,000 DWT. Vessels of DWT exceeding 300,000 tons account for 12 percent of the remaining capacity of the world fleet.

118. Freighters. The distributions of the regional and world freighter fleets are fairly similar. The major variation is a higher concentration of vessels ranging between 10,000 and 15,000 DWT, in the regional fleet, as opposed to the world fleet (47 percent and 34 percent respectively).

NAVIGATION PRACTICES

119. The purpose of this section is to describe how the Delaware River waterway system functions and to provide an overview of traffic movements, vessel operations, and the interrelationship of the component waterways in the system.

120. 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 Pilot's Association for the Delaware River and Bay. They board incoming vessels in the pilot area at the bay entrance and at the Maryland/Delaware line in the C&D Canal.

121. 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 25 years by large tankers to lighter (primarily crude oil) onto barges. Maximum drafts for tankers entering the bay is 55 ft and lightering reduces the tankers operating drafts to those acceptable for the 40 ft channel. In 1983 this anchorage was reclassified by the U.S. Coast Guard as a general purpose anchorage, however lightering is still the dominant activity.

122. 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' 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 steel facility at Fairless, 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 C&D Canal. The canal is used by container liner services which call at Baltimore as well as by lesser draft domestic vessels, tug and barge traffic, and pleasure craft.

123. A series of six Federally authorized anchorages as well as thirteen 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 void 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.

124. The Pilot's Association and Mariner's 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.

125. Traffic monitoring on the Delaware River system is accomplished by the U.S. Coast Guard, Philadelphia Maritime Exchange, and Pilot's Association. 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 assure 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.

126. 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.

127. Typical vessel speeds in the Delaware River vary between 5 and 12 knots. Larger tankers (275,000 + DWT) operate with tug assistance during light traffic situations. Passing/meeting situations are limited at bends depending on vessel and traffic conditions. Traffic keep in touch with the Maritime Exchange.

128. Vessels with drafts of 37' or less can safely operate without use of the tides. Vessels with drafts in excess of 37' 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 outcroppings in the channel.

129. FACILITY/CAPACITY ANALYSIS. In this section, the capacity of potentially benefitting facilities in the Delaware River port system is estimated.

130. Liquid Bulk. The capacity of liquid bulk terminals is determined by the capacity of available storage tanks and pipelines from wharf to storage. The capacity from wharf to storage can

generally be expanded by increasing the number or diameter of pipelines, while the storage capacity is usually dependent upon the fixed plant/refinery consumption/production or transshipment rate.

131. Table 7 presents an inventory of deep-draft facilities for liquid bulk (crude oil, petroleum products, petrochemicals, and chemicals). In order to ensure no product contamination from intermixing, crude oil is handled by separate dedicated pipelines and tanks from those used for refined petroleum movements.

132. The total existing instantaneous storage capacity of liquid bulk terminals in the Delaware River is approximately 73 million barrels, or about 11 million tons.

133. The pump capacity of liquid bulk tankers is generally designed to unload vessels in 16 hours. However, a certain amount of time at berth is lost connecting pipes, adjusting valves, and other inefficiencies, so that 24 hours at berth would be a more reasonable estimate.

134. The annual capacity of a typical crude oil berth is very large, corresponding to the unloading of approximately 125 vessels per year. The U.S. Maritime Administration publication, Port Handbook for Estimating Marine Terminal Cargo Handling Capability, estimates typical annual throughput of a crude oil berth to be 6,000,000 short tons. For the six benefitting refineries, 16 total berths are utilized, equating to total berth capacity of 96 million short tons per year. Total current estimated annual throughput capacity for Delaware River facilities is approximately 60 million tons. The refineries anticipate expanding capacity as required, by technology changes and upgrading facilities, to meet the relatively low average annual growth of only 0.8% per year for crude oil imports projected from the study year to the final year of the project life, 2055. It is important to note that the refined product pipelines from the refineries in the Gulf Coast which extend to the Northeastern U.S. refined product market are not as cost-efficient as having crude oil refined at the Delaware River refineries and then transported to the Northeastern U.S. market.

Table 7

INVENTORY OF DEEP-DRAFT FACILITIES FOR CRUDE OIL/PETROLEUM PRODUCTS/PETROCHEMICALS AND CHEMICALS

COE Reference No.	Owner	Name	Commodities	Storage Capacity (000's)	Berth Length (ft)	Alongside Depth (ft)	Pipelines from Wharf to Storage Tanks (# and diameter, inches) 36	30	24	20	18	16	14	12	10	8	6	4
				bbls														
					DELAWARE													
Philadelphia to the Sea - Christina River to Delaware Bay																		
5	Texaco Refining & Marketing Co. (R)	Pier No. 1	Crude Oil	4,975	1,100	38			1							1		
6	"	Pier No. 2	Petroleum Products	incl. above	1,000	34			1		3	1		4				
7	"	Pier No. 3	Petrol Prod/ Chemicals	incl. above	750	35					3		1	4	1			
Christina River - Port of Wilmington																		
10	Delaware Terminal Co. (S)	Tanker Berth	Petrol Prod/ Chemicals	1,200	1,000	35		1						2	1			
					PENNSYLVANIA													
Philadelphia to the Sea - Marcus Hook to Schuylkill River																		
23	Allied Chemical Co. (S)	Upper Pier	Chemicals	28	1,496	18-30									1		3	
24	Sun Refining & Marketing Co. (R)	Wharf 3C	Crude/Petrol. Prod./ Petrochem	16,240	1,000	38			1	2		1				1		
25	"	Wharf 3A	Crude/Petrol. Prod./ Petrochem	incl. above	1,500	12-32	1		1	1				1	3	6	4	2
26	"	Wharf No. 2	Crude/Petrol. Prod./ Petrochem	incl. above	650	32			1	1			1	3	5	6	5	4
27	"	Wharf No. 1	Petrol Prod.	incl. above	610	26				1				1	4	6	3	4
30	B.P. Oil Inc. (R)	Docks 1&2	Crude Oil	1,800	1,145	40			1		1			1		5	1	1
31	"	Barge Wharf	Petrol Prod.	920	1,210	20-34					1	2		2	1		2	3

Table 7 (Cont'd.)

INVENTORY OF DEEP-DRAFT FACILITIES FOR CRUDE OIL/PETROLEUM PRODUCTS/PETROCHEMICALS AND CHEMICALS

COE Reference No.	Owner	Name	Commodities	Storage Capacity (000's)	Berth Length (ft)	Alongside Depth (ft)	Pipelines from Wharf to Storage Tanks (# and diameter, inches) 36	30	24	20	18	16	14	12	10	8	6	4
32	Philadelphia Elec. Co. (S)	Chester Sta. Wharf	Fuel Oil[1]	bbls 67	407	25										1	1	
46	"	Bidystone Sta. Lower Wharf	Fuel Oil[1]	381	200	29										1		
47	"	Bidystone Sta. Upper Wharf	Fuel Oil[1]	incl. above	200	29										1		
49	Chevron Oil Corp. (R)	Hog Island Wharf	Crude Oil/ Naphtha	4,368	2,754	38			2	1								
51	Atlantic Pipeline Co. (S)	Port Mifflin Berth A	Crude Oil	570	956	42		1				3			1			
52	"	Port Mifflin Berth B	Crude Oil/ Petrol Prod.	incl. above	889	42		1			1							
Schuylkill River - Girard Point to Passyunk Ave.																		
58	Exxon Co. (S)	Barge Dock	Petrol. Prod.	908	180	33								3		5	9	
60	Swann Oil Inc. of Philadelphia (S)	Swann Oil Wharf	Petrol. Prod.	947	750	35									2		1	
61	Pioneer Oil Co. (S)	Triangle Term Pier	Petrol. Prod.	135	165	24-26											5	
62	Amoco Oil Co. (R)	West Yard Berth 4	Petrol. Prod.	565	430	26								3	1	1		1
63	Atlantic Pipeline Co. (S)	West Yard Berth 3	Petrol. Prod.	220	200	20-26									1		1	

Table 7 (Cont'd.)

INVENTORY OF DEEP-DRAFT FACILITIES FOR CRUDE OIL/PETROLEUM PRODUCTS/PETROCHEMICALS AND CHEMICALS

COE Reference No.	Owner	Name	Commodities	Storage Capacity (000's) bbls	Berth Length (ft)	Alongside Depth (ft)	Pipelines from Wharf to Storage Tanks (# and diameter, inches) 36	30	24	20	18	16	14	12	10	8	6	4
82	Atlantic Pipeline Co. (R)	Atlantic Wharf	Crude/Petrol Prod.	952	888	25				1					2	4	1	
86	Chevron Oil Corp. (R)	Wharf No.2	Crude/Petrol Prod.	5,190	300	33								5		2	4	
87	" " "	Wharves 163	Petrol. Prod/ Petrochem	incl. above	1,475	33								13	4	7	4	7
Philadelphia to the Sea - Schuylkill River to Allegheny Ave.																		
137	Namolco Inc. (S)	Pier G Port Richmond	Chemicals	238	1,423	30-36											1	
Philadelphia to Trenton - Allegheny Ave. to Newbold Island																		
140	Philadelphia Port Corp. (S)	Tioga II	Petrol. Prod/ Petrochem	1,000	620	34									2	8	3	
153	Philadelphia Elec. Co. (S)	Croyden Gen. Sta. Wharf	Fuel Oil[1]	611	500	30										1	1	
154	Meenan Oil Co. (S)	Meenan Oil Wharf	Petrol. Prod.	391	875	34						1			2			
159	U.S. Steel Corp. (S)	Mooring Wharf	Fuel Oil[1]	181	1,000	40				Not Available								
NEW JERSEY																		
Philadelphia to Trenton - Allegheny Ave. to Newbold Island																		
178	Amerada Hess Corp. (S)	Dock 1	Crude/Petrol. Prod.	2,100	285	39				1				4				
179	Texaco Inc. (R)	Tanker Dock Berths 162	Petrol. Prod.	1,193	197	29									1	2	2	1

Table 7 (Cont'd.)

INVENTORY OF DEEP-DRAFT FACILITIES FOR CRUDE OIL/PETROLEUM PRODUCTS/PETROCHEMICALS AND CHEMICALS

COE Reference No.	Owner	Name	Commodities	Storage Capacity (000's) bbls	Berth Length (ft)	Alongside Depth (ft)	Pipelines from Wharf to Storage Tanks (# and diameter, inches) 36	30	24	20	18	16	14	12	10	8	6	4
Philadelphia to the Sea - Port of Camden																		
101	Citgo Petroleum Corp. (S)	Petty's Island Term Dock	Petrol. Prod.	1,010	800	30						1		5				
Philadelphia to the Sea - Paulsboro to Delaware Bay																		
210	Koch Fuels Inc. (S)	Koch Fuels Dock	Petrol. Prod.	800	238	35						1			4	1		
214	Coastal Inc. (R)	Eagle Point Berth 1A	Crude Oil	8,620	650	35			1		1	1			4	3		1
215	"	Eagle Point Berth 1	Petrol. Prod.	incl. above	372	35										7	1	2
216	"	Eagle Point Berth 2	Crude/Petrol. Prod.	incl. above	800	40						3		3	4	1	4	1
217	"	Eagle Point Berth 3	Crude/Petrol. Prod.	incl. above	550	43						3		3	2	1	3	1
220	Mantua Chemical Term. (S)	Main Dock	Petrol. Prod/ Chemicals	4,300	1,000	40					Not Available (18 total)							
221	" " "	Barge Dock	Petrol. Prod/ Chemicals	1,300	600	30											2	
225	B.P. Oil Co. (R)	Paulsboro Term Pier 2 & Barge Berths 4&6	Petrol. Prod/ Petrochem	3,350	856	17-36						1		6		8	9	
226	" "	Paulsboro Term Pier 1 & Barge Berths 3, 5&7	Petrol. Prod/ Petrochem	incl. above	797	17-36					Not Available							

Table 7 (Cont'd.)

INVENTORY OF DEEP-DRAFT FACILITIES FOR CRUDE OIL/PETROLEUM PRODUCTS/PETROCHEMICALS AND CHEMICALS

COE Reference No.	Owner	Name	Commodities	Storage Capacity (000's) bbls	Berth Length (ft)	Alongside Depth (ft)	Pipelines from Wharf to Storage Tanks (# and diameter, inches) 36	30	24	20	18	16	14	12	10	8	6	4
228	Exxon Co. (S)	Paulsboro Wharf	Petrol. Prod.	1,621	1,320	25-40						1	1		1	5	1	
229	Sunmark Industries (S)	Paulsboro Term Pier	Petrol. Prod.	51[1]	90	35										1		
230	Mobil Oil Corp. (R)	Paulsboro Term Wharf & Berths 1, 2,3&5	Crude/Petrol. Prod.	6,200	2,388	34		1				1	1	3	2	1	1	
231	" "	Paulsboro Term Tanker Wharf	Crude/Petrol. Prod.	incl. above	822	40		1					1	1			1	
233	E.I. du Pont (S)	Repauno Plant Solvent & Sulpher Pier	Chemicals	106	840	20-35										2		
235	Monsanto Industrial Chemical Co. (S)	Delaware River Plant Dock	Chemicals	190	600	37									4			
237	E.I. du Pont (S)	Chamber Works Main Wharf	Petrol. Prod/ Petrochem/Chem	310	1,195	16-33			1					1				
			TOTAL	73,038			1	5	10	8	10	20	5	52	53	87	73	28

Note: 1 s. ton = 6.6 barrels of crude oil
1 s. ton = 7.1 barrels of refined petroleum
1 s. ton = 8.5 barels of gasoline

(R) - Refinery
(S) - Storage
[1] Fuel Oil for plant consumption

139. Coal Exports. The total estimated existing and planned coal loading (export) capacity of the Delaware River system is 19.7 million tons per year. This estimate is based on the reported existing and planned loading capacity of the individual facilities, and excludes South Jersey Port Corporation's Beckett Street Terminal which is discussed in a following section. At the present time, there is one primary export coal facility in operation, Conrail's Pier #124. This facility has been upgraded to provide an estimated capacity of 10 million tons per year. Conrail's Pier #18, Port Richmond, which once handled coal, has been closed due to obsolescence, in favor of expansion at pier #124. The north side of Conrail's Pier E, Port Richmond, has modified former grain spouts to handle coal from a new bottom dump car unloader and/or from a developed open storage/reclamation area. USX Corp.'s berthing is not currently equipped for coal export. Plans to achieve an annual throughput capacity of 8.2 million tons were developed in the early 1980's and, though not presently likely, could be implemented in the future. The estimated coal export capacity is broken down as follows:

Conrail Pier #124	10,000,000
Conrail Pier E	1,500,000
USX Corp.	8,200,000
Total	19,700,000

140. Iron Ore Imports. The total estimated iron ore import capacity of the Delaware River port system is 14.5 million tons per year at two existing terminals. This estimate is based on the reported shiploading capacity of existing equipment at the individual facilities and year-round three-shift operation. Conrail Pier #122 currently operates only 8 hours per day, 5 days a week, well below its capacity. With the decline in the U.S. steel industry, Conrail is actively restructuring Pier #122's material handling system to handle lighter materials, such as imports of fertilizer in relatively small vessel and shipment sizes. Conrail Pier #14, Port Richmond, which formerly handled iron ore, is currently inactive. USX Corp.'s berth operates on three shifts with a 4 million ton per year throughput capacity.

Conrail Pier #122	10,500,000
USX Corp.	4,000,000
Total	14,500,000

141. South Jersey Port Corporation (SJPC). The Beckett Street Terminal, operated by South Jersey Port Corporation, has experienced increased business in recent years. In the last decade, South Jersey Port has expended approximately $15,000,000 to modernize the bulk cargo handling facilities and marginal berths at Beckett Street, with the result that Beckett Street Terminal now has the capacity to handle large quantities of bulk cargo efficiently. With the present redevelopment of the Camden Waterfront, Beckett Street Terminal expansion can only occur towards the south. Plans are presently being advanced to extend the southernmost berth at Beckett Street Terminal 300 feet

southward by acquiring property from Domtar, Inc., the adjacent property owner. The land area currently owned by SJPC for Beckett Street Terminal is 74 acres. SJPC also has four berths, with 2300 L.F. of length. Expansion and development plans include additional land acreage of 260 acres and additional berthing length of 4100 L.F. Total tonnage throughput capacity projected by SJPC for Beckett Street Terminal, when fully developed by 1998 in accordance with their Long-Range Master Plan, will be in excess of 10 million tons annually.

142. Other Bulk and General Cargo. A significant number of projects are underway that would improve the capacity and efficiency of port facilities to handle the general cargo targeted by the ports of Philadelphia. The Greenwich Rail Yard in South Philadelphia will be developed into a $47 million intermodal regional transfer facility. This intermodal facility will enhance the port's ability to attract container cargo shipments. It will also allow the port to transfer ocean cargo directly to and from western destinations. Other port projects in Philadelphia include the following: (1) construction of a new warehouse for paper imports ($11.1 million), (2) expansion of the shed at Tioga I Marine Terminal ($6.9 million) (3) expansion of the fruit shed capacity at Piers 82-84 ($6.4 million).

143. Container Terminals. The Delaware River port system container facilities, in their totality, have capacity to handle over 900,000 TEUs (twenty-foot equivalent units) of containers per year based on existing infrastructure. For the potentially benefitting facilities, Packer Avenue Marine Terminal has a total container capacity of 311,000 TEUs and the Holt Cargo Systems' terminal a capacity of 156,000 TEUs annually. The Regional Intermodal Transfer Facility (RITF) being developed by the Delaware River Port Authority adjacent to the Packer Avenue Terminal could also benefit. Based on tonnage handled, capacity utilization is approximately 25% at the current time.

144. Breakbulk Facilities. The estimated maximum capacity to handle non-containerized breakbulk cargo is 4.2 million tons per year at 14 terminals. Five of the breakbulk facilities possess heavy lift cranes which can be used to load/discharge containers as well as breakbulk cargo: Holt Cargo Systems, South Jersey Port Corp.'s Broadway and Beckett Terminals, the Port of Wilmington, and Northern Shipping Co. These facilities have higher than average capacities since their heavy lift cranes have higher handling rates for containers than for conventional breakbulk. Using these cranes, the container loading/discharging capacity is estimated to be 2.2 million tons per year. Thus, total capacity at the breakbulk facilities is 6.4 million tons per year. Several assumptions were used to determine the capacity of existing breakbulk facilities. For container handling these were considering only existing heavy lift cranes, and open storage assuming 110 TEU's per acre. For non-containerized breakbulk handling these included average productivity of 20 tons per hour per gang, with 3 gangs per berth and covered storage density of 7.5 sq. ft. per ton. For all

cargoes it was assumed that there was 5 day a week operation with average of 12 hours/day and an average storage time of 15 days.

145. Dedicated Ro-Ro Facilities. The total estimated existing and planned dedicated Ro-Ro capacity in the Delaware River system is 2.8 million tons per year at six terminals. Assumptions used to determine the capacity included an loading/unloading rate of 140 tons/hour with seven day a week operation, 20 hours/day. There would be storage on chassis one unit high, 110 TEU's per acre, one TEU= 10 tons and an average storage time of 15 days.

TRADE ROUTES

146. Freight trade routes for imports and exports through Delaware River Basin ports generally reflect the industrial character of the northeastern United States. Over the past decade, exports have generally been to industrialized countries, with imports coming from the less developed countries. Except for the Canadian Atlantic coast, the three trade routes accounting for the largest tonnage have been from the less developed countries - in Africa, South America, the Caribbean, and Mexico.

147. Using 1985-1989 data, existing vessel movements were broken down into relative percentages by benefitting trade route for benefitting commodities as shown below:

CRUDE OIL	
West Africa	36.8%
North Europe	19.0%
Caribbean	16.5%
South Africa	10.3%
South America	6.6%
Southeast Asia	3.2%
China/North Korea	2.2%
Red Sea/Arabian Gulf	1.8%
Mediterranean	1.7%
South Europe	1.2%
Australia	0.4%
Canada	0.3%
COAL	
North Europe	43.0%
Mediterranean	22.3%
Canada	17.3%
South America	6.8%
South Europe	6.2%
Caribbean	3.1%
East Europe	1.2%
IRON ORE	
Atlantic Canada	67.6%
North Europe	29.6%
South Europe	1.4%
North Africa	0.7%

SOUTH JERSEY PORT CORPORATION

Scrap to Turkey	100%
Bituminous Coal from S. Amer.	100%

CONTAINERS

Europe	38%
Mediterranean	7%
East Coast-South America	20%
Australia/Europe/East U.S.	20%
Halifax	15%

Additional commodities by trade route are shown below:

IMPORTS

Iron and Steel:	Orient, Europe, Brazil
Fruit and Vegetable:	South America
Paper:	Europe, South America
Wood, Lumber Cork:	Canada
Chemical:	Europe, Africa, South America, Canada
Meat:	Australia, South America
Cork and Wood MFRS:	Asia
Fish:	South America, New Zealand
Stone:	Scotland, Nova Scotia

EXPORTS

Chemical:	Europe, England, Japan, South America
Chemical Materials:	Europe, South America, Middle East
Road Vehicles:	Middle East
Pulp and Waste Paper:	Asia
Iron and Steel:	Asia, South America, Europe
Steel Scrap:	Europe, South America, Asia
Silt Coal:	Asia
Petrocoke:	Asia

LANDSIDE TRANSPORTATION SYSTEMS

148. An integral part of the study area are the transportation systems servicing the project area and the associated hinterlands. The investigations incorporated all facets of the system: highway, rail, and pipeline.

149. The primary New Jersey highway serving the north-south corridor is the New Jersey Turnpike, a 118-mile toll road which runs from its southern terminus at the Delaware Memorial Bridge at Wilmington, Delaware to points northeast, northern New Jersey, New York and the Northeast Region (see Figure 9). East-west auto traffic is served by the Atlantic City Expressway, a 44 mile, four-lane toll road, which, in conjunction with N. J. 42/U.S. 322, provides direct access from New Jersey's eastern shore to Camden, New Jersey, and the remaining ports of the Delaware River.

150. Unlike the New Jersey side of the Delaware River which is primarily rural and suburban, the Pennsylvania side is urban represented by the Philadelphia area. The principal highway

FIGURE 8

DELAWARE RIVER
COMPREHENSIVE NAVIGATION STUDY
HIGHWAY NETWORK
Philadelphia District, Corps of Engineers

FIGURE 9

DELAWARE RIVER
COMPREHENSIVE NAVIGATION STUDY

RAIL NETWORK

Philadelphia District, Corps of Engineers

facility in the Northeast Corridor is I-95 which runs through Philadelphia, connects northern New Jersey, New York, and the New England states, and extends southwesterly to Wilmington, Delaware; Baltimore, Maryland, Washington, D.C., and points south. Primary service to the port community in Philadelphia is provided, with connection to I-95, by Delaware Avenue, a four lane road which runs parallel to I-95 and adjacent to the port facilities along the Delaware River. Major east-west movements to and from the Philadelphia ports are primarily carried by the Schuylkill Expressway (I-76). The Pennsylvania Turnpike and its Northeast Extension are 4-lane toll roads. The mainline turnpike provides for cross state movements from its eastern terminus at the New Jersey border to its western terminus at the Ohio border. The Northeast Extension provides access to northern Pennsylvania and western New York.

151. In Delaware, I-95 crosses the northern portion of the state between the Pennsylvania and Maryland state lines, a distance of 24 miles. North-south, traffic within Delaware is handled primarily by Routes 13 and 9.

152. The Delaware River port system was serviced by three trunkline railroads, the Conrail, Chessie, and Canadian Pacific Systems (see Figure 10). Conrail operates 17,700 miles of mainland track serving 16 states including the hinterland states of Delaware, Illinois, Kentucky, Maryland, New Jersey, New York, Ohio, Pennsylvania, Virginia, West Virginia, the District of Columbia, and portions of Canada. The Chessie System principal lines operate from New York City through Philadelphia, Baltimore, and Washington, D.C. Two lines operate westward from Maryland. In addition the Canadian Pacific Railroad has recently acquired the Delaware and Hudson Railroad which it will be using for Port access between Philadelphia and Canada. This will increase Philadelphia's potential market hinterland.

153. Regional Intermodal Container Transfer Facility. A major proposed plan by DRPA to improve container trade through Philadelphia involves the ongoing development of a rail intermodal yard at the Greenwich Rail terminal adjacent to the Packer Avenue Marine Terminal. The underlying purpose of the intermodal yard is to open the high cargo-generating area of the Midwest to Philadelphia through efficient rail operations near the port area. Contrail and CSX will have access to the yard, and the D&H Railway Division of Canadian Pacific Railways will also be open to the reach of Philadelphia. The intermodal yard will also open up the West Coast market, as well as the possibilities of landbridging Pacific Rim-European trade. The railyard is intended to serve as the key component to attract container lines to use Philadelphia as their load-center port. The intermodal yard is also designed to handle double-stack trains.

154. The intermodal yard is planned by DRPA to be built in two phases. The first phase will have a capacity of 270,000 lifts per year based on a conventional rail car system. Double stacking

FIGURE 10

DELAWARE RIVER
COMPREHENSIVE NAVIGATION STUDY

PIPELINE NETWORK

Philadelphia District, Corps of Engineers

could boost capacity of 449,000 lifts per year. The yard will encompass four loading tracks of 3,600 feet in length and two storage tracks. The $2.3 million initial project outlay by DRPA represents approximately half the cost of opening the facility and involves laying new track, paving, building a gate complex and container-storage area, and installing overhead cranes for hoisting containers on and off trains. An additional amount of more than $2 million will be needed for equipment to load and unload rail cars. Eventually, DRPA anticipates spending more than $30 million on the project to accommodate future increases in business. The initial phase will involve 22 acres, with expansion possible for 44 additional acres. Close by, Railport, a private intermodal facility covering 10 acres, has laid track for its operations. The Railport facility was started in 1990 when it was uncertain if the DRPA would reach an agreement to lease a portion of Conrail's Greenwich yard. The Railport and DRPA facilities will be linked by rail to each other and to the CSX intermodal yard.

155. The North Atlantic coastal ports are served by a number of clean petroleum product pipelines (see Figure 11). The Colonial pipeline, originating in the Houston/Galveston refining territory, is the largest pipeline in the U.S. It passes through major refining centers in Louisiana, gathering products for delivery throughout the eastern U.S. The Plantation Pipeline is the second largest products line from the Gulf Coast and generally parallels the route of the Colonial line. At least six product pipelines cross Pennsylvania to serve the western part of the state, Ohio, and points west from the refining center on the Delaware River. Two lines continue to the New York area refineries. Locally, the Delaware River Basin is served by numerous small pipelines which provide for internal movements of petroleum products.

156. MARKET AREAS. This section addresses the market areas for Delaware River Ports and generally examines the major overseas trade areas for the shipments through the Delaware River Ports.

157. Export Market Areas. The predominant export through the Delaware River docks is coal. Both bituminous coal from Appalachia and Anthracite silt coal from eastern Pennsylvania are exported mainly to Europe with a significant amount also traveling to the Far East. Scrap metal which is shipped from the South Jersey Port Corporation's Beckett Street Terminal is produced within the Port's own metropolitan area and is exported to Turkey. Containers are exported and imported through the Regional Intermodal Transfer Facility and other facilities such as Packer Avenue and Holt terminals.

158. Import Market Area. Crude Oil, the largest bulk commodity shipped through the Ports of Philadelphia is imported from West Africa, North Sea, Middle East, Far East, Bahamas, Mexico and Venezuela. Crude Oil is received and refined by the regional refineries within the Philadelphia metropolitan area. Iron ore is imported from Atlantic Canada, Brazil, West Africa and Europe, and

supplies the eastern Pennsylvania steel industry with nearly all of its needs. Bituminous Steam Coal is imported from South America through Beckett Street Terminal.

159. Import Markets. The market area for most Delaware River Basin imports is predominantly within a relatively narrow band surrounding the basin. Crude oil and iron ore account for about 80-90% of imports annually. The level of crude oil and iron ore imports is largely determined by national and international trends that cannot be influenced by ports or firms within the basin. The result is that while having a locational advantage, national and international factors will determine the overall level of these imports and could, under some circumstances, terminate the flows.

160. General cargo imports are distributed over a somewhat wider geographical area than exports. However, about 80% of general cargo imports terminate in Delaware River Basin states. Meats, bananas, lumber and plywood are the main general cargo imports distributed over a wide area and are subject to extensive competition between ports. For imports and exports combined, the Delaware River Regional Port Study indicates that 98-99% of general cargo origins and destinations are in Pennsylvania and New Jersey. This result appears quite consistent with earlier Bureau of Census studies.

EXISTING INSTITUTIONS

161. A number of Government agencies both affect and are directly affected by Federal navigation activities in the study area. Some of these agencies are regulatory in nature and directly affect the conduct of dredging. Others are advisory and play a role in the formulation and development of project plans. Those that are affected by Federal project activities are consulted for input as plans are developed. A list of these agencies and a brief description of their role or mission as it relates to Federal dredging activities is provided below. It is not an all-inclusive list of agencies with which project plans are coordinated but rather a list which emphasizes key agencies in the institutional framework relative to Federal navigation projects.

162. FEDERAL GOVERNMENT. The Environmental Protection Agency (EPA) is generally responsible for the enforcement of Federal laws regarding air and water quality, solid waste, and hazardous materials. Relative to Federal navigational activities, the EPA and the Corps have established the guidelines for the evaluation of the water quality impacts associated with the disposal of dredged material as required by Section 404(b)(1) of the Clean Water Act (CWA). Similarly, the EPA and the Corps have developed the evaluative criteria for the specification of ocean dumping sites in accordance with the Marine Protection, Research, and Sanctuaries Act. EPA also maintains a veto authority over decisions made by the Corps regarding specification of disposal sites under Section 404(c) of the CWA. In the Clean Air Act (Section 309), EPA has been given the authority to review and comment on actions subject to the National Environmental Policy Act (NEPA) and to refer those actions to the Council on Environmental Quality (CEQ) if the agency finds the action to be unacceptable from an overall environmental standpoint.

163. The Fish and Wildlife Service (FWS) is responsible for evaluation of project impacts to Fish and Wildlife resources and recommendations concerning the conservation of those resources and mitigation of impacts. Those recommendations must be considered in project planning (Fish and Wildlife Coordination Act). Enforcement and coordination under the Endangered Species Act is primarily the responsibility of the FWS. The FWS also is the responsible agency for compliance with the coordination and consultation requirements under the Coastal Barrier Resources Act.

164. The National Marine Fisheries Service (NMFS) is similarly responsible for evaluation of project impacts on marine life and enforcement coordination under the Endangered Species Act for endangered species in the marine environment.

165. The National Park Service, Office of Archeological Services (OAS) is charged primarily with overseeing the historic

preservation program established as a result of the Archeological and Historic Preservation Act of 1974. A primary function is the review of historic preservation reports prepared by various Federal agencies.

166. Federal agencies are required to afford the Advisory Council on Historic Preservation (ACHP) an opportunity to comment on any Federally-funded or licensed activities that may have an effect on any District, building, site, structure, or object that is listed in or is eligible for inclusion in the National Register of Historic Places.

167. U.S. Coast Guard authority includes maritime law enforcement, placement and maintenance of aids to navigation supervision over the anchorage and movement of vessels, the handling of explosives and other dangerous vessel cargoes, and safeguarding life and property on the high seas. It also enforces laws relating to oil pollution, immigration, quarantine and numerous statutes under the jurisdiction of other Federal agencies that require marine personnel and facilities.

168. The responsibilities of the Federal Maritime Commission (FMC) embrace two broad areas of commercial navigation: regulating shipping practices and ensuring financial responsibility for water pollution cleanup. The FMC licenses ocean freight forwarders and maintains surveillance over services, practices, and agreements to assure equitable treatment to all segments of the maritime industry and the general public. The FMC also administers a provision of the Water Pollution Control Act of 1970 (PL 92-500) requiring the owner or operator of every vessel over three hundred gross tons to establish and maintain evidence of financial responsibility for assuming the cost of removing oil discharged into navigable waters.

169. The Maritime Administration (MARAD) administers Federal laws designed to promote and maintain a U.S. merchant marine fleet capable of meeting the Nation's shipping needs for both domestic and foreign commerce and national security. To carry out its mandate, MARAD assists the maritime community in the areas of ship design and construction, development of advanced transportation systems and equipment, and promotion of the use of U.S. flag vessels.

170. REGIONAL AGENCIES AND ORGANIZATIONS. The Delaware River Port Authority is a federally chartered bi-state authority governed by 16 commissioners, eight from Pennsylvania and eight from New Jersey. DRPA owns and operates four bridges between southeastern Pennsylvania and southern New Jersey which together carry more than 90 million vehicles annually. It also owns and operates, through subsidiary corporation, a 14-miles long commuter rail system know as the PATCO High-Speed Line. PATCO carries more than 11 million riders annually. All DRPA revenue is derived from bridge tolls and PATCO fares. In its charter, DRPA is charged with promoting

commerce for the public and private port facilities along the Delaware River. DRPA's World Trade Division provides international and domestic marketing services for these terminals, which collectively are known as "The Ports of Philadelphia."

171. In 1988 the governors of Pennsylvania and New Jersey proposed a program to unify the port facilities under DRPA's direction. That commitment was reinforced in 1991 by a joint letter signed by the two governors in which they publicly supported changes in DRPA's compact giving it broader authority over port enhancement and regional economic development.

172. Under direction by the governors, DRPA is preparing to open an intermodal rail terminal in Philadelphia which will provide services to three major railroads, Conrail, CSX and Canadian Pacific. It has also pledged $2.6 million to meet the local share obligation for the deepening of a section of the Delaware River channel serving the Beckett Street Terminal in Camden and has agreed to act as the local share sponsor for the proposed deepening of the main river channel.

173. In addition, DRPA is studying the development of a new headquarters building along the Camden waterfront and has expanded its planning and economic development roles in order to examine new transportation and job-creation projects that will benefit the Delaware Valley Region.

174. Developed as a mechanism for planning and cooperation between two States, the Delaware River and Bay Authority (DRBA) is responsible for transportation crossings between New Jersey and Delaware and has potential responsibilities with respect to port development. Each Governor appoints five commissioners to DRBA. The DRBA operates and maintains the Delaware Memorial Bridge and the Cape May-Lewes Ferry. Because bridge and ferry crossings have been determined to be adequate for the present, the DRBA has requested specific guidance from both Legislatures on the allowable extent of its future activities, including port or marine facility development which were originally included as permissible activities in its original charter.

175. The Delaware Valley Regional Planning Commission (DVRPC) was created by Pennsylvania and New Jersey in 1965 to provide continuing, comprehensive and coordinated planning for orderly growth and development throughout the Delaware Valley region. The DVRPC specializes in transportation planning and provides consulting services to local, county and state governments, as well as to the private sector.

176. The Delaware River Basin Commission (DRBC) was created in 1961 to plan, manage and protect the Delaware River basin's water resources. The basin encompasses parts of New York, Pennsylvania, New Jersey and Delaware. The Delaware River Basin Commission has five members acting as prime decision and policy makers for the organization. The Governors from the four states and the Secretary

of the Department of the Interior comprise the five members of the Commission. The Commission is charged with protecting the water resources of a 12,500 - square-mile watershed. All public and private projects proposed within the Delaware River basin that may affect water resources of the river must obtain Commission approval. The Delaware River Basin Commission's multipurpose scope encompasses pollution control, water supply, flood control, water based recreation, fish and wildlife protection, and other aspects of water management. The DRBC's scope does not extend to navigation. The DRBC continually updates a Comprehensive Plan. The Comprehensive Plan is a master plan for the development of the water resources of the basin. All public or private water resources projects within the basin must comply with the goals of the Comprehensive Plan.

177. STATE GOVERNMENT AGENCIES. Several state agencies are involved with navigation:

Delaware Department of Natural Resources and Environmental Control.

New Jersey Department of Environmental Protection.

Pennsylvania Department of Environmental Resources.

Delaware Department of Transportation

New Jersey Department of Transportation

Pennsylvania Department of Transportation

South Jersey Port Corporation

Philadelphia Regional Port Authority

178. Each of the three state environmental agencies is tasked with the responsibility to conserve and maintain natural, scenic and aesthetic values of the environment and to assure its residents clean air and clean water. Each is responsible for the State's land and water management program and all aspects of environmental control. More specifically, they are the authority for environmental permits, monitoring and surveillance, enforcement, certification and training, planning and financial assistance. All three agencies are also responsible for their respective state's Coastal Zone Management Program. All issue Water Quality Certificates for disposal of dredged or fill material under Section 401 of the Clean Water Act.

179. All three State Departments of Transportation, have indirect navigational responsibility in planning and developing highway and rail access to port facilities. Only the Pennsylvania Department of Transportation, through its Water Facilities Loan Board, has

direct navigational involvement and only in providing loans for reconstruction and redevelopment, not for the new construction of any facilities.

180. The South Jersey Port Corporation (SJPC) was created as an agency of the New Jersey Department of Commerce and Economic Development in 1968. Its seven-member Board of Directors is appointed by the Governor. The South Jersey Port Corporation has jurisdiction over port facilities between Trenton and Cape May. Jurisdiction of the ports in the area is shared with the Delaware River Port Authority and the Delaware River and Bay Authority, but there have been no disputes over jurisdiction to date. The SJPC operates 2 terminal facilities under an agreement with the Camden Municipal Port Authority. It is a self-supporting agency, funded by the rents, rates and fees it charges the users of its facilities.

181. The Philadelphia Regional Port Authority was established in June 1989 by the General Assembly of the Commonwealth of Pennsylvania to increase coordination of port facilities and projects within an established regional port zone along the Delaware River. It has absorbed the function and property of the Philadelphia Port Corporation, including the Tioga and Packer Avenue Marine Terminals.

182. OTHER AGENCIES. There are also several city agencies directly involved in port development:

Wilmington, DE: Department of Commence
Camden, NJ: Camden Municipal Port Authority
Salem, NJ: City of Salem Port Authority
Philadelphia, PA: Philadelphia Commerce Department

Delaware County, PA: Delaware County Partnership for Economic Development

183. Private interests in port development have also joined ranks in two prominent area organizations. The Joint Executive Committee for the Improvement and Development of the Ports of Philadelphia is an organization primarily interested in channel and harbor development in the tri-State area. The Joint Executive Committee follows legislation, budget appropriations and project funding related to port and channel development in the Delaware River. The PENJERDEL Council seeks to promote port commerce as part of its concern for the region's economic prosperity. The Council is primarily a "watchdog" agency to ensure that legislation and budgets have adequate provisions for port development and viability.

PROBLEM IDENTIFICATION

MEANS BY WHICH PROBLEMS WERE IDENTIFIED

184. The identification of water and related land resource problems, needs, and opportunities in the study area has evolved from prior studies, current investigations, and continuing public coordination. Public concerns and desires have been elicited through a public involvement program in which public officials, interest groups, governmental agencies, and other segments of the public have been encouraged to become actively involved in the study process.

185. A formal public meeting was held during the reconnaissance studies and was used along with widespread distribution of initiation notices and newsletters, and agency coordination to fully identify the range of problems on the Delaware River channel and its tributaries that support commercial navigation. Coordinaiton has also been accomplished with project users and potential beneficiaries to identify problems and obtain economic data; Federal and state regulatory agencies to assess environmental concerns and views on impacts and mitigation; navigation interests regarding navigation practices and design criteria, and local sponsors to obtain views and discuss financing and local cooperation requirements. Numerous meetings have taken place which include the following:

- Mariners' Advisory Committee - to review design criteria and navigation practices.

- U.S. Coast Guard - to discuss design criteria (including one-way and asymmetric channels) and navigation aids.

- Dredging Committee for the Delaware River (established by the Delaware River Port Authority and Delaware River and Bay Authority) to discuss options for dredging disposal

- Environmental Scoping Meeting - to discuss environmental issues related to the proposed project, attended by a wide variety of public agencies concerned with environmental and cultural resources in the study area.

- Periodic meetings with PENJERDEL Council and Joint Executive Committee.

- Coordination meetings with navigation interests including oil refineries, Conrail, and public port agencies.

CONDITION IF NO FEDERAL ACTION IS TAKEN
(WITHOUT PROJECT PROFILE)

186. The without project condition is the most likely condition expected to exist over the planning period in the absence of implementing a plan of improvement. It provides the base line for estimating the benefits, costs and impacts for alternative with-project conditions. Each component is described in the following paragraphs.

187. NATURAL AND SOCIAL RESOURCES. Manmade activities will continue to affect both the waters and the ecology of the Delaware River Basin. Industrialization and urbanization along the Delaware River and its principal tributaries have caused severe alteration of the aquatic ecosystem. Gradual water quality improvements as a result of wastewater treatment improvements and improved land use controls should result in a gradual resurgence of the formerly diverse aquatic estuarine community. The extent of this improvement will however, not be as large as originally anticipated. While dissolved oxygen is no longer a limiting factor, concentrations of trace chemicals and the elimination of many prime habitat areas have become limiting factors in estuarine aquatic productivity.

188. While limited population growth in urban areas is expected, suburban and rural areas are projected to have up to a 0.5% annual population change. Industrial and commercial development along vacant land bordering the riverbanks is expected to continue, causing impacts to terrestrial and cultural resources.

189. More detailed estimates of long term area-wide future conditions relative to natural and social resources would be speculative, at best. It is reasonable to assume that changes will occur, however reliable forecasts are impossible. Such factors as economic conditions, social attitudes, human needs, resource availability, political influences, Government policies and regulations, international affairs, and natural forces such as weather cycles and biological adaptability would influence future without project conditions. In particular, sea level rise attributable to the Greenhouse Effect has the potential to affect salinity conditions in the Delaware River and Bay as well as wetlands and shoreline erosion. It is assumed based on historical tide gage records between 1912 and 1986 that sea level has been rising at an approximate average rate of 0.0129 feet per year (Hicks and Hickman, 1988). For the purposes of this study future natural and social conditions are considered to be comparable to existing conditions throughout the planning period, except where specifically noted.

190. WATERWAY CONDITIONS. It is anticipated that in the future waterways within the Delaware River system would be maintained to

the same degree as in the Existing Conditions section; i.e. the Delaware River channels maintained to current project dimensions. It is expected, however, that the deepening of the Delaware River in the Vicinity of Camden, N.J. (Beckett Street) project to 40 feet, authorized by the Water Resources Development Act of 1988 and currently undergoing Preconstruction Engineering and Design will be constructed.

191. DREDGING TECHNIQUES AND DISPOSAL AREAS. Existing dredging techniques and disposal methods will not change substantially in the future. Shoaling is expected to be concentrated in those areas where it has been in the past, requiring continued use of existing disposal areas and new areas in the future as capacity is reached. Use of hydraulic and hopper dredges under contract will continue to be the dominant method of dredging although bucket dredging will also be used. The use of hopper dredges, bottom dumping to an overboard disposal site in Delaware Bay, would also occur periodically.

192. Disposal Needs for 40 Ft. Maintenance Based on Current Conditions. As a result of new dredging practices introduced in 1955, material dredged from the river is now deposited solely within confined, upland disposal sites. Bucket dredging, which is rehandled in a diked basin, is the only method by which material is not pumped directly into upland sites along the river. The annual volume of dredged material has been reduced to approximately 5.4 million cubic yards a year. Formerly, open water disposal and agitation dredging led to shoaling and additional dredging requirements.

193. In order to maintain the full width channel to a depth of 40 feet, a minimum of two new disposal sites will be needed during the 50 year project life, depending on ultimate dike heights. One site will be needed in Reach A in the first half of the planning period and another in Reach B. The ultimate capacity of existing sites and the number of new sites required will depend on maximizing dike heights of existing disposal sites. Refer to Table 8.

TABLE 8
DISPOSAL AREA
MAINTENANCE REQUIREMENTS
FOR FULL WIDTH
40 FOOT CHANNEL
DURING THE 50 YEAR STUDY PERIOD
(2005-2055)

REACH	MAINTENANCE PLAN
REACH A	Up to year 2007 goes to National Park with dike raising could extend to year 2027. New site required to replace National Park.
REACH B	Replacement sites needed before year 2005 if dikes at existing Federal sites can not be raised and lease at Oldmans not be extended beyond current expiration in 1991. With further dike raising and extending use of Oldmans can defer new sites acquisition until year 2030. By acquiring a large new site earlier could limit the need for acquisition to a single site.
REACH C	Sufficient capacity at Killcohook and Penns Neck to handle project maintenance up to year 2014 with further dike raising, capacity Could be extended throughout the 50 year planning period. Replacement may be required.
REACH D	Sufficient capacity at Artificial Island for 50 years of project maintenance
REACH E	Sufficient capacity at Buoy 10 for 50 years of project maintenance

194. FUTURE FLEET TRENDS. The forecasts presented in this section are based on the John I. Jacobs, PLC, publication for crude oil vessels, the U.S. Maritime Administration (MARAD) projections for dry bulk, container, and general cargo vessels, and the March 1990 Institute for Water Resources (IWR) study, Fleet Forecasts For The United States to 2020 (conducted by DRI; Temple, Barker, and Sloane; and Lloyd's Maritime Information Services Ltd.). The benefit analysis incorporated no shifts in the vessel fleets over the project life with the proposed channel improvements. For example, the data base for crude oil vessels with sailing drafts greater than 40 feet has not incorporated any potential shift in the fleet since the naturally deep water in the lower Delaware Bay allows utilization of very large tankers that are lightered prior to navigating the 40 foot without project condition depth. Also, the users stated that a shift in the fleet was not expected in the foreseeable future. The operators of these vessels have made an economic decision to lighter tonnage at Big Stone Beach Anchorage on to barges until the point where the sailing draft is sufficiently reduced to allow the vessels to travel upriver to the pertinent facility. Even with a deepened main channel, they are expected to make the same economic decision and carry the equivalent amount of tonnage in the same vessels. If a shift in the distribution of the crude oil tanker fleet to a greater percentage of larger vessels as expected in the future in the Fleet Forecasts For The United States to 2020 was incorporated into the analysis, this would have the impact of increasing project benefits. The data bases for crude oil vessels with less than 40 foot sailing drafts, coal and iron ore have also not included a shift in the vessel fleet over the project life. Also, benefitting commodities using the SJPC terminal (scrap, and steam coal) are anticipated to continue the existing practice of chartering the most cost efficient vessel size as the channel is deepened. Container vessels will utilize larger post-Panamax vessels on four major trade routes.

195. Crude Oil Vessels. The data for the current tanker fleet mix, new tanker deliveries and orders, and scrapping of tankers has been obtained from World Tanker Fleet Review (John I. Jacobs, PLC). A comparison was made of the fleet mix of the world tanker fleet for 1983 and 1986 (Table 9). Although the total tanker fleet was reduced by approximately 3 percent during this period, the percent distribution of the fleet remained relatively unchanged. Significantly, vessel classes of importance to this study showed a percentage increase: 100,000-150,000 DWT=increase from 9.1% to 9.6%; 90,000-99,999 DWT=increase from 4.0% to 4.4%; and 40,000-89,999 DWT=increase from 21.3 % to 21.6%. The new tanker deliveries data showed that 114 vessels were delivered in 1986. The overall distribution for new deliveries was similar to the 1986 tanker fleet distributions. New tanker orders at the end of 1986 equaled 184 vessels and was also similar to the existing fleet distributions (see Table 9).

196. Table 9 also presents the number of tankers scrapped in 1984, 1985, and 1986. Vessels scrapped per year has decreased. A total of 526 vessels were scrapped over the 3-year period. The percent distribution shows that vessels less than 50,000 DWT comprised 42 percent of tankers scrapped. Tankers greater than 160,000 DWT represented another 28 percent. Only 4% of vessels were scrapped in the highly important vessel class, for this study, of 100,000-159,999 DWT. Overall, a trend towards more efficient vessels in the 100,000-159,999 DWT class at the expense of either smaller or larger vessel classes is being established in the world fleet. This trend will affect the size of tankers that will use the Delaware River port system main channel to transport crude oil to refineries in the study area.

197. Fleet Forecasts For The United States to 2020 projects that the tanker fleet will more than double total capacity by the year 2020. This projection makes the very strong case that the future fleet will be able to handle the total projected growth of crude oil imports through the Delaware River port system. Most of the vessel classes will maintain their relative percentage of the total fleet capacity over the projection period, resulting in each vessel class approximately doubling its capacity by 2020.

198. Dry Bulk Vessels. Recognizing the speculative nature of fleet forecasts and the difficulty of predicting far into the future, MARAD's year 2005 projections are assumed to continue to represent the estimate until the 50th year of the project life, 2055. According to the MARAD forecasts, the number of dry bulk vessels serving the Atlantic Coast is expected to rise from 327 in 1980 to 463 in 1995 and 833 in the 2005-2055 period. This increase in the number of vessels will be accompanied by a general shift towards larger bulk carriers. The share of vessels of 175,000 DWT or above serving the Atlantic coast is expected to increase from zero percent of fleet capacity to five percent in 1995 and to 15 percent for the 2005-2055 period. In the 125,000-175,000 DWT category, the percent of fleet capacity will also rise from zero to five and 15 percent, respectively. The shift will be less significant for medium-sized vessels with DWT ranging between 70,000 and 125,000 tons with shares of 12, 26, and 27 percent, respectively. Conversely, the proportion of vessels in "Handymax" size (30,000 to 50,000 DWT) will decrease from 24 to 20 and 14 percent, respectively.

199. In defining growth scenarios for the world fleet of dry bulk carriers, the construction trends used in the MARAD forecasts were compared with current trends in vessel construction. It was noted that the construction trends in 1976-1977 and 1980-1981 represented extreme outlooks on the future of large bulk carriers. Forty-nine percent of the capacity built in 1976-1977 were composed of vessels of DWT lower than 50,000 tons, as opposed to only 35 percent during 1980-81. Also, 26 percent of the vessels built in 1980-81 were

TABLE 9
COMPARISON OF FLEET MIX FOR 1983 AND 1986

Size Group DWT	Number of Vessels Dec. 31, 1983	Dec. 31, 1986	Percent-Distribution 1983	1986
10,000/39,999	1,409	1,336	47.1	49.0
40,000/89,999	638	589	21.3	21.6
90,000/99,999	119	120	4.0	4.4
100,000/159,999	272	262	9.1	9.6
160,000/249,999	193	133	6.5	4.9
250,000/399,999	331	265	11.1	9.7
400,000 +	27	22	0.9	0.8
	2,989	2,727		

COMBINATION OF NEWBUILD DELIVERIES AND NEW ORDERS
COMPARISON OF FLEET MIX WITH EXISTING FLEET MIX

Size Group DWT	Number of New Building Deliveries	New Orders At End of 1986	Total New Deliveries	Percent Distribution Deliveries and Orders	1986 Fleet
10,000/39,999	56	74	130	44	49
40,000/89,999	31	56	87	29	21
90,000/99,999	9	12	21	7	4
100,000/159,999	9	27	36	12	10
160,000/249,999	6	3	9	3	5
250,000/399,999	3	12	15	5	10
400,000 +	0	0	0	0	1
Total	114	184	298	100	100

NUMBER OF TANKERS SCRAPPED FROM 1984 TO 1986

Size Group DWT	Number of Tankers Scrapped 1984	1985	1986	Total	Percent Distribution
10,000/49,999	102	69	50	221	42
50,000/99,999	58	55	21	134	26
100,000/159,999	6	9	7	22	4
160,000 +	44	73	32	149	28
Total	210	206	110	526	100

larger than 125,000 tons, as opposed to only 15 percent for vessels built in 1976-77. Nevertheless, because so many other factors enter into consideration in fleet forecasting, the 2005 estimates were not significantly different in terms of fleet distribution. Thus, the 50,000 to 125,000 DWT category, which is a range of vessels of major importance in this study, is expected to make up approximately 50 percent of the total vessel fleet in the MARAD forecasts.

200. Fleet Forecast For The United States to 2020 expects the fleet to increase total capacity by 37% by the year 2020. All vessel classes are anticipated to maintain their relative percentage of the total fleet capacity over the projection period.

201. South Jersey Port Corporation. The without project condition vessel fleet assumed to be operating over the period of analysis was based on an analysis of past historical fleets during which changes in channel conditions occurred. This analysis showed that the fleet servicing the terminal assimilated a normal distribution with a mean sized vessel in the most cost efficient vessel deadweight class. Over time, as improvements to the channel and berthing areas have occurred at the terminal, the fleet distribution has maintained its normal tendencies with the mean sized vessel shifting into the most cost efficient vessel class in the fleet. Therefore, a comparable shift was applied to the existing fleet to estimate the fleet distribution in the 40 foot (MLW) without project condition.

202. Containerships. Containerships will continue to increase in size over the next decade based on trends in construction. A regression model developed by the DRPA for various vessel characteristics indicated that containerships built during the next decade should range between 4300 and 4500 TEUs versus the latest generation of containerships which averages 3200 TEUs. There also exists the reasonable probability of post-Panamax vessels reaching 5000 TEUs within the next decade if pertinent markets requiring this size vessel continue to expand. Currently, about 10 percent of the fleet has design drafts of at least 40 feet. We expect the trend toward deeper vessels to intensify.

203. COMMODITY PROJECTIONS. This section presents forecasts for each of the relevant commodities:

-The most likely forecasts for a commodity for the Delaware River ports. Forecasts were developed as being market driven (either by regional market demand for the imported commodities or by world markets for the exported commodities) from the study year to the final year of the project life.

204. Introduction. The DRI/McGraw-Hill/Temple, Barker, & Sloane (DRI/TBS) World Sea Trade Service was applied to develop commodity projections for crude oil, coal, and iron ore. International trade was modelled for the individual commodities over time. Specific

forecasts were developed showing inbound and outbound trade for 22 individual OECD member countries with 28 regional aggregates or countries worldwide.

205. This world trade forecasting methodology utilized both econometrically derived forecasts (when feasible and accurate) and less dynamic, propensity-based models. This resulted in models of commodity trade that were robust and yet relatively stable over time. Unlike many other attempts at modelling international trade flows, DRI's forecasts were developed using commodity specific models rather than sharing out total trade down to the individual product categories. Thus, commodity-specific factors were introduced both into the models and the final results. Imports and exports among the major developed market economy countries (22 OECD countries for which primary trade data was available) were balanced with exports dependent, in the case of intra-OECD trade flows, on import demand patterns.

206. Forecasts were based on estimates of macroeconomic variables drawn from DRI's extensive set of macroeconomic models (over 47 countries are modelled regularly as part of the DRI International Service). Trade models, while depending upon macroeconomic factors, were not directly lined up to country-specific trade forecasts drawn from DRI's macroeconomic services. The overall forecasts were checked by DRI against other projections of trade volumes to insure that they were reasonable.

207. Econometric Modelling Techniques. International trade was modelled both econometrically and using general propensity models driven by total trade estimates. Commodity trade balances were maintained and final forecasts integrated supply and demand by considering changes in market share as well as market demand. While solutions were not simultaneous, they did yield consistent OECD-wide forecasts of trade so that estimates of U.S. exports depended on European import demand as well as U.S. export competitiveness in European markets.

208. Compared to a typical macroeconomic model, each commodity model represented a mix of more than 500 structural equations, combined with an equal number of average relationships. By combining these past patterns with macroeconomic variables derived from DRI macroeconomic forecasts, robust estimates of world trade trends for specific commodities were generated. The integration of macroeconomic information with commodity-specific and region-specific trade data into a single forecast covered more than 40 commodities, 24 countries, and trade to and from 35 regions. Thus, the forecasts represented an overall picture for international trade characterizing direction of trade as well as total demand or supply.

209. Measuring Real Volume for Internationally Traded Products. Before discussing the structure of the world trade models in more detail, it was important to address the units of measurement that are being ultimately forecast. While for theoretical reasons it is important to forecast value of trade first rather than some quantity based measure, developing internationally consistent measures of real volume of trade when prices and exchange rates are constantly changing is difficult.

210. There is no simple method for deflating current dollar trade values into a measure of constant volume of trade. The method used was an attempt to develop a standardized methodology for deflating nominal trade values in order to allow cross country comparisons. Two principles guided the approach: 1) real changes in commodity prices should be captured; and 2) exchange rate changes should not be introduced mechanically, in order to avoid assuming the full effect of the change in international prices are passed onto buyers by sellers.

211. The lack of fully consistent, trade specific prices for commodities led DRI to develop a hybrid methodology using U.S. price statistics, exchange rates, and general export and import price indices. These synthetic measures were specific to OECD countries, specific to the commodities analyzed, and also specific to the direction of the trade.

212. U.S. Dept. of Labor price indices for U.S. imports and exports were applied. These indices are developed using survey data from U.S. importers and exporters and are commodity specific, but not specific to the direction of trade. So, to understand the effect of U.S. dollar changes on, for example, Japanese export volumes, it is necessary to abstract from these commodity-specific U.S. dollar price indices by including the impact of changes in exchange rates and general export price trends in Japan.

213. In general, for OECD country exporters, U.S. export commodity price indices for historical data and DRI price forecasts were used. For exports of LDC regions, U.S. import commodity price indices were used. For imports from OECD regions, DRI developed synthetic import price indices, specific to commodities, importing countries, and exporters; i.e., for the French imports of product k from Japan, DRI used Japanese export prices to the world for product k. When used in conjunction with the dollar denominated French exports, the result was a volume measure of French exports from Japan. These synthetic measures capture some of the dynamic movement in prices paid by importers, and are considered reasonable measures of price changes associated with commodity price trends and exchange rate adjustments.

214. Export prices for LDC's are the same as U.S. import price deflators for similar commodities based on the assumption that LDC's have kept their currency values consistent with U.S. prices

and that they have an ability to price for export consistent with developed country market developments. The only exceptions among the LDC regions are the three emerging Asian countries: Korea, Taiwan, and Hong Kong. Small adjustments in import prices for changes in these countries' exchange rates were introduced into the model's structure. The import price trends are regional and are based on export price trends of exporters. The aggregate price is the combination of export price trends weighted by actual levels of trade.

215. The advantages to the model, of having such a systematic method of measuring volume of trade across so many countries which use so many different definitions and statistical collection methods, outweigh the deficiencies of the system. The result is that estimates of the volume of trade are fully consistent with general price trends in the commodities represented and with changes in exchange rates among OECD member countries.

216. Structure of the Model. Each commodity specific trade route is constructed by DRI as a unique whole representing the exchange of products for that commodity between the major industialized countries and the world community. There are in excess of 200 countries trading in the world at present. To make the world trade model manageable, this number of countries has been subdivided into 28 partner regions.

217. The detail provided, however, is reasonable given the fact that a complete worldwide forecast is available for each of the 19 major OECD markets that account for fully 80% of world trade. Intra-developing country trade is not represented in the models structure due to the lack of reliable and timely reporter-partner country data on trade among the developing countries.

218. Reporter countries are those for which reliable detailed trade data and DRI macroeconomic forecasts are available regularly (see List A below). Listed industrialized countries account for approximately 95% or more of the trade of the OECD group (only Iceland is excluded).

List A: Major Industrialized Reporter Countries (Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Swizerland, United Kingdom, United States); Newly Industrializing Asian Developing (Hong Kong, South Korea, Taiwan)

List B: Partner Regions Used in the DRI World Trade Model
WORLD: All countries including Socialists
OECD: All 24 members of the OECD
NE: Northern European Countries
SEU: Southern European Countries
JAPAN: Japan

CANADA: Canada
U.S.: United States
AZ/NZ: Australia/New Zealand
LDC: Less Developed Countries
LATIN AMERICA
WLA: Western Latin America
ELA: Eastern Latin America
Argentina
Brazil
CLA: Carribean Basin (Central America, Mexico, and Caribbean Islands)
MEDITERREAN/PERSIAN GULF
MED: All countries bordering on the Mediterrean Sea including North Africa, Egypt, Middle East
PG: All countries bordering on the Persian Gulf
INDIAN SUBCONTINENT: India, Pakistan, Bangledesh, Afghanistan, Sri Lanka
FAR EAST
NICs (Newly Industrialized Countries in Asia)
Korea, Taiwan, Hong Kong
SEA: Southeast Asia (Singapore, Malaysia, Indonesia, Phillippines, Thailand)
AFRICA
SAF: Southern Africa, including Angola, Zambia, Zimbabwe, Malawi, and South Africa
EAF: East Africa including Kenya, Ethiopia, Uganda
WAF: West Africa including Ghana, Togo, Nigeria
EASTERN EUROPE: All countries in Eastern Europe including the Soviet Union and Yugoslavia

219. The Process: The Multistage Approach to Global Trade Forecasting. Trade for each commodity is first arranged in arrays representing the imports or exports for the reporters with each of the partner regions separately indicated. Thus, for each partner region, the export and import flows of the individual OECD reporters (see List A) for 10 years of history are arrayed in a single block of data. Within the same block, the data of the U.S. trade with the Northern European countries (summed together), and the French trade with its Northern European partners is included in the partner region sum.

220. All models are estimated using a pooled cross-sectional modelling technique. Pooled cross-sectional models combine information on many countries over a shorter time interval rather than relying upon country specific time series models over longer time periods. Because international trade data is consistently available only from 1978 at revision 2 of the UN's Standard International Trade Classification), and because pooled cross-sectional models of trade are capable, in theoretic literature, of identifying changing patterns of trade, this approach is both very practical and also theoretically justified. Thus, the econometric

models are jointly developed for 21 independent countries at the same time.

221. Cross country models are based on a theory that suggests patterns of future trade can be determined by observing the relationship between market size and economic wealth of more than a single country. Thus, the pattern of trade of an advanced, service dominated economy like the U.S. may serve as a template for future patterns of trade of other countries not as large or as wealthy.

222. The econometric relationships vary depending upon whether import or export data are used. Most of the variance explained, however, is explained by the more general economic variables for which the calculated coefficients are general to the entire set of OECD countries included in the estimating equation. To assure that non-economic factors that affect the propensity of a country to import or its ability to export a specific product are included, individual country intercepts are also calculated. The form that these intercept terms take, i.e., the independent variable that they modify, differs depending whether it is an export or import model used. Thus, for each country, the econometric equation is made up of two parts: 1) coefficients specific to that country, and 2) coefficients common to the set of countries:

223. Mikt= f(General Parameters) + bikt*Di, where i is the reporter country, k is the product type, and t is the trade direction; and where Di is the dummy variable (either 0 or 1) for each reporter country (this dummy variable has the same dimension as the trade data or the exogenous assumption data, and there is a 1 present where the country's own data is in the array and a zero where the other country's data is sequenced).

224. <u>Econometric Variables included in the DRI World Trade Models:</u>
Import equations may depend upon:
-Traded goods consumption as a share of GNP
-Import share of traded goods consumption
-Population size (market potential)
-Investment share of Gross Domestic Product
-Import prices (the adjusted local currency price after taking into account changes in local exchange rates, cross rates of exchange, and U.S. commodity price trends)
-Import prices for specific importing regions (U.S., Japan, and Northern Europe)
-Consumption of commodity (specific coefficients for U.S., Japan, Canada, Northern Europe, and Southern Europe)
-Ratio of Production of Commodity to Consumption (specific coefficients for U.S., Japan, Canada, Northern Europe, and Southern Europe)
-Country specific intercepts
-Country specific adjustment variables (for refining estimates using a two-stage estimation procedure)

Exports are a function of the following variables:
-Goods production share of Gross Domestic Product
-Exports of merchandise, adjusted for service component, as a share of production of goods
-Per capita Gross Domestic Product
-Population size
-Exchange rate adjusted wage rates
-Real growth in output relative to OECD real growth in output
-Relative wage rates (in U.S. dollars)
-Per capita GDP of exporter to importing region
-Exporter's price (includes adjustments for commodity prices, general export price trends relative to U.S. price trends and exchange rates) in importer's currency
-Investment share of GDP
-Production of Commodity (regional specific coefficients for U.S., Canada, Japan, Northern Europe, Southern Europe)
-Country specific variables measuring demand growth and relative prices in importing regions
-Country specific adjustment variables (developed using the iterative method of model adjustment)

225. The following regional variables are used in this sub-model:
-Population size (the market to be reached)
-Per capita GDP (the region's wealth)
-Relative prices: a combination term combining export prices and exchange rate movements
-Export share (a measure of regional success or trade intensity)
-Region specific coefficients for total imports
-Region specific consumption estimates for commodity
-Region specific production to consumption ratios for commodity
-Region specific intercepts (non-economic factors affecting imports from OECD)

226. To insure that the best estimation and forecasting approach is used whenever feasible, the model uses built-in software that measures the accuracy of any technique over the historical data period. It determines whether an alternative approach should be applied when their are doubts about the accuracy of the estimate of trade over the historical period.

227. Non-Econometric Approaches to Forecasting International Trade. In cases where the econometric approaches may not be sufficiently accurate (generally occurring when there is an insuficient number of observations), stable, non-econometric estimates of trade flows are developed by DRI using average patterns associated with historical periods. Such methods must, necessarily, choose criteria on which to base estimates, and such estimates are typically less volatile than the actual data they represent.

228. These non-econometric estimates are based on propensity models that use data from two macroeconomic variables rather than a single variable. The result is a forecast more accurate than simply applying proportional growth to total trade that would result from a single variable model.

229. For these non-econometric propensity models, parameters are developed. Each parameter relates for either imports or exports of a country reporter (i), and its trade with a regional group (d) of a single commodity (k). Each parameter is a function of the total demand for the commodity from the world.

230. As an example of this technique, the average import propensity against total imports of the product k from region d by country i would be calculated as follows:

APM(ikd)=M(ikd, 1985 to 1988)/M(ik,World, 1985 to 1988)

231. If the simple average technique were used exclusively, the resulting forecast would have only the variation inherent in the actual trade itself. A proportional model must yield an estimate of growth consistent with the pattern of trade of the independent variable used to forecast the model. To utilize variation in trade, period to period, for the non-econometric approach, a structure must be introduced to the simple proportional models.

232. To capture this historical variation, an approach was developed that mimics the change in the ratio over time and forecasts this change, assuming some limits on its growth rate, in the forecasting model. Thus imports, if forecast using a propensity model, reflect the changing share of the source market in total imports from the world of the commodity and the imports from the world reflect economic factors impacting on demand. This combination yields a unique forecast for each flow that will be different than the base forecast for the total trade with the world, as the following example equation shows:

GRAPM(ikd)=%Growth (APM(ikd,x-y)),where %Growth is the compound annual rate of growth for the period x-y, so that

M(ikd,t+1)=(APM(ikd,t)*(1+GRAPM(ikd))*M(ik,World,t+1)

where M is imports of country i, of product k, from region d, for time t; APM is the mean average propensity to import k from d over the period x-y relative to imports from the world of commodity k for the same time period; GRAPM is the growth rate of the APM, the market share; and M(ik,World) is the imports of the commodity from the world.

233. <u>Integration of Econometric Forecasts with Non-Econometric Model Results.</u> As discussed above, the DRI World Trade Model has to combine elements of both methods to insure that results are reasonable estimates of future patterns of growth. To do this, the

system uses a weighted distribution of estimates for trade from the stochastic propensity and econometric models.

234. Because of the huge number of trade flows forecasted and their interdependence, it is critical that the DRI World Trade Model incorporates internal tests and limits to insure that valid, reasonable forecasts are developed. With the logarithmic forms used in the econometric models, limits are imposed in the models assuring the quality of forecasts not singly, but rather for all countries and regions included in the modelling system.

235. A hierarchy of choice has been developed. If there are sufficient observations, then econometric models have been developed. If, however, there were insufficient degrees of freedom for accurate statistical models to be developed, then alternative, non-econometric approaches have been used. Or if the volume of trade was particularly small or erratic, then non-econometric approaches have again been used.

236. If an econometric model was sufficiently accurate, judged by the Standard Error as an initial test, then its forecasting accuracy was tested over the historical period in order to assess if individual country forecasts should depend upon the cross-country model results or whether they should depend, instead, upon forecasts derived from the propensity model approach (which is typically also based on the econometric model for imports from the world).

237. To do this, an average error over the period (the cumulative average percentage deviation of the forecast from the actual) for each reporter was estimated. The pooled cross-sectional model technique allowed the easy separation of each of the 19 reporters once the multi-country model was estimated. If the standard error for country i from region d for product k was over a maximum limit, MaxError, then the stochastic propensity method was used instead of the econometrically determined forecast for trade. When the standard error for the country was less than MaxError, but greater than MinError, then the non-econometrically determined estimate of trade was used. A formula was used to fix the weights:

ADJUST=(Standard Error-MinError)/(MaxError-MinError)

238. From this formula, if the Standard Error for the equation was close to the MinError, then the majority of the influence will be derived from the econometric specification. If, on the other hand, the Standard Error is closer to the MaxError then the opposite is the case.

239. If the standard error of the equation was less than the MinError, then only the forecast, adjusted by the estimated standard error for the flow (from the econometric model), is utilized.

240. Integration of Import and Export Estimates. At the end of the first stage of forecast development, preliminary forecasts of exports and imports were developed by DRI. In the second stage, these preliminary, independent estimates were merged to yield a jointly consistent forecast. The sum of the parts in the model, i.e., the demand by regions, was compared to the demand estimated by the model's equations from all sources (from the OECD, from the LDC, and from the World). For each commodity, these other estimates served as additional information and were averaged with the forecasts developed by summing the regional values. Moreover, the DRI model methodology calls for the merging of information on demand and supply from the export and import models. For intra-OECD trade, the import demand forecast serves as the template and the export supply models are used to measure market share among the export sources. Through a series of steps, the export and import estimates for countries and regions are merged together.

241. The DRI World Trade Modelling System fits together structurally, not through a set of interlocking bilateral relationships, but through a set of interrelated regional/country relationships. Thus imports of 21 reporters with the U.S. is one element in the model, as is imports of the 21 with Northern Europe taken as a single unit. Imports from the entire set of OECD countries for each of the 21 reporters is a third element. Thus, total trade of the U.S., for example, measured through reporter imports alone would be the sum of elements of each partner array for each trade direction.

242. Consistency then is gained through the integration of export and import data. American imports, from members of the Economic Community, are the exports of the individual countries in the EEC to the U.S.

243. Summary. The DRI World Trade Model is thus based on an integrated framework that analyzes data for 24 countries, exports and imports, with more than 28 major import or export regions/countries. This information is derived from a total data sample of 24 reporters with 200 countries.

244. Commodity specific forecasts are developed based on a combined econometric and average propensity framework where export and import flows are fully integrated to insure global consistency. All DRI forecasts are based on the latest econometric model variables related to patterns of trade appropriate to the individual commodity considered.

245. Crude Oil Forecast. Average annual growth of crude oil through the Delaware River system under the most likely scenario from the study year to the end of the project life is projected at the very modest rate of 0.8% per annum. The future projection was accomplished through the consideration of future growth trends in

population, economic activity, and refined petroleum product demand in the market area for the Delaware River refineries.

246. The impacts of volatility in world oil markets that occurred during the late 1970's through the 1980's are clearly reflected in historical cargo statistics for Delaware River crude imports. The "Second Oil Shock" of 1979-1980, resulting from the shut-off of Iranian crude to U.S. markets, played a critical role in shaping the profile of U.S. and Delaware River crude imports. U.S. imports of crude from alternative sources, including the newly commercialized Alaskan fields, surged in response to the supply curtailment; Delaware River imports of crude rose from 51 million short tons (MST) in 1978 to 55 MST in 1979. Sharp increases in world crude oil prices associated with the disruption of supply initiated a movement toward lower consumption levels and reduced economic growth (the recession of 1980-82). Delaware River crude imports dropped sharply from 55 MST to 43 MST between 1979 and 1980, before declining moderately over 1980 to 1983, reaching a trough of 38 MST by the end of the period. The steepness of the decline in world oil demand for crude oil during the early 1980's set the stage for the collapse of OPEC prices in 1985-1986 and contributed towards the current oversupply in world markets. Stronger economic growth in the U.S. and other industrial countries, together with the lower price of oil, has recently resulted in sharp increases in importation of both crude oil and refined petroleum products. Delaware River imports advanced from 38 MST in 1983 to 49 MST in 1989. Table 10 presents commodity projections by trade route.

247. Coal Exports. Coal has been a major export commodity in past years, although fluctuations have characterized the cargo flow. U.S. coal shipments have experienced significant competition from slow demand growth, intensive price competition, new foreign production, and excess export capacity. These problems have been magnified for the Ports of Philadelphia, as transport coal efficiencies and infrastructural development have been realized at the competing ports of Hampton Roads and Baltimore, resulting in recent erosion in Philadelphia's share of coal exports.

248. A long term decline in U.S. metallurgical coal shipments is tied, in part, to technological advances, greater availability of alternative sources of coal, and falling coal prices. Newly emerging nations are likely to pose the greatest threat, due to their practices of government subsidization and price support programs, together with large supplies of comparatively inexpensive labor. Thus, Philadelphia exports in the future are anticipated to be almost entirely bituminous steam coal and anthracite coal.

Table10. DRI Projected Growth in Crude Oil Coming Into the Port of Philadelphia by Trade Route
(Short tons)

Trade route	1989 Actual	1995 Forecast tonnage	1995 Percent growth 1989-1995	1995 Percent change 1989-1995	2000 Forecast tonnage	2000 Percent growth 1995-2000	2000 Percent change 1989-2000	2005 Forecast tonnage	2005 Percent growth 2000-2005	2005 Percent change 1989-2005
Canada	51576	0	-100.000	-100.0	0	0.000	-100.0	0	0.000	-100.0
Caribbean Basin	1983448	1439592	-5.201	-27.4	1064839	-5.852	-46.3	1039624	-0.478	-47.6
China & North Korea	859227	1080788	3.898	25.8	1407481	5.424	63.8	1619722	2.849	88.5
East Coast of South America	2030422	6470781	21.310	218.7	8643250	5.961	325.7	10286974	3.543	406.6
Far Eastern NIE	0	0	0.000	0.0	0	0.000	0.0	0	0.000	0.0
Japan	0	0	0.000	0.0	0	0.000	0.0	0	0.000	0.0
Northern Europe	2913204	979708	-18.609	-66.4	858833	-2.599	-70.5	699885	-4.011	-76.0
Other Mediterranean	663380	1063451	8.183	60.3	787335	-5.835	18.7	883765	2.338	33.2
Red Sea & Arabian Gulf	9517043	11861277	3.738	24.8	13868238	3.176	45.7	15566779	2.338	63.6
South Pacific (a)	36359 (b)	36560	0.092	0.6	39094	1.349	7.5	38361	-0.378	5.5
Southeast Asia	224430	149426	-6.554	-33.4	177548	3.509	-20.9	177080	-0.053	-21.1
Southern Africa	4339473	6226242	6.202	43.5	8344109	6.030	92.3	8146520	-0.478	87.7
West Coast of South America	2316120	1736886	-4.683	-25.0	2119066	4.058	-8.5	2407989	2.589	4.0
Southern Europe	1124018	472656	-13.444	-57.9	625678	5.770	-44.3	799767	5.032	-28.8
West Africa	19277552	25446265	4.736	32.0	27185918	1.331	41.0	28240679	0.764	46.5
Total	45336252	56963634	3.878	25.6	65121389	2.713	43.6	69907145	1.428	54.2

(Continued)

Table 10. (Continued)

Trade route	1989 Actual	Forecast tonnage	2015 Percent growth 2005-2015	Percent change 1989-2015	Forecast tonnage	2030 Percent growth 2015-2030	Percent change 1989-2030	Forecast tonnage	2055 Percent growth 2030-2055	Percent change 1989-2055
Canada	51576	0	0.000	-100.0	0	0.000	-100.0	0	0.000	-100.0
Caribbean Basin	1983448	1098888	0.556	-44.6	1175661	0.451	-40.7	1005207	-0.625	-49.3
China & North Korea	859227	2040765	2.338	137.5	2425346	1.158	182.3	2299701	-0.213	167.6
East Coast of South America	2030422	15124224	3.929	644.9	19662587	1.765	868.4	20298890	0.127	899.7
Far Eastern NIE	0	0	0.000	0.0	0	0.000	0.0	0	0.000	0.0
Japan	0	0	0.000	0.0	0	0.000	0.0	0	0.000	0.0
Northern Europe	2913204	412707	-5.145	-85.8	169716	-5.752	-94.2	31184	-6.552	-98.9
Other Mediterranean	663380	1064501	1.878	60.5	1194666	0.772	80.1	1035243	-0.571	56.1
Red Sea & Arabian Gulf	9517043	18750276	1.878	97.0	21043033	0.772	121.1	18234933	-0.571	91.6
South Pacific (a)	36359 (b)	32510	-1.641	-10.6	17737	-3.959	-51.2	4032	-5.753	-88.9
Southeast Asia	224430	204168	1.434	-9.0	242280	1.148	8.0	224389	-0.306	-0.0
Southern Africa	4339473	8610917	0.556	98.4	9212517	0.451	112.3	7876832	-0.625	81.5
West Coast of South America	2316120	2809311	1.553	21.3	2836276	0.064	22.5	2069321	-1.253	-10.7
Southern Europe	1124018	1246147	4.535	10.9	1937617	2.986	72.4	2569366	1.135	128.6
West Africa	19277552	28802590	0.197	49.4	28307376	-0.116	46.8	24203206	-0.625	25.6
Total	45336252	80197004	1.383	76.9	88224812	0.638	94.6	79852304	-0.398	76.1

249. 1987 was a down year for movements of export coal through Pier 124 as, in particular, the effect of the large 1986 drop in the price of a highly competitive fuel source, crude oil, from $28/barrel to as low as $10/barrel, was fully felt on Pier 124 coal exports. Total shipments dropped from 3.9 million tons in 1986 to 1.9 million tons in 1987. However, improved export years were seen in 1988 and 1989 with 2.3 and 2.6 million tons shipped, respectively, as crude oil prices settled at a more stable level of $16-$18/barrel and the world economy improved. The annualized growth rate from 1987 to 1989 was 15.4%. The outlook for continued movements of coal through Pier 124 is clouded because of the ongoing plan by the facility owner, Conrail, to shift movements to a terminal in Baltimore. However, by the base year, coal is expected to be moving through Philadelphia. Table 11 presents the coal export projections assuming movements through Pier 124.

250. Iron Ore Imports. Iron ore imports on the Delaware River serve as key raw material inputs to the manufacture of steel in the Eastern and Western Pennsylvania regions. Reflecting the decline of U.S. industry, especially output from older, low-technology facilities of the Eastern Seaboard states, imports of iron ore have dropped dramatically over the last decade. Flows of iron ore on the Delaware River declined from 7.3 MST in 1977 to a trough of 2.8 MST in 1983. The recession of 1980-82 served to reduce domestic demand for steel and steel-products, while the emergence of lower-cost competition from Asian producers resulted in a loss of market share for U.S. mills.

251. The import level of iron ore rebounded in 1984 to 3.6 MST, and has stabilized near that tonnage level over the recent past. For the most likely scenario, Delaware River imports of iron ore are projected in Table 12 by trade route.

252. South Jersey Port Corporation (Beckett Street Terminal). Total tonnage processed at the terminal has historically grown 67% for the time period for the last ten-year period. SJPC provided a short term forecast of tonnage which extrapolates a smoothed historical average annual growth rate. An examination of historical commodity movements have shown that the specific bulk commodities imported and exported through the terminal have changed over time as commodity markets have changed. However, as markets have changed the terminal has consistently maintained positive growth in tonnage regardless of the type of commodities handled. Based on this long term trend, one potentially benefitting commodity, the import of bituminous coal was assumed to grow at an annual rate equal to the long term growth rate. Scrap export projections to Turkey were developed using a Box-Jenkins ARIMA Time-Series Model applying historic data as input, and verified with projections developed by the WEFA Group. Tonnage for the project base year is estimated to be as follows:

Exports:	
Scrap	1,525,000
Imports:	
Bituminous Coal	244,000
TOTAL	1,769,000

253. Container Terminals. The Delaware River Port Authority has provided projections, developed by the WEFA Group, which anticipate average annual growth of 3.7% for container traffic through the Delaware River port system to the year 2005. This trend is expected to be representative of the growth which would occur during the first twenty years of the project life for purposes of this analysis, and then held constant over the remainder of the project life. Refer to Table 13

Table 11. DRI Projected Growth in Coal Leaving From the Port of Philadelphia by Trade Route
(Short tons)

Trade route	1989 Actual	Forecast tonnage	1995 Percent growth 1989-1995	Percent change 1989-1995	Forecast tonnage	2000 Percent growth 1995-2000	Percent change 1989-2000	Forecast tonnage	2005 Percent growth 2000-2005	Percent change 1989-2005
Canada	448680	522361	2.567	16.4	520184	-0.083	15.9	477913	-1.681	6.5
East Coast of South America	54826	5487	-31.862	-90.0	5683	0.704	-89.6	5216	-1.700	-90.5
Eastern Europe	57966	41492	-5.420	-28.4	32761	-4.615	-43.5	34371	0.964	-40.7
Northern Europe	854449	824242	-0.598	-3.5	846235	0.528	-1.0	820673	-0.612	-4.0
Other Mediterranean	582868	853353	6.560	46.4	586196	-7.235	0.6	291611	-13.033	-50.0
Southern Europe	197586	213465	1.297	8.0	197709	-1.522	0.1	187567	-1.048	-5.1
Total	2196375	2460400	1.910	12.0	2188768	-2.313	-0.3	1817351	-3.651	-17.3

Trade route	1989 Actual	Forecast tonnage	2015 Percent growth 2005-2015	Percent change 1989-2015	Forecast tonnage	2030 Percent growth 2015-2030	Percent change 1989-2030	Forecast tonnage	2055 Percent growth 2030-2055	Percent change 1989-2055
Canada	448680	394062	-1.911	-12.2	241196	-3.220	-46.2	60175	-5.402	-86.6
East Coast of South America	54826	4174	-2.204	-92.4	3411	-1.337	-93.8	2837	-0.734	-94.8
Eastern Europe	57966	37051	0.754	-36.1	42199	0.871	-27.2	37102	-0.514	-36.0
Northern Europe	854449	726945	-1.205	-14.9	674503	-0.498	-21.1	529430	-0.964	-38.0
Other Mediterranean	582868	40172	-17.981	-93.1	18632	-4.993	-96.8	52785	4.253	-90.9
Southern Europe	197586	197457	0.515	-0.1	210354	0.423	6.5	152665	-1.274	-22.7
Total	2196375	1399861	-2.576	-36.3	1190295	-1.075	-45.8	834994	-1.408	-62.0

Table 12. DRI Projected Growth in Iron Ore Coming Into the Port of Philadelphia by Trade Route
(Short tons)

Trade route	1989 Actual	1995 Forecast tonnage	1995 Percent growth 1989-1995	1995 Percent change 1989-1995	2000 Forecast tonnage	2000 Percent growth 1995-2000	2000 Percent change 1989-2000	2005 Forecast tonnage	2005 Percent growth 2000-2005	2005 Percent change 1989-2005
Canada	1481796	1767710	2.984	19.3	1811329	0.489	22.2	1711596	-1.126	15.5
East Coast of South America	2300036	3106570	5.138	35.1	4482764	7.610	94.9	5720694	4.998	148.7
Northern Europe	52714	55573	0.884	5.4	58215	0.933	10.4	51553	-2.401	-2.2
Western Africa	0	0	0.000	0.0	0	0.000	0.0	0	0.000	0.0
Total	3834546	4929853	4.277	28.6	6352308	5.201	65.7	7483843	3.333	95.2

Trade route	1989 Actual	2015 Forecast tonnage	2015 Percent growth 2005-2015	2015 Percent change 1989-2015	2030 Forecast tonnage	2030 Percent growth 2015-2030	2030 Percent change 1989-2030	2055 Forecast tonnage	2055 Percent growth 2030-2055	2055 Percent change 1989-2055
Canada	1481796	1396536	-2.014	-5.8	920571	-2.740	-37.9	340971	-3.895	-77.0
East Coast of South America	2300036	8480257	4.015	268.7	11766061	2.207	411.6	13119948	0.437	470.4
Northern Europe	52714	38187	-2.957	-27.6	11905	-7.478	-77.4	900	-9.814	-98.3
Western Africa	0	0	0.000	0.0	0	0.000	0.0	0	0.000	0.0
Total	3834546	9914980	2.853	158.6	12698537	1.663	231.2	13461819	0.234	251.1

TABLE 13

PROJECT CONTAINER CARGO
NORTH ATLANTIC PORTS
(000'S TEUs)

	1985	1990	2000	2005	MARKET SHARE
NEW YORK	2367	3035	3640	5235	64.9%
BALTIMORE	706	905	1086	1561	19.4%
NORFOLK	401	514	740	887	11.0%
PHILADELPHIA	171	219	315	378	4.7%
TOTAL	**3645**	**4674**	**5605**	**8061**	**100.0%**

PROBLEMS, NEEDS, AND OPPORTUNITIES

254. The following sections discuss the problems, needs, and opportunities for the region with regard to the adequacy of the waterways, facilities, and landside transportation systems to accommodate vessels and commodity movements.

255. NEED FOR WATERWAY IMPROVEMENTS. Waterway dimensions present problems in many of the project areas within the region. The following paragraphs include a summary of problems and needs as well as the potential for further study effort.

256. Philadelphia to the Sea. The major problem identified on the Philadelphia to the Sea project is the need for a deeper access in order to handle the present and future tankers, dry bulk carriers and container vessels more efficiently. Provision of a deeper channel would reduce the non-structural practices, such as lightering and light loading now in use by the restricted vessels. In addition, several users are likely to use larger vessels if a deeper channel is provided.

257. With channel deepening there will be a need to evaluate the deepening of anchorages, as well as tributary projects and access channels to the public terminals. The realignment of the channel under the Benjamin Franklin Bridge, as requested by local shippers, also warrants consideration, to provide more efficient movement to the upper channel.

258. Philadelphia to Trenton. Problems along the Philadelphia to Trenton project generally consist of the need for adequate channel maintenance to the Mercer County Generating Station and the need for maintenance of the 40 foot channel up to the USX Steel facility at Fairless. There is no identified need for deepening of the access to Tioga Marine Terminal beyond the authorized 36 feet. Problems related to maintenance of the channel project to Duck Island and adequate maintenance of the 40 foot channel are problems which should be handled by the Operations and Maintenance program. The USX plant is the only facility identified which is constrained by the 40' main channel. Therefore, in the absence of multiple beneficiaries further study does not appear to be in the Federal interest.

259. Christina River (Wilmington Harbor). No present interest for further deepening of the project has been identified. Subsequently facility expansion of the Port of Wilmington facility onto the Delaware River could be handled by Continuing Authorities efforts under Section 107.

260. Schuylkill River. The Water Resources Development Act of 1988 authorized deepening the lower Schuylkill River from 33' to 40'. No need for further deepening of the project has been identified.

261. Delaware River in the Vicinity of Camden. A need exists for additional depths at South Jersey Port Corporation's Beckett Street Terminal in Camden to efficiently handle the dry bulk vessels calling at that facility. Further study is warranted of deepening the main channel as well as the access to Beckett Street Terminal, since this is a public terminal and improvements would be within the Federal interest. South Jersey Port Corporation has plans to extend Beckett Street Terminal's southernmost berth and has recently adopted a Port masterplan for the development of new berth space to the south of the existing terminal. Bulk vessels calling at the existing facilities can benefit from main channel deepening and deeper access to the terminal.

262. NEED FOR DREDGED MATERIAL DISPOSAL. Dredging and associated disposal in the study area involves two distinct operations. Federal project dredged material is usually disposed of in Federally owned or leased sites. In many cases it is the responsibility of the Federal Government to provide the necessary disposal areas. Non-Federal dredging includes berth maintenance and dredging to provide access from berthing areas to one of the Federally maintained channels. Most of this associated material is placed in disposal areas that are provided by the dredging contractor or sites owned by the facilities.

263. Annual historic dredging quantities for the deep draft projects in the Delaware River System total about 11 million cubic yards annually including 8 million from the Federal projects and 3 million from non-Federal.

264. The problem of dredged material disposal is project specific. A description of the problems associated with each specific Federal deep draft project and the specific maintenance volumes follows:

265. Delaware River, Philadelphia to the Sea. Annual maintenance dredging volumes total about 5.4 million cubic yards for this project's features. Eight existing upland disposal sites are located along the project. In order to adequately handle dredged material from the existing Federal project through the study period at least two new upland dredged material disposal sites were projected to be needed in the upper river and possibly one in the middle river depending on ultimate dike heights. Any further deepening of the project would require additional site development with provision of disposal areas a non-Federal responsibility in accordance with the W.R.D.A. of 1986.

266. Delaware River, Philadelphia to Trenton. The upland dredged material disposal sites were leased by the local sponsor. During the study period two additional sites were projected to be needed by the year 2010 to handle the existing project maintenance, which averages 550,000 cy annually. Provision of additional sites is a non-Federal responsibility.

267. Christina River, Wilmington Harbor Project. Two existing Corps upland disposal areas and the additional disposal area under construction will provide sufficient disposal capacity through 2030 for existing project conditions. An additional site will be required beyond that for maintenance operations during the remainder of the study period, which average 1.2 million c.y. annually.

268. Schuylkill River. This project is hydraulically dredged and the material deposited in an upland disposal area with sufficient disposal capacity through the year 2030. An additional site will be required during the study period to accommodate maintenance dredging which average 310,000 c.y. annually unless the dike heights can be raised above 50 feet.

269. Delaware River in the Vicinity of Camden. The maintenance requirements of this project are limited and have been included with those for the Philadelphia to the Sea project since this project is geographically located within the latter's boundaries. Annual maintenance volumes are approximately 10,000 c.y,

270. Additional Requirements. Beyond the disposal areas established to sustain existing maintenance requirements, additional disposal capacity may be required. The construction and maintenance of waterway improvement resulting from this study will require additional disposal areas beyond that discussed above.

271. ADEQUACY OF TRANSPORTATION NETWORK. The capacity analysis examines the overall adequacy of the transportation systems with respect to the level of current usage and future requirements.

272. Highway Assessment. The primary regional access highways in New Jersey are the New Jersey Turnpike and I-295, serving the northshore corridor. In addition Route 55 was completed in 1989 which provides more direct access from the Philadelphia-Camden area to southeastern New Jersey. Regional access to and from the Delaware River ports from New Jersey appears adequate to sustain normal traffic growth through the 1990's and well past the year 2000 as presently planned construction and improvement projects are completed. Throughout the study period the highway system will continue to be maintained and upgraded as it has historically to provide adequate highway access to New Jersey.

273. The primary regional access highways in Pennsylvania are the mainline Pennsylvania Turnpike (I-276), the Northeast Extension of the Turnpike (Route 9), I-95, and the mainline Schuylkill Expressway (I-76) with its Vine Street extension. The recently constructed I-476 connects I-95 near Chester with the Pennsylvania Turnpike at its junction with the Northeast Extension. Now that the I-476 and the Vine Street extension are completed, the network provides adequate access to and from the Delaware River Ports and will sustain normal traffic growth through the 1990's and well past

the year 2000. Throughout the study period the highway system will continue to be maintained and upgraded as it has historically to provide adequate highway access to Pennsylvania.

274. The Delaware highways evaluated for adequacy were the Delaware Turnpike (I-95), US 40 in the Northeast Corridor, and US 13 and 301 on the Delmarva Peninsula. A new alternative north/south route which would reduce congestion on Route 13 is planned for construction in the early 1990's. These highways are adequate to sustain normal traffic growth through the 1990's and well past the year 2000.

275. The primary interstate and intrastate highway system serving the Delaware River Ports and its hinterlands is currently operating at less than full capacity. With the planned completion of such highway links as I-295, I-195, and I-287 in New Jersey, the widening of the Delaware Turnpike and I-95 in Pennsylvania, and other Pennsylvania and New Jersey improvements, it would appear the highway access to the region will be adequate into the future. Constraints to regional development and port operations are not expected to result from any regional highway access bottlenecks. There are no known problems related to highway access from port terminals.

276. Rail Transportation Assessment. Conrail and the Chessie railroads provide the primary rail service connection between the Philadelphia ports and the hinterland region they serve. Each of the two railroads operates at levels considerably below its stated capacity and present no constraint to project port development and commodity movements.

277. Both companies have made considerable investments in improving their systems in recent years, including rehabilitation of trackage and new rolling stock. Conrail has spent over $200 million on track rehabilitation in the northeast U.S. since 1976. An additional $42 million has been spent by Conrail to expand and upgrade its Pier 124 coal facility to handle upwards of 10 million tons of coal per year. In further support of its coal operation, Conrail has acquired more than 5000 additional hoppers, raising its fleet on serviceable hoppers to 35,000. Other investments have been made in the form of a rail container facility in Morrisville, which will also serve the Philadelphia Region. Another intermodal facility is planned for the Greenwich Rail Yard in South Philadelphia which will enhance the port's ability to attract containerized cargo and maintain its market share. In addition, the Canadian Pacific's acquisition of the Delaware and Hudson Railway in the $25 million dollar purchase in 1991 will add a third truckline with access throughout Canada and replace considerable international traffic now entering Canada via Halifax, Nova Scotia.

278. Overall, rail capacity is adequate, as is service to area shippers. Previous studies have found that Conrail's overall

service reliability and equipment supply have improved substantially in recent years. With its present utilization between 30-50% of capacity, the company can provide for substantial expansion in throughput as the need arises.

279. A similar ability exists for the Chessie system. Handling capacity on Chessie-operated lines are upwards of 50 trains daily into and out of the Philadelphia/Wilmington area. However, an average of only 10 trains operates daily.

280. A third railroad, Canadian Pacific via its D&H Railway subsidiary has recently gained access to the area and will service DRPA's regional intermodal transter facility.

281. Air Transport Assessment. Based on information provided by the Philadelphia International Airport, total plane movements appear to have remained relatively constant except for commuter (passenger) traffic. Four basic categories contribute to this movement: carrier, commuter, military, and general aviation. It appears, analyzing available data, that the trend toward movement of cargo by air is slowing. Area facilities are adequate for any increase in movements. At this time, it does not appear that air freight transport facilities will constrain any potential development of the ports in the study area.

282. Pipeline Transportation Assessment. The North Atlantic coastal ports are served by a number of clean petroleum products pipelines. The Colonial Pipeline, originating in the Houston/Galveston refining territory, is the largest pipeline in the United States. It passes through major refining centers in Louisiana, gathering products for delivery throughout the eastern United States. By connection to other pipelines, petroleum can be gathered from many major Texas and Louisiana refineries. Important delivery points include Norfolk and York River, VA: Baltimore, MD, Paulsboro and Trenton, NJ: Philadelphia and Marcus Hook, PA: and New York Harbor. A connection with the Buckeye pipeline extends service to Long Island, NY. The Colonial Line can deliver 732,000 barrels per day to the northeastern United States through its 32-inch pipe, with an ultimate capacity of 930,000 barrels per day. The Plantation Pipeline is the second largest products line from the Gulf Coast, and generally parallels the route of Colonial line. Although the line ends at Washington, D.C., it also serves a major section of the North Atlantic Coast and has a capacity of over 400,000 barrels per day.

283. At least six product pipelines cross Pennsylvania to serve the western part of the state, Ohio, and points west from the refining centers on the Delaware River. Two lines connects to New York-area refineries. The major Buckeye Pipeline connects to several other pipeline systems in the midwest, providing a continuous link to the Gulf Coast refineries. Part of the Buckeye system and the Texas Eastern Pipeline includes the famous Little

Big Inch Line, constructed during World War II to serve the East coast in an emergency. The Delaware River refineries are tied to the New York-area refineries by three pipelines besides the Colonial line: the Sun Oil Line (14-inch), the Buckeye line (16-inch), and the Harbor Projects line (16-inch). The present pipeline system operates below capacity and does not represent a constraint to future oil refinery production.

284. ADEQUACY OF PORT FACILITIES. It can be expected that adequate facilities will be available for the level of tonnage projected in the future for those commodities identified to benefit from a channel modification. As per ER 1105-2-100, in projecting commodity movements, sufficient capacity of hinterland transportation and related facilities, including port facilities, should be assumed unless there is substantive data to the contrary. No major throughput capacity problems in handling projected tonnage over the project life are anticipated. Port facilities are expected to be upgraded and replaced as the need arises. Landside transportation systems are also expected to keep pace with commerce requirements.

285. Crude Oil. The import level for crude oil is forecasted to be 79 million tons in 2055. The refineries will need to expand their current 60 million ton capacity modestly in order to process the tonnage projected. The refinery capacity is expected to increase in the future through technology changes, upgrading facilities, expansion, and new development in order to accomodate project commodity flow.

286. Coal. The maximum coal export forecast over the project life is 1.8 million tons. This volume will not require an increase in capacity, as current capacity is 10 million tons.

287. Iron Ore. Iron ore imports are forecast to be 13 million tons in the year 2055. This volume can be accomodated by a modest increase in capacity of existing facilities (10.5 million tons).

288. South Jersey Port Corporation. Benefitting tonnage is projected to be approximately 3.5 million tons in 2055. This volume can be accomodated by capacity to be available by 1998, based on the long-range Master Plan of the South Jersey Port Corporation.

289. Containers. Benefitting tonnage is projected to be 2 million tons in 2055, which can be handled by existing capacity.

290. The Beckett Street Terminal, operated by South Jersey Port Corporation, has experienced increased business in recent years. In the last decade, South Jersey Port has expended approximately $15,000,000 to modernize the bulk cargo handling facilities and marginal berths at Beckett Street, with the result that Beckett

Street Terminal now has the capacity to handle large quantities of bulk cargo efficiently.

291. South Jersey Port Corporation (SJPC). The Land area currently owned by SJPC for Beckett Street Terminal is 74 acres. SJPC also has four berths, with 2300 L.F. of length. Expansion and development plans include additional land acreage of 260 acres and additional berthing length of 4100 L.F. (to be completed by 1995). Throughput capacity projected by SJPC for Beckett Street Terminal for all commodities, when fully developed by 1998 in accordance with their Long-Range Master Plan, will be in excess of 10 million tons of bulk commodities annually.

292. Oil Pollution. The input of oil into the Delaware River results form several activities, including refinery and other industrial operations, urban runoff, municipal waste, and tanker traffic. In 1975, the input of oil from onshore operation (not including that resulting from tanker operations) was estimated at 59,000 gallons per day or about 21.5 million gallons per year. Following enactment of the Clean Water Act in 1977, this oil discharge decreased by over one-half.

293. The potential for oil spills and concern over the negative environmental impacts involved is very much a public concern. Any oil spill event in the Delaware River must be reported to the National Response Center. Under the National Oil Spill Contingency Plan (NCP), there are National, Regional, and Local Response Teams. The Region III and Region II Emergency Response Teams have jurisdiction in the Delaware River Comprehensive Navigation Study area. The Region III Response Team consists of representatives of the following:

- Environmental Protection Agency
- U.S. Coast Guard
- Department of Agriculture
- Department of Commerce
- Department of Defense
- Department of Energy
- Department of Health and Human Services
- Department of the Interior
- Department of Labor
- Federal Emergency Management Agency
- Commonwealths of Pennsylvania, Virginia, and District of Columbia
- States of Delaware, Maryland, and West Virginia

294. The Region II Response Team is composed of the same Federal agencies plus the States of New Jersey and New York. Under the Regional Contingency Plan (RCP) in the Delaware River Comprehensive Navigation Study Area the U.S. Coast Guard Captain of the Port, Philadelphia (COTP) is designated as the on scene cleanup coordinator (OSC). The OSC can call upon support for spill clean

up from the Atlantic Strike Team (located at Fort Dix, NJ), a specially trained and equipped contingent of NCP's National Strike Team; the Delaware Bay and River Cooperative (DB&RC), a consortium of oil, chemical, and petroleum transportation companies which operate two cleanup vessels and have an assortment of other kinds of cleanup equipment at their disposal; members of the Regional Response Team; and representatives of the Local Response Team such as the New Jersey State Police and the Philadelphia Fire Department. The Regional Contingency Plan is updated on a continual basis and would be updated to reflect any changes in current vessel traffic patterns due to a modified project.

295. U.S. Coast Guard data from 1973 to 1989 on vessel-related oil spills in the Delaware River revealed a gradual decline in both the number of spill incidents and the volume. Much of it can be attributed to the increase in tanker vessel size and the use of larger tank barges for lightering. Twenty-five percent of the spills analyzed involved residual fuel oil, 20 percent involved crude oil, and another 20 percent involved diesel fuel. Additional petroleum-related materials spilled in the river were gasoline, other distillate fuel oils, and waste oil. On a volume bases, crude oil comprised 44 percent of material spilled followed by residual fuel oil with 26 percent.

296. Lightering operations have occurred at the Big Stone Beach Anchorage since the 1960's. Transfer accidents in the Delaware River occur at a rate one-half that of the national average of 8 accidents per 1000 transfers. The average national lightering spill is about 32 gallons. For the Delaware such spills are immediately cleaned up using an oil skimmer which is permanently stationed at Lewes, Delaware and operated by the Delaware Bay and River Cooperative.

297. Most of the oil spilled into the Delaware River has been the result of tanker and barge accidents. Refer to Table 13 for a listing of the major oil spills which have occurred in the Delaware River since 1973. Major incidents such as these are usually the result of human error and structural or mechanical failures. After an oil spill event, a prompt and efficient oil spill cleanup can reduce many adverse impacts. An analysis of recent large spills in the Delaware River reveals that cleanup operations are generally very effective at removing the spilled oil from the water and protecting ecologically sensitive shoreline areas. Records show that the DB&RC vessels have been able to recover 60 to 70% of the spilled oil. In the aftermath of the catastrophic Exxon Valdez oil spill in Prince William Sound Alaska, several actions have been taken to lessen the chances and reduce the impacts from similar spills that may occur in the future. Since the enactment of the Oil Pollution Act of 1990, all vessels must have spill response plans to deal with the worst case oil spill that could occur.

Table 14 - Major Oil Spills in the Delaware River, 1973-1989

Year	Volume (gallons)	Vessel Source	Location	Accident Type
Spills Greater than 100,000 Gallons				
1973	126,000	Tanker	Marcus Hook	Grounding
1974	285,000	Tanker	Philadelphia/Camden	Collision
1975	500,000	Tanker	Marcus Hook	Collision
1976	134,000	Tank Barge	Marcus Hook	Grounding
1978	630,000	Tank Barge	New Castle-Reedy Island	Sinking
1979	189,000	Tank Barge	Marcus Hook	Collision
1985	525,000	Tank Barge	Philadelphia/Camden	Grounding
Spills Greater than 10,000 Gallons but less than 100,000				
1973	14,720	Tanker	Ocean Throughway to Delaware Bay	Grounding
1974	13,000	Tanker	Philadelphia/Camden	Fire/Explosion
1975	12,000	Tanker	Marcus Hook	Collision
1975	73,000	Tugboat	Philadelphia/Camden	Capsizing
1976	84,000	Tanker	Philadelphia/Camden	Collision
1979	16,800	Tanker	Philadelphia/Camden	Pipe Rupture

These plans must be in place by February 18, 1993. Also, the Marine Spill Response Corporation (MSRC) was created and incorporated in 1989. This not-for-profit corporation was created to assist in the cleanup of large oil spills using state of the art technology. Lastly, there is increasing public pressure to require vessels that transport oil to have double hulls, back-up steering and emergency back-up propulsion systems.

298. Although minor spills also occur periodically, the Delaware River has functioned safely considering the huge volume of oil that is transported on the river. Channel dimensions have not been identified as a contributing factor to the previous accidents or oil spills on the Delaware River. Through proper planning and design of waterway improvements and navigation aids, the potential for accidents can be minimized. There is potential to reduce oil pollution due to lightering operations by main channel deepening. This would alleviate the need for lightering vessels in the 40' to 45' range.

299. Summary of Problem Identification. In summary, this section has provided an assessment of the present and expected future problems within the study area that could have an effect on navigation.

300. The current authorized channel dimensions on the main stem and Delaware River in the Vicinity of Camden present a constraint to efficient vessel movement. The Delaware River main stem channel dimensions constrain dry and liquid bulk movements. Alternatives such as lightering, lightloading and waiting for tides are in themselves inadequate to solve the problem.

301. The facility adequacy assessment described above indicates that in the near term there are expected to be no problems related to the Delaware River regions facility or cargo handling capabilities. However, in the mid to long-term, beyond 2020, given the expected growths in commodity movements, it appears that there will be a need for general cargo and dry bulk facilities open for public use. It has been assumed, based on the historic and current trends and facility development plans, that facilities will be developed or utilized to the degree required to meet regional demands in the future. The capacity of the existing landside transportation network along with the proposed improvement is expected to be able to provide adequate service to and from the hinterlands, both now and in the future.

PLAN FORMULATION

302. Plan formulation is the process of establishing study objectives, identifying and developing alternative measures, evaluating and assessing alternative plans, and selecting the best plan. The purpose of this section is to provide the background process and procedures followed in this study.

PLANNING OBJECTIVES

303. The following planning objectives were established for formulation of plans to address the problems, needs and opportunities identified under the without project conditions over the study's 50 year period of analysis:

Provide adequate and safe navigation channels and appurtenances to accommodate vessels travelling along the Delaware River for which existing channel dimensions are a problem.

Identify and systematically examine alternatives available for increasing the efficiency of waterborne commerce.

Identify and evaluate acceptable disposal sites and techniques for disposal of material dredged within the study area, such that dredged material disposal capacity is sufficient for initial construction and maintenance requirements during the study period.

Protect fish and wildlife resources in the study area during initial construction and project maintenance.

PLANNING CONSTRAINTS

304. The formulation and evaluation of alternative plans must be constrained by technical and economic criteria. Further constraints are caused by environmental policies and institutional requirements.

Project features will be designed in accordance with criteria contained in Corps of Engineers' regulations for deep-draft navigation channels, with consideration to the views of pilots and the U.S. Coast Guard regarding safety of design.

Dredged material disposal areas should be capable of handling all types of material normally dredged in the Delaware River (silt, sand, rock).

Channel designs and projected vessel usage should be compatible with the vertical and horizontal clearances

provided by existing bridge or utility crossings which cannot be relocated at a reasonable cost.

Project vessel usage and channel depth requirements should not exceed limitations to vessel size presented by waterway dimensions both along the trade route and at the port of the trading partner.

305. ECONOMIC CONSTRAINTS

In accord with ER 1105-2-100, Chapter 6, Section VII, NED Benefit Evaluation Procedures: Transportation (Deep Draft Navigation), the estimation of deep-draft navigation benefits was accomplished. Economic constraints limit the range of alternatives considered based on principles of project optimization. The following items constitute the economic constraints foreseen to impact formulation of alternatives to be considered:

-Shippers are assumed to use the least cost mode of transportation if there are no overriding noneconomic factors influencing modal preference including shipment size and vessel availability.

-Shippers are expected to make maximum use of nonstructural measures in order to minimize transportation costs.

-Analyses of project benefits and costs are to be conducted in accordance with Corps of Engineers' regulations and must assure that any plan is complete within itself, efficient and safe, and economically feasible.

-Economic evaluations of project justifications must assume that authorized channel dimensions are maintained and will evaluate the incremental justification of channel modifications.

306. ENVIRONMENTAL CONSTRAINTS. Appropriate measures must be taken to ensure that resulting projects are consistent with local, regional, and state plans, and that the necessary permits and approvals are likely to be issued by the regulatory agencies. Identification of a viable NED plan necessitates likely approval for required permits and certificates.

The Coastal Zone Management Programs in the states of Pennsylvania, New Jersey and Delaware each prohibit certain activities as being contrary to fundamental coastal resource management goals, even with full mitigation. These activities are:

	Prohibited in		
Activity	PA	NJ	DE
Wetland destruction	*		
Stream relocation		*	

Stream modification resulting in increased flooding potential	*	*	*
Shellfish/oysterbed destruction		*	*

Compliance with numerous Environmental Quality Protection Statues and other Environmental Review Requirements will also be required. These include:

- Archaeological and Historical Preservation Act
- Clean Water Act, as amended
- Clean Air Act of 1977
- Coastal Zone Management Act of 1972, as amended
- Endangered Special Act of 1973, as amended
- Fish and Wildlife Coordination Act
- Marine Protection, Research and Sanctuaries Act
- National Historic Preservation Act, as amended
- National Environmental Policy Act, as amended
- Rivers and Harbors Act
- Executive Order 11988 Floodplain Management
- Executive Order 11990 Protection of Wetlands
- Executive Order 12114 Environmental Effects of Major Federal Actions

PLAN FORMULATION RATIONALE

307. The formulation process used to develop and evaluate alternative plans was based on the consideration of all possible alternatives with the potential for addressing the planning objectives and meeting the technical, economic and socio-environmental criteria. This process was accomplished in several different formulation iterations, or cycles. The first step included the preliminary screening of all possible structural and non-structural alternatives and their associated features. Based on technical and economic reasons, a number of these measures were subsequently evaluated in the formulation process, involving several iterative cycles, each with different emphasis.

MANAGEMENT MEASURES

308. The purpose of this portion of plan formulation, accomplished during the development of the reconnaissance portion of the study, was to screen alternative solutions to navigation problems of Federal interest. There are numerous measures which address the efficiency of waterborne commerce. These measures fall into the broad categories of waterway conditions, disposal of dredged material, and provision of adequate landside facilities and transportation. A variety of structural and non-structural measures are possible for these various components of the waterborne transportation system. Most of the non-structural waterway measures are currently in practice to make optimum use of the existing Delaware River projects. These management measures

include those which are within the authority of the Federal government to implement, as well as those which are within the authority of non-Federal governments, port authorities, corporations, and shippers.

309. WATERWAY IMPROVEMENTS. The waterway-related measures which could improve the safety or efficiency of waterborne commerce include:

Structural	Non-Structural
. Channel modification (widening, deepening, realignment, extension)	. Transshipment (lightering, topping off, or modal shifts)
. Anchorages	. Use of high tides for vessel movements, loading, unloading
. Breakwaters and Jetties	. Lightloading
. Aids to Navigation	. Modification to pilot regulations
	. Tug assistance
	. Modification of vessel design or operational characteristics
	. Scheduling/traffic management

310. DREDGED MATERIAL DISPOSAL. Measures to provide additional disposal area capacity and maximize capacity at new sites include the following:

- raising dikes
- dewatering
- reusing dredged material
- extending leases
- using sedimentation basins to reduce shoaling
- acquiring new upland sites
- ocean/bay disposal (filling holes, bottom dumping, and thin layering)
- island/wetland/upland creation

FORMULATION AND EVALUATION CRITERIA

311. GENERAL. All plans were formulated and evaluated on the basis of technical, economic, and socio-environmental criteria. These criteria, along with intangible considerations, permitted the development and tentative selection of plans which best responded to the planning objectives. The specific criteria are as follows:

312. TECHNICAL CRITERIA. The following technical criteria are used to develop and analyze alternative plans:

Each alternative is designed as a complete project that does not obligate the Federal government to future work, except for maintenance as provided by law.

Analyses of project benefits and costs are to be conducted in accordance with Corps of Engineers' regulations and must assure that any plan is complete, efficient, safe, and economically feasible in terms of current prices.

The formulation of disposal area sites will consider the effect that channel deepening could have on the existing Federal project and existing Federally provided disposal sites. These options varying the means the local sponsor provides for disposal capacity are:

a) Deposit all material (initial construction and increased maintenance) into an upland Federal disposal site and require local sponsors to reimburse the Federal government.

b) Deposit all material into a Federal upland disposal site but require local sponsors to transfer material to a locally provided final site.

c) Deposit all material into a disposal site provided by the local sponsors.

d) Deposit the required volume of material (initial construction and increased maintenance) into a locally provided disposal site while using a Federally provided site as economically practicable.

e) Deposit material at an aquatic site in Delaware Bay with consideration for beneficial uses such as wetland/island/upland creation, oyster seed bed creation, and sand stockpile.

313. Any use of Federal disposal areas on a reimbursement basis by local sponsors should make the government whole, have no significant impact on the remaining capacity of the Federal sites, and should not result in a short-term need for replacement sites by the Federal government which could impact the maintenance dredging capabilities.

314. Channel and turning basin designs are in accordance with design criteria contained in EM 1110-2-1613, titled "Engineering and Design-Hydraulic Design of Deep Draft Navigation Projects" dated 8 April 1983. Safe underkeel clearance is to be established through coordination with the appropriate pilots and vessel operators and the U.S. Coast Guard. For quantity computations, up to two (2) feet below the channel design depth (overdepth) is

allowed as a tolerance in the dredging operation, the present practice for dredging contracts.

315. Designs and layout of alternatives is to be coordinated with the appropriate pilots and vessel operators and the U.S. Coast Guard to assure safe design. Layout of suitable navigation aids is to be accomplished by the U.S. Coast Guard.

316. SOCIO-ENVIRONMENTAL CRITERIA. The following socio-environmental criteria and intangible effects were considered in the plan formulation and evaluation:

Protect public health, safety and well-being.

Avoid, where possible, detrimental environmental impacts and include features to prevent unavoidable adverse effects.

PRELIMINARY SCREENING OF ALTERNATIVE MEASURES

317. GENERAL. The following discussion describes the formulation and screening of alternative measures in the plan development of this study. Both structural and non-structural measures are addressed.

318. STRUCTURAL MEASURES. The formulation and screening of structural measures is discussed below.

319. Channel Modification. Channel modifications benefits existing or potential users by allowing use of larger vessels, reducing or eliminating more costly non-structural measures, preventing accidents and vessel damages, allowing a shift to waterborne movement from a more costly mode, or by lowering total transportation costs for commodities moving through other ports or to other origins and destinations. The problem identification section indicates that there is a significant amount of traffic in the Delaware River and Bay region which utilizes one or a combination of several non-structural measures due to channel limitations. Channel modification is addressed for all problem areas on the Delaware River where there appear to be problems with the depth, width, alignment or length of navigation channels.

320. Anchorages. Anchorages for general use are designated by the U.S. Coast Guard for short term anchoring (48 hours maximum without special permission). Ships may anchor while waiting for favorable tidal conditions, safe weather conditions for operation, repairs or for the availability of berth space. Lightering is conducted at some general anchorages. Special anchorages may be designated for specific purposes such as for tanker lightering, anchoring of ships carrying explosives and natural gas, or anchoring of naval vessels. Investigation of anchorage utilization is included as a necessary part of this study.

321. Breakwaters and Jetties. Breakwaters are used to protect a harbor or beach from the force of waves. As such breakwaters alleviate the effects of wave action, such as beach erosion or damages to vessels or harbor structures. Jetties are constructed at the entrance of restricted waterways to minimize the effect of cross currents on navigation as well as to reduce the amount of shoaling occurring in the channel. Neither would be a benefit to navigation along the main channel of the Delaware River.

322. Navigation Aids. Navigation aids include range lights, buoys, lightships, raycon beacons, maritime radio beacons, loran, fog signals, and sunken vessel markings, all of which are installed and maintained by the U.S. Coast Guard. These aids mark navigation channels and maneuvering areas for safe movement of vessels and provide reference points with which pilots can determine vessel position. Means to improve navigation aids will be investigated in conjunction with the Coast Guard.

323. Oil Pipeline. This alternative would require construction of a crude oil facility as a means of improving importing of crude oil into athe Delaware Estuary. A pipeline terminal would require continued use of larger tankers for transatlantic travel. Earlier Deepwater Port studied for Delaware Bay all predicted more imported oil and greater use of larger tankers than now thought reasonable. Delaware River tanker traffic would be reduced with construction of a crude oil pipreline but not eliminated since outbound chemicals and refined products will still need to travel by water.

323. Big Stone Beach Anchorage Terminal, Delaware Bay. An oil terminal and pipeline option from this location to the refineries was analyzed in detail as part of the North Atlantic Coast Deepwater Port Study done in the early 1970's. The corps concluded at that time that net benfits were marginal and potential ecological and social costs to the coastal zone were considerable. Without a project sponsor no recommendation for future studies was made. A group of oil multi-component artificial island port located here. While no formal recommendations were made interest was developed.

324. An updated analysis of an island terminal facility located in the lowaer Delaware Bay off Big Stone Beach Anchorage was reanalyzed by the Corps in 1984. Designed like the main channel deepening to handle coal and iron ore as well as crude oil, benefits could only offset 60% of the high construction cost of $1.4 billion assuming present commodity levels. Attempts to find an interested project sponsor for this alternative were unsuccessful. Reducing the size and providing only for a crude oil facility was less viable economically. The State of Delaware was opposed to this alternative due to the ecological and secondary development effects expected.

325. The environmental effects of constructing an oil pipeline are expected to be high. Even with maxing use of existing rights-of-ways-there would be sizable wetland and terrestrial impacts. The opposition on environmental grounds to a recent product pipeline proposal from the Delaware City Terminal to an existing pipeline at Marcus Hook was considerable. The potential for spills and long term leakage into the groundwater were both raised.

326. One other location off the mouth of the Maurice River on the New Jersey side of the bay was evaluated in detail as part of the Deepwater Port Study. This site was dismissed due to greater dredging quantities and higher costs than would occur with the Big Stone Beach site plus the resulting ecological impacts of terminal location in a more productive area, including oyster habitats.

327. There are no other locations in the Bay for a pipeline terminal which could be developed without at least double the amount of terminal dredging. The impacts of pipeline construction and operation would, like a pipeline with a terminal at Bid Stone

Beach, be considerable, although the amount of wetlands impact might be less for a terminal off the Maurice River.

328. Location in Lower Delaware River, Reach D Reach D extends from Bombay Hook to the Chesapeake and Delaware Canal. There are no locations found where a pipeline terminal facility could be developed without considerable berth dredging. Massive terminal dredging. Massive terminal dredging (over 10 million cubic yards) would be necessary in addition tot he 15 to 22 million cubic yards of river channel dredging needed to provide a 45 foot channel somewhere in this reach. This added cost would, couple with the economic and ecological costs of a 60 mile pipeline, make this option uneconomical. The loss in commercial fishery (finfish and shellfish) would be an additional negative factor. The effect on the oyster industry would likely be devasting.

329. Locations in the Lower Middle Delaware River, Reach C Like a terminal in reach D, dredging quantities would be substantial. Combined channel and berth yardage could range between 35 and 40 million cubic yards for initial dredging, even with the use of the Texaco terminal channel. This is 70 to 80% of the dredging quantities of deepening the entire channel. A channel only deepened to here would exclude coal, iron ore, and othr cargoes which account for 20% of the benefits of main channel deepening. Channel with the added cost of operating the pipeline is the additional maintenance dredging associated with locating in this heavily shoaled area. This option appears less economically viable than channel deepening. Also ther does not appear to be an environmental benefit from a terminal here and a 20 mile pipeline.

330. Marcus Hook Terminal, Reach B A terminal located here would serve the 4 remaining upstream terminals by providing a 15 mile pipeline. The least costly plan would likely involve modifying the Marcus Hook Anchorage. Initial dredging yardage for th channel deepening and terminal facility could be about 5 million cubic yards less than full channel deepening. The overall dredging saving might be less since channel realignment into rock outcrops would probably be necessary. The amount of annual maintenance will be even greater than the full length channel deepening since Marcus Hook is the most heavily shoaling segment in the river. The minimal reduction in intial yardage also assumes no compensation for lost anchorage capacity and minimal resultant reduction in safety. Other commodities which account for 20% of the project benefits could also not benefit from this scheme.

331. The need to expand the anchorage by even one or two of the three berthing areas required for a terminal would require destruction of shallows and probably freshwater wetlands which border the anchorage.

332. Other Locations in the Middle Delaware River, Reach B and Locations in the Upper Delaware River, Reach A There are no location whithin these 2 reaches which appear better thatn the Marcus Hook location. Elsewhere dredged yardages are likely to increase to 50 million cubic yards. This approximates the amount of dredging required to deepen the entire channel length and would result since partial use of an existing anchorage at alternative locations is not possible.

333. In conclusion of a crude oil pipeline alternatives has identified no alternative which appears to even approach the overall viability.

334. NON-STRUCTUAL MEASURES. The following non-structural measures were considered during preliminary planning for the study.

335. Transshipment. Transshipment means the transfer of cargo from one means of transport to another. Lightering and topping off generally refer to transfer of cargo between a large deep-draft vessel and a smaller vessel or barge in order to maximize the cargo tonnage carried over a long voyage. However, the term can also apply to intermodal shifts such as transfer of cargo from a vessel to rail car, truck, or pipeline enroute to its final destination. Lightering and topping off are practiced where vessel design drafts exceed available channel depths at the port and for years has been commonly practiced for liquid bulk commodity shipments due to the main channel depth of the Delaware River. This measure does not provide the opportunity to alleviate current problems for the Delaware River.

336. Use of High Tides. Movement of deep draft vessels at high tide in channels of restrictive depth is a means of increasing efficiency of commodity movements. Costs for tidal delays are generally small in comparison to transportation savings over a long voyage. Where channel depths are below the potential vessel operating draft, loading or unloading of vessels timed around peak tides can also maximize the tonnage of cargo carried per vessel. This practice has become standard for bulk shipments allowing up to three feet of additional loading for vessels using high tides. Therefore, it does not have the potential for alleviating current problems related to the depth of the main channel.

337. Split Deliveries. Where vessel design drafts exceed available depths at particular ports, trips can be made there when the vessel is partially loaded. By arranging vessel calling patterns so that initial offloading or final onloading occurs at the deeper ports of call, the vessels can still call at ports with lesser depths available. Such occurrences have occurred in the Delaware River with bulk commodities. However, this measure does not alleviate the current problems related to the depth of the main Delaware River channel.

338. Lightloading. Lightloading can reduce overall transportation cost per ton of cargo where channel depths are restrictive. A lightloaded larger vessel can often carry greater tonnage than a fully loaded smaller vessel of equal draft. Therefore, more tonnage can be carried per vessel trip and a cost savings might be achieved due to lower operating cost per ton over the overall trip if transfer costs to the second vessel are low. Lightloading for bulk commodities is a common practice and does not provide the opportunity for alleviating the identified navigation problems.

339. Pilot Regulations. The pilot regulations for safe movement of vessels for the Delaware River are published in the Code of Federal Regulations, Title 33, Subchapter D. The regulations are established through a rather lengthy process which includes public meetings and formal review and comment periods. The regulations govern port and waterway safety, use of anchorages, international navigation rules, aids to navigation, and other areas of concern. Modifications to these regulations is possible, though they have been established for safety and efficiency of operation. However, modifications to pilot regulations are difficult to implement and provide no opportunity for alleviating the identified navigation problems.

340. Tug Assistance. Using tugs for turning, docking, and navigating in restrictive waterways is a common way of minimizing the need for larger channel and maneuvering areas. In the Delaware River system, tugs are used as safety precautions in vessel docking at many locations. Also along the Delaware River, Philadelphia to Trenton Project where there are draw bridges, if a bridge failed to open or a vessel lost power and a collision was imminent, tugs could facilitate an emergency stop. Use of tugs in these instances is expected to continue under any future channel scheme and this measure does not provide the opportunity to alleviate current navigation problems of insufficient depth.

341. Modification of Vessels. Rather than modifying or enlarging channels due to vessel characteristics, the reverse is also possible. Vessels can be designed or modified to carry additional tonnage as an alternative to larger waterways. An example is the Panamax size vessel which is designed around the constraint of operation through the Panama Canal. Other examples include LASH vessels, extension of container ships, special barge designs to include loading equipment, or special vessel control features such as stern or bow thrusters to increase vessel maneuverability in restricted waterways. There is insufficient traffic to justify development and construction of a fleet solely for use in the Delaware River. Thrusters have become commonplace on larger vessels and this trend, which will aid vessel maneuverability especially with docking, is expected to continue.

342. Scheduling/Traffic Management. Where problems include traffic congestion or backlog, scheduling of arrivals and departures can minimize demurrage costs while vessels wait for berth space. Traffic management can be used to minimize accidents, to maximize the efficiency of vessel movements, to avoid vessel delays for through traffic due to vessels turning or docking, to avoid queuing problems, and to reduce transportation costs by minimizing fuel consumption. None of the problems identified could be rectified by scheduling/traffic management; berth utilization generally averages less than 25% at nearly all facilities, minimizing the potential benefits of this option. The Delaware River pilots coordinate between themselves to alleviate any problems with queuing delays as vessels perform docking maneuvers and to avoid passing at bends.

343. DREDGED MATERIAL DISPOSAL. The following measures were considered during preliminary planning for the study. Each of the measures considered was screened to identify those that had the greatest potential to satisfy the disposal needs for a channel deepening project. Those demonstrating potential were evaluated further.

344. Raising Dikes. Containment dikes are periodically raised to increase the useful capacity of a site. The maximum height of a containment dike is based on engineering considerations such as slope stability and existing subsurface conditions. The dike heights are periodically increased by stepping in or encroaching into the disposal area with successive lifts designed for one or more periods of filling. The actual height increase depends upon the characteristics and volume of material to be placed and an allowance for freeboard (usually 2 feet). The final dike elevation in Federally owned sites considers safety, lease agreements, effects on adjacent properties, and future land use in addition to the technical limitations. Conversely, final dike elevation in privately owned sites is usually controlled by easement, local ordinances and owner's future plans for the site. Based on technical considerations, the study generally considers the maximum elevations to be 70 feet above original ground for new disposal areas. This measure is an economical way to minimize the need for additional site acquisition and periodic dike raisings will be incorporated into disposal plans.

345. Dewatering of Dredged Material. Dewatering dredged material is a common practice that is employed to increase the useful life of any disposal area. Field tests which were conducted as part of the Dredged Material Research Program (DMRP) have proven that even some of the more difficult types of dredged material can be efficiently dewatered. Interior surface trenching and perimeter trenching by dragline and backhoe are effective ways to achieve a greater degree of dewatering than can be done through natural drainage. These methods have been utilized at existing Philadelphia District disposal areas, where capacity is at a

premium. Both methods appear to be cost effective and will be used to the maximum extent practical for new disposal areas. Other more complex methods exist, such as those involving under-drainage systems and vacuum pumping. However, these methods are extremely costly with variable results and consequently were not considered further in this study.

346. The study considered a variety of advanced equipment designed specifically for the purpose of improving the construction practices of digging dewatering trenches. In mid 1983, an amphibious rotary trencher was purchased by the Philadelphia District and has been used since. This vehicle has the capability to dig a trench between 18 to 48 inches in depth at a speed of about 2-3 miles per hour. The effect of the trenching on the shoal to disposal area (wet to dry) ratio is dependent upon the type of material, the network and depth of the trenching, the time elapsed between the placement of the dredge material and the initiation of trenching, and the length of time available for drainage and drying of the dredged material. The wet to dry ratio of 1.5 to 1 used for this disposal analysis includes the use of this rotary trencher and other dewatering techniques currently used.

347. Reusing Dredged Material. The sale of dredged material was initiated by the Philadelphia District in 1972 as a means of extending the useful life of existing disposal sites as well as providing a means of more efficiently utilizing the dredged material. The material is sold in quantity as excess government property directly from the disposal area. It has many productive uses, such as for landfill or construction activities. The future volume of material that can be reused in this manner depends on such factors as demand, type and quality of material, and distance between the disposal site and reuse site. Some of the varied uses of dredged material are discussed in the following paragraphs.

- Highway Fill. Although it is likely that there will always be a market for this purpose, indications are that it will be less than previously experienced. The interstate highway program in the vicinity of the study area is nearly completed thereby eliminating the long range need for this material. State and county highway officials have indicated that their future need (as highway fill) will also be limited.

- Shoreline Protection. Shoreline protection involves the deposition of dredged material onto eroding shoreline as direct beach placement, underwater berms, wetland creation, or offshore stockpiles. A major source of suitable (sandy) material could come from the dredging operations performed in the Delaware Bay. In some cases the added transportation and placement costs, might result in increased costs in comparison to other alternatives for disposal, however such measures can be recommended in accordance with applicable cost sharing

requirements, if local sponsors agree to finance the cost differential. This alternative has sufficient viability to be investigated further as part of this study.

- Land Reclamation. This concept involves the placement of dewatered dredged material in areas such as abandoned pits and quarries, strip mines, sanitary landfills, agricultural soil enrichment, and resource recovery. Following an inventory of abandoned pits and quarries and cost analyses of a selected typical location reclamation of this type proved to be unjustified and was eliminated from further consideration. Although there are no strip mines in the immediate vicinity of the study area, the concept was investigated based on data from the City of Philadelphia, which has used this method to dispose of sewage sludge. Assuming similar unit costs for dredged material, the cost of this method would be prohibitive. Use of dredged material in sanitary landfills to level the terrain or act as an impermeable cover has been performed on a small scale. It is anticipated that relatively small amounts of dredged material may be used for this purpose where fine grained material is available at disposal areas located within a short haul distance from sanitary landfill sites, however the concept has little potential as a solution given the large volumes of dredged material. The need for soil enrichment is being met by using sludge offered without charge from local sewage treatment plants and discourages the marketability of the dredged material for agricultural use which requires farm payments. Fine grained material contained in certain disposal areas could be used for construction materials such as lightweight aggregate and bricks. However, the success of a resource recovery operation would be difficult because continuous access to the raw material is not assured, the initial capital investment is high, and most importantly, favorable market conditions must be established and maintained. At the present time cheaper and better quality materials are available to the producers of these materials. Consequently, this alternative was eliminated from further consideration.

348. Extending Leases. Lease extension for disposal areas which the government does not own is a viable way to minimize the need for site acquisition. This is currently practiced to the maximum extent for the Delaware River Philadelphia to Trenton project and other tributary projects. However, the practical limit for this is controlled by planned uses for these sites and this does not represent a long-term solution for initial construction and project maintenance.

349. Using Sedimentation Basins to Reduce Shoaling. This measure considered the possibility of reducing the historical shoaling pattern by forcing sedimentation to occur in concentrated areas (deposition basins) or other locations more accessible to available

disposal sites. Consideration was also given to reducing the shoaling in the channel by forcing the sedimentation to occur outside the area being maintained. Prior studies were evaluated to determine the effectiveness of such measures as shoreline modifications, in-river training dikes and sedimentation traps. Shoreline modifications and training dikes are designed to streamline the channel and encourage transportation of shoal material. By increasing flow velocities or redirecting the current patterns shoal material can be transported upstream or downstream of a problem area. Sediment traps are pits dredged either in the main channel or adjacent to it. By decreasing the flow velocity, sediment is deposited at a concentrated pre-determined location. Studies to reduce or eliminate shoaling had been conducted in the past through the use of a hydraulic model of the Delaware River Estuary at WES. These analyses considered the existing system of twelve training dikes which had been constructed in the Delaware River to regulate and control tidal flow and sedimentation. Based on reviews of the model studies, it was concluded that the historic shoaling pattern cannot be further altered by additional measures and no new sediment traps or dikes should be developed. Therefore, further consideration is not warranted.

350. Site Management. Under this alternative, consideration was given to management practices (other than dewatering) that would extend the useful life of existing dredged material disposal areas. This measure would assure that the need for new dredged disposal areas were kept to a minimum. Management practices include baffle dikes, outflow facilities and use of optimal lift thickness to assure maximum drainage of dredged material. The current practice has been to construct as many interior baffle dikes and sluice gates as are needed in each disposal area so that the sediment particles are retained within the disposal site and, at the same time, the drying process is accelerated. Along with these measures, the District has normally used thin lift thicknesses to minimize the cost of dewatering. These management practices have been used in the past with good results and will continue to be used in the future.

351. Acquiring New Upland Sites. Consistent with past practice on the Delaware River and its tributaries, acquisition of new upland sites could potentially accommodate the dredged material associated with major channel deepening initial construction and maintenance. As documented in previous studies by the Tidal Hydraulics Committee and the Philadelphia District, disposal of dredged material in confined upland sites reduced the annual volume of maintenance dredging in the river from about 15 to 16 million cubic yards to about 6 million cubic yards since the 1950's. This reduction is attributable to positive removal of sediment from the river in comparison to agitation dredging and open water rehandling techniques previously practiced in the District. In addition, upland disposal techniques allowed effective maintenance of the authorized 40 foot channel depth, whereas previous methods resulted

in an effective depth of about 36 feet. Investigation of new upland sites warrants further consideration.

352. Ocean/Bay Disposal. Disposal of dredged material in aquatic areas can be accomplished by bottom dumping from hopper dredges or barges as well as through other techniques. Filling of deep holes can be a practical disposal technique to avoid impacts on more valuable shallow water aquatic habitat. In addition, thin layering of disposed material can be accomplished to limit impacts on the benthic organisms and minimize habitat destruction via burial. This methodology however impacts a much larger surface area.

- Bottom Dumping. Bottom dumping of dredged material at the Federal site near Buoy 10 in lower Delaware Bay has been practiced to a limited degree in the past for sandy materials from the lower bay channel segments which experience little shoaling and require less frequent maintenance. Such disposal sites are economically viable if they are close to dredging locations yet located significantly enough away so that the material is not reintroduced as a sediment source for shoaling. Ocean dumping would require further significant hauling costs and is not considered further.

- Filling Holes. Filling deep holes to create shallows or to create a more uniform bathymetry may have limited potential for material disposal. In the upper river the few holes that do exist are generally located parallel to the channel and behind islands or the training dikes which have been constructed in the river to train flows and maintain the channel depths to the maximum extent through natural scour due to focused currents. Most of the undredged holes have also resulted due to the scour which occurs on the landward side of training dikes and islands. As such it is apparent that any such filling of holes with dredged material would likely reintroduce the material back into the river to be redredged and placed in an upland site as part of maintenance operations. Any further consideration of this option should consider the increased O&M dredging which might result and may require evaluation of dikes to properly confine the material. In the lower river and bay filling of holes has been considered in previous studies but due to the uncertainty that exists about the currents which initially formed the holes. Re-suspending of dredged sediments placed in the deep hole could contribute to future shoaling problems. In addition many of the deep hole sites within the bay area are located in and around the Big Stone Anchorage, in the pilots area, or within the Cape May/Lewes Ferry route. By filling these holes the risk of adversely affecting navigational access to these areas could increase. Therefore, no deepholes identified within the project area could be used for dredged material disposal.

- Thin layering. Thin layering of dredged materials is a relatively new technique for disposal in aquatic environments which is designed to minimize the disturbance to benthic organisms by limiting material placement to a 1 foot layer or less. Primary considerations for this technique are type of material, proximity to the channel, and availability of equipment. Two techniques are employed; use of a barge mounted discharge pipe with a swiveling baffle to allow barge oscillation during disposal operations and also spray techniques. Barge operations would be limited to areas with a depth sufficient for barge draft, but this technique might be suitable for various material types. Spray techniques can be employed in shallower areas and have been tried in wetlands areas to gradually raise their level. That technique is not well suited to materials with high organics content or gravels and rocks. Both techniques require a reasonable offset from the channel so that material suspended by the surface discharge operations does not immediately return to the channel. The Mobile District has used an offset of about 2500 feet from its deep draft channels and 1000 feet from smaller projects, however considerations at other locations include the currents, material type, and the slope of the bottom. Due to the currents in the upper river, the fine/silty properties of the material, and the limited distance from the channel, this option does not warrant consideration. There is also insufficient area in the upper river beyond a 2000 foot distance from the channel and associated anchorages and access to berths to accommodate dredged quantities for a 45' channel deepening. In the lower Delaware River thin layering may be possible as the river widens, however consideration must be given to the turbidity and resuspension of fine materials as it effects the environment and requires more costly maintenance dredging operations. In the Delaware Bay this measure would be precluded by the abundance of oyster grounds which are protected under the respective CZM plans. Thin layering with fine sands would destroy the habitat in the oyster grounds by changing the hard bottom characteristics required for oysters.

353. Wetlands/Island/Upland Creation. Dredged material disposal in aquatic environments can also be used to create wetlands, islands, or uplands. U.S. Army Corps of Engineers regulation ER 1165-2-27 promotes the use of dredged material for creation of shallow water and wetland habitats. In certain cases this would require construction of dikes to contain material and protect it from erosive waves and currents. Several of the existing Federal disposal areas and islands in the river have been created using dredged material. These techniques generally involve filling water depths of 30 feet and less and present the opportunity to dispose of significant quantities of dredged material. Although the loss of medium and shallow water depth habitat would result from this option, the creation of an additional marsh or island habitat would

be created. Therefore, further consideration of these options is warranted.

354. RESULTS OF PRELIMINARY SCREENING. The preliminary screening concluded that there were no non-structural measures which would by themselves adequately address the planning objectives in a manner which would increase the safe and efficient movement of commerce through the Delaware River system. Many of these non-structural measures are widely used by Delaware River vessel pilots and shippers under the existing conditions. Dredged material disposal is a major element in any navigational analysis and it appears that the primary measures to be investigated further include new upland sites, development of aquatic sites as marshes or islands, and limited variations for aquatic disposal.

CYCLE 1 - GENERAL SCREENING FOR DREDGED MATERIAL DISPOSAL AREA POLYGONS

355. A computerized technique called Spatial Analysis Methodology (SAM) was used for the initial screening phase of this study. SAM can be defined in simple terms as a computerized data management and analysis tool designed specifically to handle "Spatial" or mapped data. SAM was originally developed by the Corps' Hydrologic Engineering Center (HEC) through a pilot study program for comprehensive watershed planning. In this study, SAM's specific application was to perform an automated suitability screening using various kinds of (spatial) data to determine the relative attractiveness of parcels for disposal activities. SAM is comprised of two main components:

1. A data bank of pertinent physiographic characteristics, and
2. A series of computer programs designed to perform utility or analysis functions.

356. Although seemingly complicated, the methodology is a rather straight-forward procedure of collecting and storing necessary mapped data in the computer, defining the criteria for screening polygons, instructing the computer to search the data bank for areas having the desired combination of characteristics, and then displaying the results in graphical or tabular form for further analysis or consideration (refer to Figure 13 for the schematic approach used in the attractiveness modeling).

357. The study area encompassed a 5 mile band on either side of the Delaware River channel. This area was subdivided by a uniform grid array into a data base of approximately 43,500 grid cells, each cell being about 18 acres in size. Each grid cell was identified by 13 distinct surface and sub-surface characteristics called "parameters". Each parameter was further subdivided into categories or "variables" (see Table 17 for a list of the parameters and variables).

358. The identification of parameters and variables was based on available mapping or, in some cases, maps specifically developed as part of the study. The data were transferred from the maps to the computer data base using a technique called polygon digitizing. Having identified the spatial distribution of each of the parameters and variables, the next step involved assigning a weighing factor to each data variable cell to describe its relative attractiveness for dredged material disposal. The weightings varied from 0 (least attractive) to 10 (most attractive). If for some reason, a particular feature rendered the area totally unacceptable, the cell was designated with values of "-1" for that variable. A "-1" would cause a variable to be excluded from further consideration. Finally, a relative index weighing was established to relate the importance of one parameter to another.

FIGURE 11

DELAWARE RIVER
COMPREHENSIVE NAVIGATION STUDY
MAIN CHANNEL DEEPENING

SCHEMATIC OF
ATTRACTIVENESS MODELING

PHILADELPHIA DISTRICT, CORPS OF ENGINEERS

TABLE 15

SCALE OF ACCEPTABILITY FOR WEIGHTING
POTENTIAL DISPOSAL SITES

-1	0	1	2	3	4	5	6	7	8	9	10
UNACCEPTABLE (EXCLUDED)		LEAST ACCEPTABLE				GENERALLY ACCEPTABLE				MOST ACCEPTABLE	

PARAMETER	VARIABLE	VARIABLE WEIGHTING FACTOR (RELATIVE ACCEPTABILITY) NED
1. Archaeological Sensitivity Zones	0 Other	10
	1 High Sensitivity	0
	2 Medium Sensitivity	5
	3 Low Sensitivity	10
2. Historic Sites	0 Other	10
	1 Historic Sites	0
	2 Historic Districts	0
3. Groundwater Recharge Zones	0 Other	10
	1 Zone I	10
	2 Zone II	8
	3 Zone III	6
	4 Zone IV	4
	5 Zone V	2
	6 Zone VI	0
4. Recreation	0 Other	10
	1 Federal Park	0
	2 State Parks, Forest & Wildlife Mgt. Areas	0
	3 County Parks	0
	4 Fairgrounds	0
	5 Local Parks	0
	6 Campgrounds	0
	7 Golf Courses	0
	8 Private Parks	0
	9 Marinas	0

TABLE 15 (Cont'd)

PARAMETER	VARIABLE	VARIABLE WEIGHTING FACTOR (RELATIVE ACCEPTABILITY) NED
5. Fish and Wildlife Sensitive Areas	0 Other	10
	1 (Reserved)	5
	2 Finfish	5
	3 Wading Bird and Seabird High Use Areas	5
	4 Major Waterfowl Areas	5
	5 Muskrat Areas	5
	6 (Reserved)	5
	7 Conservation/Natural Areas	5
	8 High Fishing Areas	5
	9 Exculsionary Trout Areas	0
	10 Trout Waters	5
	11 Shellfish	0
	12 (Reserved)	5
	13 Exclusionary Wading Bird & Seabird Colonies	0
	14 Exclusionary Waterfowl Areas	0
	15 Exclusionary Muskrat Areas	0
	16 (Reserved)	5
	17 Exclusionary Conservation/ Natural Areas	0
	18 (Reserved)	0
	19 Exclusionary Terrestrial Game Areas	0
	20 Combination of 2 and 3	0
	21 Combination of 2 and 4	0
	22 Combination of 2 and 5	0
	58 Combination of 2, 13, 15 and 17	0
6. Land Use and Land Cover	0 Other	10
	1 Urban and Built up	-1
	2 Normal Bottom (10'-42')	5
	3 Shallow (10')	5
	4 (Reserved)	5
	5 (Reserved)	5
	6 Forested Uplands	10
	7 Orchards	5
	8 Cropland	10
	9 Rangeland	10
	10 Other Agricultural Land	10
	11 Barren Land	10
	12 Strip Mining Land	10
	13 Active CE Disposal Site	10

TABLE 15 (Cont'd)

PARAMETER	VARIABLE	VARIABLE WEIGHTING FACTOR (RELATIVE ACCEPTABILITY NED
	14 Inactive CE Disposal Site	10
	15 Private, Industrial, Municipal Landfills	10
	16 Sewage Sludge Landfill	10
	17 Deep Water Bodies (42')	10
	18 Inland Water Bodies (Lakes/Ponds)	5
7. S.C.S. Important Farmlands	0 Other	10
	1 Unique Farmland	5
	2 Prime Farmland	5
	3 Additional Farmland of Statewide Importance	10
	4 Additional Farmland of Local Importance	10
8. D.O.I. Wetlands	0 Other	10
A. One Wetland Type 50% or Greater Cell Coverage	1 Palustrine	0
	2 Riverine (Intertidal Flats/Intermittent Streams)	0
	3 Estuarine	0
	4 Lacustrine	0
	5 Marine	0
B. One Wetland Type Less Than 50% Cell Coverage	6 Palustrine	0
	7 Riverine (Intertidal Flats/Intermittent Streams)	0
	8 Estuarine	0
	9 Lacustrine	0
	10 Marine	0
C. Mixed Wetland Types (Dominant Type Indicated 50% or Greater Cell Coverage)	11 Palustrine	0
	12 Riverine (Intertidal Flats/Intermittent Streams)	0
	13 Estuarine	0
	14 Lacustrine	0
	15 Marine	0
D. Mixed Wetlands Types (Dominant Type Indicated Less Than 50% Cell Coverage)	16 Palustrine	0
	17 Riverine (Intertidal Flats/Intermittent Streams)	0
	18 Estuarine	0
	19 Lacustrine	0
	20 Marine	0
E. Three or More Wetlands Types	21 Mixed Wetlands 50% or Greater Cell Coverage	0

TABLE 15 (Cont'd)

VARIABLE WEIGHTING FACTOR (RELATIVE ACCEPTABILITY

PARAMETER	VARIABLE	NED
	22 Mixed Wetlands Less Than 50% Cell Coverage	0
9. Navigation Features	0 Other	10
	1 Main Channel	-1
	2 Entrance Channel	-1
	3 Anchorage Areas	-1
	4 Dredge Disposal Sites In Water	10
10. Groundwater Protection Zones	0 Other	10
	1 Zone I	10
	2 Zone II	7
	3 Zone III	5
	4 Zone IV	5
	5 Zone V	3
	6 Zone VI	0
11. Construction and Development	0 Other	10
	1 Urban and Built Up	-1
	2 Normal Bottom (10'-42')	0
	3 Shallow (10')	3
	4 (Reserved)	0
	5 (Reserved)	0
	6 Forested Upland	7
	7 Orchards	7
	8 Cropland	10
	9 Rangeland	10
	10 Other Agricultural Land	10
	11 Barren Land	10
	12 Strip Mining Land	10
	13 Active CE Disposal Site	7
	14 Inactive CE Disposal Site	7
	15 Private, Industrial, Municipal Landfills	5
	16 Sewage Sludge Landfill	5
	17 Deep Water Bodies (42')	0
	18 Inland Water Bodies (Lakes/Ponds)	7
12. Elevation Ranges	1 -30' Depth and Greater (Datum is Mean Low Water)	10
	2 -30' to 0' Depth (Datum is Mean Low Water)	9
	3 Mean Low Water to 20' NGVD	7
	4 20' to 40' NGVD	5
	5 40' to 60' NGVD	3

TABLE 15 (Cont'd)

FACTOR

ACCEPTABILITY

PARAMETER	VARIABLE	VARIABLE WEIGHING (RELATIVE NED
	6 60' NGVD	0
13. Distance Bands Philadelphia To Trenton: From Center of Channel	1 0' to 5000'	10
	2 5000' to 10000'	8
	3 10000' to 15000'	6
	4 15000' to 20000'	4
	5 20000'	0
Distance Bands - Philadelphia To Sea; From 30' Depth (Datum is Mean Low Water)	1 0' to 3000'	10
	2 3000' to 6000	8
	3 6000' to 9000'	6
	4 9000' to 12000'	4
	5 12000'	0

BLANK

BLANK

TABLE 16

DISPOSAL SITE SELECTION BASED ON VARYING INDEX VALUES

(PARAMETER IMPORTANCE)

PARAMETER	NED
Archaeological Sensitivity Zones	1
Historic Sites	1
Groundwater Recharge Zones	1
Recreation	1
Fish and Wildlife Sensitive Areas	1
Land Use and Land Cover	1
S.C.S. Important Farmlands	1
DOI Wetlands	1
Navigation Features	1
Groundwater Protection Zones	3
Construction and Development	3
Elevation Ranges	3
Distance Bands - Philadelphia to Trenton	5
Distance Bands - Philadelphia to Sea	5

TABLE 16

DISPOSAL SITE SELECTION BASED ON VARYING INDEX VALUES

(PARAMETER IMPORTANCE)

PARAMETER	NED
Archaeological Sensitivity Zones	1
Historic Sites	1
Groundwater Recharge Zones	1
Recreation	1
Fish and Wildlife Sensitive Areas	1
Land Use and Land Cover	1
S.C.S. Important Farmlands	1
DOI Wetlands	1
Navigation Features	1
Groundwater Protection Zones	3
Construction and Development	3
Elevation Ranges	3
Distance Bands - Philadelphia to Trenton	5
Distance Bands - Philadelphia to Sea	5

359. The criteria defining the attractiveness of a cell for the disposal of dredged material incorporated the rationale involved in selecting potential disposal areas. These criteria assumed that the results would be technically feasible, cost effective and environmentally acceptable.

360. The NED screening, conducted with a view to reasonably maximize national economic development, consistent with protection of the environment, emphasized those parameters involving engineering feasibility and cost efficiency of dredging and dredged material disposal. Parameters such as surface and sub-surface features that would be indicative of construction suitability, topographic elevation, and distance to dredging reaches were all considered to be of prime importance.

361. Table 17 provides the relative index weightings, used for each parameter. A preliminary version of the weightings was coordinated with a Plan Formulation Committee for disposal studies which was comprised of a cross-section of environmental agencies and dredging interests. Comments resulting from this coordination were reflected in adjustments to the values or resolved through clarification to the originator of the comment. The values shown in Tables 13 and 17 were ultimately used in the data base.

362. Based on the attractiveness modelling, computer printouts were produced at a 1:24,000 scale for the purpose of overlaying the output directly on U.S.G.S. quadrangle sheets. Attractiveness of each cell was represented by the different densities of various typed characters and overprints to provide a readily distinguishable basis for identifying attractive cells. Where adjacent attractive cells could be identified which might be combined into a large polygon, they were outlined and plotted on the U.S.G.S. quadrangles. A total of 308 upland and aquatic polygons were identified in this manner. Table 19 shows the distribution of these new polygons according to state location and type. In addition, all Federal and private existing disposal areas were identified as attractive.

363. Within the Delaware Bay, potential disposal areas were identified through interviews with the local officials, review of previous correspondence and reports, and public notices, rather then using SAM. Aerial photographs, maps, U.S.G.S. quadrangle, and surveys were also obtained to identify other possible locations for dredged material disposal operations. Due to the size of the Delaware Bay, study area encompassed a 10 mile band on either side of the Delaware River channel, unlike the 5 mile band in the northern reaches. Table 20 shows 184 possible sites for te Delaware Bay. The site names are applicable to the U.S.G.S. quadrangle in which the site is located. In the case of overboard (OB) disposal, deep hole filling (DH), and some island creation (I) the site names are an abbreviation of the type of alternative.

TABLE 17

DISPOSAL POLYGON OUTPUT

Polygon Location (State/County)

Polygon Type	NJ Castle	DE Kent	DE Philadelphia Total	PA DE Delaware	PA Camden	NJ Gloucester	NJ Salem	NJ Cumberland	New
Upland	9	2	270	5	0	52	90	16	96
Aquatic	2.5	1	23	0	0	5	3	3	8.5
Combination	1	0	15	3	2	0	1	1	7
Total	12.5	3	308	8	2	57	94	20	111.5

TABLE 18
DISPOSAL OPTIONS FOR DELAWARE BAY

Site	Size App	Type
Canton NJ C 1	165 Acres	Upland
C 2	100 Acres	Upland
C 3	165 Acres	Upland
C 4	150 Acres	Upland
C 5	250 Acres	Upland
C 6	140 Acres	Upland
C 7	100 Acres	Upland
C 8	140 Acres	Upland
C 9	100+Acres	Upland
C 10	240 Acres	Upland
C 11	100 Acres	Upland
C 12	120 Acres	Oyster seed bed creation
C 13	160 Acres	Island Creation

TABLE 18

DISPOSAL OPTIONS FOR DELAWARE BAY

Site	Size App.	Type
Bem David Point BD 1	190 Acres	Upland
BD 2	160 Acres	Upland
BD 3	140 Acres	Upland
BD 4	85 Acres	Upland
BD 5	200 Acres	Upland
BD 6	200 Acres	Wet land creation
BD 7	160 Acres	Oyster seed bed creation
BD 8	200 Acres	Wetland Creation
BD 9	200 Acres	Oyster seed bed creation
Cedarville CV 1	100 Acres	Beachfill
CV 2	175 Acres	Upland
CV 3	145 Acres	Upland
CV 4	105 Acres	Upland
CV 5	105 Acres	Upland
CV 6	200 Acres	Upland

TABLE 18
DISPOSAL SITE OPTIONS FOR DELAWARE BAY

Site	Size App	Type
CV 7	165 Acres	Upland
CV 8	185 Acres	Upland
CV 9	200 Acres	Upland
Fortescue F 1	200 Acres	Wetland Creation
F 2	215 Acres	Island Creation
F 3	100 Acres	Beachfill
Port Morris PN 1	200 Acres	Wetlands Restorations
PN 2	450 Acres	Oyster seed bed creation
PN 3	200 Acres	Wetland Creation/ Restoration
Heislerville H 1	100 Acres	Upland
H 2	200 Acres	Upland
H 3	680 Acres	Upland
H 4	440 Acres	Upland

TABLE 18

DISPOSAL SITE OPTIONS FOR DELAWARE BAY

Site	Size App	Type
H 5	150 Acres	Uplands
H 6	100 Acres	Sand stockpile
H 7	100 Acres	Beachfill
H 8	160 Acres	Island Creation
H 9	160 Acres	Island Creation
H 10	500 Acres	Thinlayering
H 11	500 Acres	Thinlayering
Rio Grande RD 1	120 Acres	Upland
RD 2	160 Acres	Upland
RD 3	130 Acres	Upland
RD 4	100 Acres	Beachfill
RD 5	100 Acres	Beachfill
RD 6	320 Acres	Oyster Seed Bed

TABLE 18

DISPOSAL OPTIONS FOR DELAWARE BAY

Site	Size App	Type
Cape May CM 1	170 Acres	Upland
CM 2	140 Acres	Upland
CM 3	130 Acres	Upland
CM 4	100 Acres	Beachfill
CM 5/6	200 Acres	Beachfill/ Shore Protection
Woodbine WB 1	160 Acres	Upland
WB 2	150 Acres	Upland
WB 3	175 Acres	Upland

TABLE 18
DISPOSAL OPTIONS FOR DELAWARE BAY

Site Name	Size App	Type
Taylors Bridge TB 1	110 Acres	Upland
TB 2	300 Acres	Upland
TB 3	120 Acres	Upland
TB 4	120 Acres	Upland

TABLE 18
DISPOSAL OPTIONS FOR DELAWARE BAY

Site Name	Size App	Type
Bombay Hook BB 1	120 Acres	Upland
BB 2	500 Acres	Thinlayering
Little Creek LC 1	380 Acres	Upland
LC 2	210 Acres	Upland
LC 3	225 Acres	Upland
LC 4	170 Acres	Upland
LC 5	160 Acres	Upland
LC 6	98 Acres	Upland
LC 7	314 Acres	Upland
LC 8	100 Acres	Island Creation
LC 9	200 Acres	Wetland Creation/Restoration
LC 10	100 Acres	Sand Stockpile
LC 11	200 Acres	Under water berms shore protection
LC 12	200 Acres	Under water berms shore protection
Frederica FR 1	115 Acres	Upland
FR 2	105 Acres	Upland
FR 3	135 Acres	Upland

TABLE 18
DISPOSAL OPTIONS FOR DELAWARE BAY

FR 4	160 Acres	Upland
FR 5	220 Acres	Upland
FR 6	240 Acres	Upland
FR 7	330 Acres	Upland
FR 8	150 Acres	Upland
FR 9	140 Acres	Upland
FR 10	160 Acres	Upland
FR 11	160 Acres	Upland
FR 12	200 Acres	Upland
FR 13	200 Acres	Upland
FR 14	285 Acres	Upland
FR 15	115 Acres	Upland
FR 16	250 Acres	Upland

TABLE 18
DISPOSAL OPTIONS FOR DELAWARE BAY

Site Name	Size App	Type
Frederica FR 17	130 Acres	Upland
FR 18	130 Acres	Upland
FR 19	170 Acres	Upland
FR 20	80 Acres	Upland
FR 21	160 Acres	Upland
FR 22	100 Acres	Upland
FR 23	130 Acres	Upland
FR 24	175 Acres	Upland
FR 25	120 Acres	Upland
FR 26	100 Acres	Beachfill
FR 27	200 Acres	Underwater bermes/Shore protection
FR 28	100 Acres	Sand stockpile
FR 29	200 Acres	Underwater bermes/Shore protection

TABLE 18
DISPOSAL OPTIONS FOR DELAWARE BAY

Bennetts Pier BP 1	160 Acres	Upland
BP 2	170 Acres	Upland
BP 3	150 Acres	Upland
BP 4	100 Acres	Beachfill
Mispillian River MS 1	400 Acres	Upland
MS 2	160 Acres	Upland
MS 3	250 Acres	Upland
MS 4	150 Acres	Upland
MS 5	125 Acres	Upland
MS 6	120 Acres	Upland
MS 7	200 Acres	Upland
MS 8	100 Acres	Upland
MS 9	120 Acres	Upland
MS 10	100 Acres	Upland
MS 11	150 Acres	Upland

TABLE 18
DISPOSAL OPTIONS FOR DELAWARE BAY

Site Name	Size App	Type
MS 12	230 Acres	Upland
MS 13	370 Acres	Upland
MS 14	350 Acres	Upland
MS 15	110 Acres	Upland
MS 16	160 Acres	Upland
MS 17	100 Acres	Beachfill
MS 18	200 Acres	Wetland Creation
MS 19	100 Acres	Beachfill
MS 20	110 Acres	Upland
MS 21	200 Acres	Shore protection off shore berms
MS 22	120 Acres	Upland

TABLE 18
DISPOSAL OPTIONS FOR DELAWARE BAY

Milton ML 1	190 Acres	Upland
ML 2	210 Acres	Upland
ML 3	105 Acres	Upland
ML 4	190 Acres	Upland
ML 5	470 Acres	Upland
ML 6	140 Acres	Upland
ML 7	190 Acres	Upland
ML 8	175 Acres	Upland
ML 9	160 Acres	Upland
ML 10	130 Acres	Upland
ML 11	290 Acres	Upland
ML 12	325 Acres	Upland
ML 13	310 Acres	Upland
ML 14	320 Acres	Upland
ML 15	450 Acres	Upland

TABLE 18
DISPOSAL OPTIONS FOR DELAWARE BAY

Site Name	Size App.	Type
Lewis L 1	160 Acres	Upland
L 2	135 Acres	Upland
L 3	100 Acres	Upland
L 4	100 Acres	Beachfill
L 5	200 Acres	Sand stockpile
L 6	100 Acres	Beachfill
L 7	100 Acres	Beachfill
CH 1	100 Acres	Beachfill
CH 2	100 Acres	Beachfill

TABLE 18
DISPOSAL OPTIONS FOR DELAWARE BAY

OB 1	100	Overboard
OB 2	120	Overboard
OB 3	80	Overboard
OB 4	170	Overboard
OB 5	120	Overboard
OB 6	160	Overboard
OB 7	100	Overboard
OB 8	95	Overboard
DH 1	100	Deep Hole
DH 2	100	Deep Hole
DH 3	100	Deep Hole
I1	200	Island Creation
I2	90	Island Creation
I3	110	Island Creation

CYCLE 2 - MANUAL SCREENING OF POLYGONS FOR DISPOSAL AREAS

364. Following the identification phase the polygons were manually screened to consider linear features (i.e. roads, streams) or isolated structures that the model was not as well suited to appraise and to redefine boundaries. Since the characteristics of an 18 acre cell were considered by the computer to be one variable for each parameter (based on the center of the cell primarily), there were numerous cells which appeared less attractive during this process. In the Delaware Bay a 100 acres cell was considered. Also, during this step, consideration was given to cost factors such as: minimum disposal area size requirements, man-made improvements or navigation channels/access, reasonable disposal pipeline routes to reach the polygon, reasonable effluent water courses to the river, and accessibility for construction and maintenance. Finally, the candidate upland polygons were field visited to assure that some feature that might render it unrealistic was not missed (such as new development subsequent to the land use mapping input to the spatial model).

365. Following this analysis the number of realistic Delaware River polygons was reduced from 308 to 74. In the Delaware Bay the number was reduced from 184 to 72. These locations then entered a third cycle of screening.

CYCLE 3 - INSTITUTIONAL/ENVIRONMENTAL SCREENING

366. In order for a candidate site to be considered viable for further study, it was considered necessary for it to pass a screening of institutional and environmental criteria. From an institutional standpoint it was considered necessary that a candidate site not include public park land or designated wildlife areas. In addition, sites were screened to assure that they had no significant affect on adjacent residential properties and communities. This rationale is clearly important, as is evidenced by the limitations imposed by Congress on the development of the Penns Grove Federal disposal area in Section 1131 of the W.R.D.A. of 1986 (PL 99-662), due to its proximity to residential properties.

367. From an environmental perspective candidate sites were also screened to eliminate those which would involve activities prohibited by a Federally approved Coastal Zone Management (CZM) Plan. Such candidate sites could not be considered implementable and did not warrant further study. The New Jersey CZM plan specifically prohibits the relocation of rivers, streams, and creeks and the filling of ponds. Therefore, any aquatic or upland sites which involved these activities was eliminated from further consideration. Both the Delaware and New Jersey CZM plans also prohibit the destruction of shellfish/oyster beds. The Pennsylvania CZM plan specifically prohibits the destruction of

wetlands. All three states prohibit actions which reduce flood flow capacity and thus increase flooding potential.

368. Based on the findings of geotechnical exploratives the Delaware River segment (Reach A-D) is predominantly fine-grained material. However, the Delaware Bay (Reach E) was divided into four subreaches, E-1 through E-4. Reach E-1 and E-3 consist of fine-grained sediments; reaches E-2 and E-4 are predominantly coarse grained. The coarse-grained sediments are suitable for beachfills, oyster bed creation, wetland creation, and offshore stockpiling, while the fine-grained sediments may be used for wetland creation or disposed of in an upland site. A summary of the gradation analysis is contained in Table 1 of the Geotechnical Appendix.

369. Table 17 shows the results of Cycle 3 screening which further reduced the number of candidate sites from 74 to 38 for the Delaware River. The remaining sites included, 24 upland and 9 aquatic (9 for creating islands/marsh and 5 for creating uplands) these are discussed further in Cycle 6. Table 17A shows a reduction from 72 sites to 34 sites in the Delaware Bay.

TABLE 19
DELAWARE RIVER
INSTITUTIONAL AND ENVIRONMENTAL SCREENING

Site Name	Institutional Location	Environmental Acceptability	Overall Acceptability	Acceptability
13 E	Moorestown, NJ	No, Borders large new suburban residential development	Yes	No
13 F	Cimmaminson, NJ	Yes	Yes	Yes
17A	East Greenwich/ Center City, NJ	Yes	Yes	Yes
17B	East Greenwich/ Center City, NJ	Yes	Yes	Yes
17C	New Jersey TurnPike/ Berkely Rd, NJ	Yes	Yes	Yes
17D	New Jersey TurnPike/ Berkely Rd, NJ	Yes	Yes	Yes
17G	Tennaco, NJ	Yes	Yes	Yes
17O	Gats, NJ	Yes	Yes	Yes
17P	Mantua Cr., NJ	No, Site borders 13 residents	No, Would fill Mantua Crk. channel	No
18B	Deptford, NJ	No, Recent residential develop-ment surrounds site	Yes	No
15D	Raccoon Cr, NJ	Yes	Yes	Yes

TABLE 19 (CONT'D)

Site Name	Location	Institutional Acceptability	Environmental Acceptability	Overall Acceptability
Raccoon Is	Raccoon Cr, NJ	Yes	Yes	Yes
15E	Sun Oil, Monuanto, NJ	Yes	Yes	Yes
15F	Sun Oil, Oldmans NJ	Yes	Yes	Yes
15G	Nortonville, Oldmans, NJ	Yes	Yes	Yes
15P	Harrisonville, Oldsman Cr, NJ NJ	Yes	No, 85% site wetlands - remaining site to small	No
16M	East Greenwick, NJ	Yes	Yes	Yes
16T	Centre Square Beckett, NJ	No, Congressional prohibition 1960's	Yes	No
16Y	Repanpo, NJ	Yes	Yes	Yes
16Z	Rt 322, NJ	Yes	No, Stream relocation required	No
16DD	Repaupo, NJ	Yes	No, 95% site wetlands stream relocation required	No
21E	Kay Gardens, NJ	Yes	Yes	Yes
21F	Pedricktown, Perkintown Rd. NJ	Yes	Yes	Yes

TABLE 19 (CONT'D)

Site Name	Location	Institutional Acceptability	Environmental Acceptability	Overall Acceptability
21T	Rt 40/Turnpike, NJ	Yes	No, Stream relocation required	No
21Y	Repaupo, NJ	Yes	Yes	Yes
21AA	Pedricktown, Rd. NJ	No, New residential development on lowerside and considerable residential disruption	Yes	No
22BB	Woolwick, NJ	Yes	Yes	Yes
15H Island	Claymount, DE	Yes, island compatible with adjacent waterfront park	Yes, but reduce by 100 access to prevent flow disruption of Neaman Creek	Yes
15H Upland	Claymount, DE	No, upland would not be compatible with adjacent waterfront park	Yes (report above)	No
15I Island	Oldmans Creek	Yes	Yes, but reduce 200 acres to present flow disruption	Yes
15I Island	Oldmans Cr. NJ	Yes	Yes, but reduce by 200 acres to prevent flow disruption	Yes

TABLE 19 (CONT'D)

Site Name	Location	Environmental Acceptability	Overall Acceptability	Acceptability
15J Upland	Oldmans Cr. NJ	Yes	Yes	Yes
16O Island	Chester Monds, NJ	Yes	Yes	Yes
16O/Upland	Chester Monds, NJ	No, In flight path-Phila., International Institutional Airport	No	No
16P Island	Greenwich, NJ	Yes	No, blocks Cromweed creek, Greenwick Lake	No
16P Upland	Greenwick, NJ	Yes	No, blocks Cromweed creek, Greenwick Lake	No
16R Island	Tinicum Island PA	No, State Wildlife	No, Site detailed special area/protected	No
16R Upland	Tinicum Island PA	No, State Wildlife	No, site detailed special area/protected	No
20H	Langollen Estate New Castle, DE	No, Eastern portion County park	Yes	No
20Q	Adjacent to Killcohook/Lehigh	Yes	Miles crk. through center/NJ CZM prohibits filling of Creek	No
21D	Mannington, NJ	Yes	Yes	Yes
21J	Haines Neck Rd./ Mannington, NJ	Yes	No, Stream relocation required	No

TABLE 19 (CONT'D)

Site Name	Location	Institutional Acceptability	Environmental Acceptability	Overall Acceptability
21L	Mannington, NJ	Yes	Yes	Yes
21M	Mannington, NJ	Yes	Yes	Yes
23C	Delaware City, DE	Yes	Yes	Yes
23D	Delaware City, DE	Yes	Yes	Yes
23E	Corbert, DE	Yes	Yes	Yes
23F	Corbert, DE	Yes	Yes	Yes
23G	Corbert, DE	Yes	Yes	Yes
23H	Corbert, DE	Yes	Yes	Yes
24T	Harrisonville, NJ	No, recently developed Wildlife refuge	Yes	
24U	Harrisonville, NJ	No, 25 homes adjacent/ community Pt. Pleasant	Yes	No
24CC	Harrisonville, NJ	Yes	No, 80% site wetlands (remaining sites too small)	No
25D	Harrisonville, NJ	No, Pipeline disruption	Yes	No
25G	Harrisonville, NJ	No, Adjacent development	Yes	No

TABLE 19 (CONT'D)

Site Name	Location	Institutional Acceptability	Environmental Acceptability	Overall Acceptability
25I	Salem, NJ	Yes	Yes	Yes
20A Island	Pea Patch, DE	Yes	Yes	Yes
20A Upland	Pea Patch, DE	Yes	Yes	Yes
24E/Island	Pea Patch, DE	Yes, but eliminate existing island	Yes	Yes
24E/Upland	Pea Patch, DE	No, upland disrupts Historic Park; Herony	Yes	No
24G Island	Reedy Island DE	Yes, but reduced size	Yes	Yes
24G/Upland	Reedy Island DE	No, disrupts State Wildlife area	Yes	No
24I Island	Salem Cove, NJ	Yes	No, Flow disruption/ Salem River/ Mill Creek	No

TABLE 19 (CONT'D)

Site Name	Location	Institutional Acceptability	Environmental Acceptability	Overall Acceptability
24I	Salem, Cove	Yes	No, Flow disruption/ Salem River/Mill Creek	No
24N	Elsinboro, NJ	Yes	No, 80% wetlands/ remaining site too small	No
24O	St. Georges, DE	Yes	Yes	Yes
25J	Salem, NJ	Yes	Yes	Yes
25K	Salem, N	Yes	Yes	Yes
27D	Appoquinink, NJ	No, Appoquinink wildlife area	No, 100% wetlands	No
24L Island	North of Artificial Island, NJ	Yes	No, Tidal flow blockage	No
24L Upland	North of Artificial Island, NJ	Yes	No, Tidal flow blockage	No
27C Island	Appoquinink, DE	Yes	No, Tidal flow blockage/185 acres wetland	No
27C Upland	Appoquinink, DE	Yes	No, Tidal flow blockage/185 acres wetland	No
27F Island	Appoquinink, DE	Yes	No, Tidal flow blockage/1900 acres wetland	No

TABLE 19 (CONT'D)

Site Name	Location	Institutional Acceptability	Environmental Acceptability	Overall Acceptability
27F Upland	Appoquinink, DE	Yes	No, Tidal flow blockage/1900 acres wetland	No
27H Island	Appoquinink, DE	Yes	Yes	Yes
27H Upland	Appoquinink, DE	Yes	Yes	Yes
27I Island	Appoquinink, DE	Yes	Yes	Yes
27I Upland	Appoquinink, DE	Yes	Yes	Yes
27J Island	Artificial Island/ Hope Cr., NJ	Yes	No, Tidal flow blockage/Hope Cr.	No
27J Upland	Artificial Island/ Hope Cr., NJ	Yes	No, Tidal flow blockage/Hope Cr.	No
27Q Island	Artificial Island/ Hope Cr., NJ	Yes	No, Tidal flow blockage	No
27Q Upland	Artificial Island/ Hope Cr., NJ	Yes	No, Tidal flow blockage	No
28A Island	Artificial Island/ Hope Cr., NJ	Yes	No Oyster Beds	No

TABLE 19 (CONT'D)

Site Name	Location	Institutional Acceptability	Environmental Acceptability	Overall Acceptability
28A Upland	Artificial Island/ Hope Cr., NJ	Yes	No Oyster Beds	No
28B Island	Artificial Island/ Hope Cr., NJ	Yes	No Oyster Beds	No
28B Upland	Artificial Island/ Hope Cr., NJ	Yes	No Oyster Beds	No
32C Island	Artificial Island/ Hope Cr., NJ	Yes	No Oyster Beds	No
32C Upland	Artificial Island/ Hope Cr., NJ	Yes	No Oyster Beds	No
32E Island	Artificial Island/ Hope Cr., NJ	Yes	No Oyster Beds	No
32E Upland	Artificial Island/ Hope Cr., NJ	Yes	No Oyster Beds	No

TABLE 19 (CONT'D)

Site Name	Location	Institutional Acceptability	Environmental Acceptability	Overall Acceptability
34F Island	Artificial Island/ Hope Cr., NJ	Yes	No Oyster Beds	No
34F Upland	Artificial Island/ Hope Cr., NJ	Yes	No Oyster Beds	No
33G Island	Artificial Island/ Hope Cr., NJ	Yes	No Oyster Beds	No
33G Upland	Artificial Island/ Hope Cr., NJ	Yes	No Oyster Beds	No
33F Island	Artificial Island/ Hope Cr., NJ	Yes	No Oyster Beds	No
33F Upland	Artificial Island/ Hope Cr., NJ	Yes	No Oyster Beds	No

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TABLE 20
DELAWARE BAY
CYCLE 3 - INSTITUTIONAL/ENVIRONMENTAL SCREENING

SITE NAME	TYPE	INSTITUTIONAL ACCEPTABILITY	ENVIRONMENTAL ACCEPTABILITY	OVERALL ACCEPTABILITY
Canton N.J. C1	Upland	No Schools Across Highway	No Stream within Area	N
C2	Upland	Y	Y	Y
C11	Upland	Y	Y	Y
C12	Oyster Bed Creation	Y	N Unsuitable Silty Material	N
C13	Island Creation	Y	Y*	Y
Ben Davis BD1	Upland	N Wildlife Management Area	Y	N
BD5	Upland	N Wildlife Management Area	Y	N
BD6	Wetland Creation	Y	N Oyster Bed within Area	N
BD8	Wetland Creation	Y	N Oyster Beds within Area	N
BD9	Oyster Seed Bed Creation	Y	N Unsuitable Silty Material	N
Cedarville CV1	Beachfill	Unsuitable Silty Material	Unsuitable Silty Material	N

* Pending Benthic Testing

TABLE 20
CYCLE 3 - INSTITUTIONAL/ENVIRONMENTAL SCREENING

SITE NAME	TYPE	INSTITUTIONAL ACCEPTABILITY	ENVIRONMENTAL ACCEPTABILITY	OVERALL ACCEPTABILITY
CV6	Upland	N Fish and Wildlife Management Area	Y	N
Fortescue F1	Wetland Creation	Y	Y *	Y
F2	Island Creation	Y	Y *	Y
F3	Beachfill	Y	Y	Y
PN1	Wetland Creation	Y	Y *	Y
PN2	Oyster Seed Bed Creation	Y	N Unsuitable Silty Material	N
Rio Grande RD1	Upland	Y	Y	Y
RD4	Beachfill	Y	Y	Y
RD5	Beachfill	Y	N Unsuitable Silty Material	N
RD6	Oyster Seed Bed Creation	Y	N Unsuitable Silty Material	N

*Pending Benthic Testing

TABLE 20
CYCLE 3 - INSTITUTIONAL/ENVIRONMENTAL SCREENING

SITE NAME	TYPE	INSTITUTIONAL ACCEPTABILITY	ENVIRONMENTAL ACCEPTABILITY	OVERALL ACCEPTABILITY
Cape May CM2	Upland	Y	Y	Y
CM4	Beachfill	Y	Y	Y
CM5/6	Beachfill/Shore Protection	Y	Y	Y
Delaware Taylors Bridge TB1	Upland	State Designated Wildlife Area	No Wetlands in Area/No Streams	N
Bombay BB2	Thin layering	Y	N Oyster Lease Bed	N
Little Creek LC8	Island Creation	N Bombay Hook, Natural Wildlife Area	N Oyster Lease Bed	N
LC9	Wetland Creation / Restoration	Y	Y *	Y

TABLE 20

SITE NAME	TYPE	INSTITUTIONAL ACCEPTABILITY	ENVIRONMENTAL ACCEPTABILITY	OVERALL ACCEPTABILITY
LC10	Sand stock pile	Y	Y *	Y
LC11	Under water berms/ shore protection	Y	N Oyster Beds	N
LC12	Under water berms / shore protection	Y	N Oyster Beds	N
Frederica FR18	Upland	Y	N Pond in Area	N
FR19	Upland	Y	Y	Y
FR26	Beachfill	Unsuitable Silty Material	Unsuitable Silty Material	N
FR27	Underwater berms/ shore protection	Y	N Oyster Bed	N
FR28	Sand stock pile	Y	Y *	Y
FR29	Under water berms/ Shore Protection	Y	N Oyster Bed	N

* Pending Benthic Testing

TABLE 20

CYCLE 3 - INSTITUTIONAL/ENVIRONMENTAL SCREENING

SITE NAME	TYPE	INSTITUTIONAL ACCEPTABILITY	ENVIRONMENTAL ACCEPTABILITY	OVERALL ACCEPTABILITY
Bennetts Pier BP1	Upland	Y	Y	Y
BP2	Upland	Y	Y	Y
BP4	Beach Fill	Y	N Unsuitable Silty Material	N
MS2	Upland	N Milford Neck Wildlife Area	Y	N
MS3	Upland	Y	Y	Y
MS12	Upland	Y	Y	Y
MS14	Upland	N State Park	N Stream/Wetlands	N
MS15	Upland	N State Park	Y Stream/Wetlands	N
MS16	Upland	N State Park	Y	N
MS17	Beachfill	Y	N Unsuitable Silty Material	Y
MS18	Wetland Creation	Y	Y *	Y
MS19	Sand Stock Pile	Y	Y *	Y

* Pending Benthic Testing

TABLE 20
CYCLE 3 - INSTITUTIONAL/ENVIRONMENTAL SCREENING

SITE NAME	TYPE	INSTITUTIONAL ACCEPTABILITY	ENVIRONMENTAL ACCEPTABILITY	OVERALL ACCEPTABILITY
MS20	Upland	N Historic Area	N Wetlands Border site	N
MS21	Underwater Berms/Shore Protection	Y	N Oyster Seed Beds in Area	N
Milton ML1	Upland	Y	N Wetlands	N
ML2	Upland	Y	Y	Y
ML4	Upland	Y	Y	Y
ML9	Upland	Y School grounds Residential Area	Y	Y
Lewis L1	Upland	Y	Y	Y
L2	Upland	Y	Y	Y
L3	Upland	N Historic Site University Del	Y	N
L4	Beachfill	Y	Y	Y
L5	Sand stock pile	Y	Y *	Y
L6	Beachfill	Y	Y	Y
L7	Beachfill	N	N	N
CH1	Beachfill	N National Park	N Shore Bird Nesting Area	N
CH2	Beachfill	N National Park	Y	N

TABLE 20
DELAWARE BAY
CYCLE 3 - INSTITUTION/ENVIRONMENTAL SCREENING

SITE NAME	TYPE	INSTITUTIONAL ACCEPTABILITY	ENVIRONMENTAL ACCEPTABILITY	OVERALL ACCEPTABILITY
084	Overboard	Y	Y *	Y
I 1	Island Creation	Y	Y *	Y
I 3	Island Creation	Y	Y *	Y

* Pending Benthic Testing

CYCLE 4 - INITIAL CHANNEL DEEPENING ANALYSIS

370. This analysis was conducted at a reconnaissance level of detail without indepth analysis of physical design conditions and navigation practices. Cycle 4 studies were initiated in April 1983 following the approval of the Plan of Study/Reconnaissance Study. This analysis is to address the main channel which was not analyzed in the Reconnaissance Study.

371. This analysis cycle used Waterborne Commerce statistics up to and including the year 1982 which were the latest available at that time. Total tonnage moved in 1982 on the main Delaware River channel between Philadelphia and the Sea was 81,618,754 tons. This total had percentage components of 62 percent foreign traffic, 18 percent coastwise traffic, and 20 percent internal and local traffic.

372. Cycle 4 formulation analyzed deepening the main Delaware River channel to depths of 42, 45 and 50 feet. Shoaling rates and dredging records were analyzed to determine suitable starting conditions (authorized depth, existing depth or natural depth). Dredged quantities and rock excavation quantities were calculated assuming bottom cut deepening along existing sideslopes. This would reduce existing bottom channel widths slightly. These quantities included a two foot overdepth. Disposal of dredged material was planned for disposal areas along each reach of the Delaware River, similar to the area distribution of the existing Federal sites which have been found to reasonably minimize the costs of dredging and disposal operations. No anchorage dredging was included for this analysis. No relocations or associated features were required for the 42 foot depth while the 45 foot plan was estimated to require two utility relocations and associated costs for bulkhead modification at six locations. The 50 foot plan was estimated to require six utility relocations and associated costs for the six bulkhead modifications. Costs were developed using the Dredged Material Disposal Management Model (D2M2) developed by the U.S. Army Corps of Engineers Hydrologic Engineering Center. This model can be used to estimate the total average annual cost of the least cost disposal scheme, considering such factors as dredging and disposal area diking costs, for initial construction and maintenance types of dredging plant, site acquisition costs, and annual site operations and maintenance. The computer solution is based on a present worth comparison of all dredging and disposal costs over the planning period for an iterative series of analyses which vary site selection and the timing of acquisition to arrive at a least cost solution.

373. For existing Delaware River traffic, crude oil was identified as the major commodity beneficiary. Coal, grain, iron ore, and scrap were also projected to accrue benefits. When this cycle of analysis was performed container fleet projections were unclear,

therefore, no benefits were claimed for containers. The potential benefits for diverted traffic were also estimated.

374. All the crude oil terminals except the Getty (now Texaco), Delaware City facility were projected to benefit from a deeper main channel. This facility maintains an access channel to its berth of only 35 feet and would not modify their access due to a deeper main channel. Tidewater Grain, Pier 122 (iron ore), Pier 124 (coal), and South Jersey Port Corporation's Beckett Street Terminal (scrap) were identified as beneficiaries in this cycle. A comparison of the project costs and benefits for this cycle is presented below in Table 18 using an September 1991 price level.

375. Based on the net benefits for the three depths, shown in Table 18, it was concluded that the 50 foot project would not be economically feasible under conditions occurring at that time and it was eliminated from further study. Further study of deepening the channel up to and including 45' was found warranted in order to determine the optimum channel.

CYCLE 5 - NAVIGATION SYSTEM ANALYSIS

376. The purpose of Cycle 5 formulation was to complete more detailed design studies and updated economic studies in order to conduct optimization of the regional waterway system. This required further analyses of the main Delaware River channel deepening including evaluation of further improvements at tributary projects consistent with main channel depths, studies of realigning the channel under Benjamin Franklin bridge realignment in the vicinity of Marcus Hook, and the Delaware River Anchorages.

TABLE 21

CYCLE 4 FORMULATION, MAIN CHANNEL DEEPENING
DELAWARE RIVER, PHILADELPHIA TO THE SEA

Project Costs	42 foot Project	45 foot Project	50 foot Project
Project First Cost	$60,941,000	$369,904,000	$761,782,000
Amortized First Cost	5,053,000	29,552,000	63,166,000
Operation & Maintenance	1,953,000	4,861,000	10,344,000
Total Ave. Annual Costs	7,006,000	34,413,000	73,510,000
Project Benefits			
Exist. & Future Commod.	13,437,000	29,397,000	47,914,000
North Atlantic Diversions	9,923,000	15,192,000	23,856,000
Total Annual Benefits	23,360,000	44,589,000	71,770,000
Benefit/Cost Ratio	3.33	1.29	0.98
Net Benefits	16,354,000	10,176,000	- (1,740,000)

377. Cycle 5 studies were conducted in the period between 1986 and 1988. Several important developments occurred during the period. The major regional gain elevator on the Schuylkill River ceased operation in December 1985 and remained closed, available for sale. The grain elevator at Port Richmond's Pier E which had been integrated with coal exports by Energy Terminals Incorporated was not functioning and not likely to resume in the near future. Grain, which was once thought to have major potential as a growth export from the Port of Philadelphia was considered to have a bleak future. On the other hand crude oil and petroleum products, the largest waterborne commodities increased their amount of annual tonnage during this timeframe. The region's refineries were streamlined insuring more efficient and competitive operations. Coal, the largest export commodity from the Port of Philadelphia, had almost a fourfold increase to 4.7 million tons

exported in 1985 compared to 1.2 million tons in 1984. General cargo tonnage increased during 1986 and the port captured the majority of tonnage into the region for particular commodities such as Chilean fruit and meats.

378. The selection of design vessels was made following a review of existing and future vessel distributions and coordination with pilots, ship captains, and the Coast Guard. More detailed consideration was given to the physical conditions as they impacted on design requirements.

379. In keeping with the recommendations of Cycle 4 to analyze channel depths of 41 to 45 feet, the initial analyses concentrated on the selected depths of 42' and 45' for several of the options under investigation. Then the main channel analysis was conducted using one foot increments up to 46 feet as a system analysis. The first evaluation was of realignment of the main channel in Philadelphia Harbor.

380. DELAWARE RIVER CHANNEL REALIGNMENT AND BENJAMIN FRANKLIN BRIDGE. The alignment of the 40 foot MLW deep draft channel under the Benjamin Franklin Bridge passes close to its west abutment where the minimum vertical clearance is only 129 feet (MHW), the least clearance of any bridge between Trenton and the Sea. The other bridges provide clearances of 135 (MHW) and greater as shown on Table 19. Figure 14 shows the current channel dimensions in the vicinity of the Benjamin Franklin Bridge and the vertical clearances. According to representatives of the Delaware River Pilots' Association and the Mariners' Advisory Committee, the 129' constraint causes both a safety hazard to vessels passing under the bridge and inefficient vessel operations. These inefficiencies were reported to include the cost of disassembling mast-mounted equipment on some vessels, delays due to tide conditions and ballasting requirements, and the use of smaller vessels than desired. These problems were experienced by the Navious Fleet which calls at the U.S.X. Steel plant in Fairless Hills.

a. The navigational depths considered ranged from 40' to 45'. An additional 2' was included for all depths to allow for overdepth dredging. Vessel depth allowance parameters were evaluated and found to require a total of five feet in order to allow for squat, trim and freshwater sinkage and safe underkeel clearance.

TABLE 22

Minimum Vertical Clearances at Delaware River Bridge Crossings

Vertical Bridge Name	Type	Location	Minimum Clearance (MHW)
Delaware Memorial Twin Bridges	Fixed	Wilmington, DE	188' (for 40' channel)
Commodore Barry Bridge	Fixed	Chester, PA/Bridgeport, NJ	181' (for 40' channel)
Walt Whitman Bridge	Fixed	Phila, PA/Gloucester, NJ	139'/150' (for 40/37 channel)
Benjamin Franklin Bridge	Fixed	Phila, PA/Camden, NJ	129'/135' (for 40/37 channel)
Conrail Bridge	Vertical Lift	Phila, PA/Delair, NJ	135' (40 channel)
Betsy Ross Bridge	Fixed	Phila, PA/Pennsauken, NJ	135' (for 40' channel)
Tacony-Palmyra Bridge	Bascule	Phila, PA/Palmyra, NJ	-
Burlington-Bristol Bridge	Lift	Burlington, NJ/Bristol, PA	134'
Turnpike Bridge	Fixed	Bristol, PA/Florence, NJ	135'

FIGURE 12

DELAWARE RIVER COMPREHENSIVE
NAVIGATION STUDY
MAIN CHANNEL DEPENING

CHANNEL REALIGNMENT
UNDER BEN FRANKLIN BRIDGE

PHILADELPHIA DISTRICT
CORPS OF ENGINEERS

Sample vessels that called at U.S.X. Steel are as follows:

Vessels Calling at U.S.X. Steel During 1984

Deadweight Tons	50,000	63,000	73,000
Design Draft	39'	42'	44'
Air Clearance (@ 39' Draft)	111'	118 '	132'

381. The vessel class which is restricted by the 129 ft. MLW clearance at the Ben Franklin Bridge during an inbound, cargo-laden passage is the 73,000 DWT vessel. With an air height of 132 feet it is necessary to disassemble the vessel's mast in order to pass with a sufficient margin of safety under the Ben Franklin Bridge. It is unlikely that a cargo-laden vessel of that size could add ballast to pass under the bridge because of the 40 foot depth restriction. The realignment would shift the 40 foot channel closer to the center of the bridge, thus providing a minimum of 135 ft. (MHW) vertical air clearance without prolonged tidal delays.

382. A benefit analysis showed that $43,000 per year could be saved by realigning the channel and quantifying the following benefits:

a) time saved in not having to disassemble the mast,
b) time saved in not having to take on ballast

The analysis assumed a 0.9% growth rate in tonnage shipped. Costs were analyzed using the D2M2 model. It should be noted that project costs are not high since this section of the Delaware River is deeper than authorized in many areas and is relatively stable, requiring little maintenance dredging.

383. Table 20 shows the results of the economic analysis. The resultant benefit/cost ratio of 0.14 showed that the realignment was economically unjustified for the existing channel depth of 40 feet. The economic analysis was also based on benefits to a single user. Further studies identified no other potential users. This portion of the study was suspended. Subsequently, a change in plan operation has curtailed iron ore shipment eliminating the need for any realignment.

384. DELAWARE RIVER CHANNEL REALIGNMENT AT MARCUS HOOK, PENNSYLVANIA. Cycle 5 evaluations of channel deepening included a realignment of the channel of Marcus Hook including the Marcus Hook, Chester and Eddystone Ranges. Figure 15 shows the dimensions of the existing projects and the realignment (40' x 800'). The adjacent Marcus Hook Anchorage is fully maintained to its authorized dimensions of 40' x 2300' x 13,650' (mean).

385. The numerous rock outcroppings along the Pennsylvania side of the channel represent a major channel deepening cost. The proposed realignment which was analyzed in an attempt to reduce channel deepening dredging of sediment in shallower areas outside the existing channel while avoiding expensive rock excavation. The cost of rock removal ranges from five to twenty times more expensive than that for sediment, depending upon the dredging technique employed. Table 21 lists the cubic yardage of sediment and rock excavation for the realigned channel and the existing configuration.

386. For the initial comparison of costs, the channel realignment was assumed to reduce the size of the anchorage. In effect the plan would cause some disbenefits unless the anchorage were shifted, however, these considerations were intentionally deferred to later cycles of formulation, if further study was indicated. Formulation of the alternatives was conducted on a least cost basis since benefits would remain constant regardless of alignment. It demonstrated that channel deepening along the existing alignment at Marcus Hook was more cost-effective than realigning the channel to avoid rock excavation. This realignment was not recommended for further investigation.

387. DELAWARE RIVER, PHILADELPHIA TO THE SEA ANCHORAGES. As discussed in earlier sections, the anchorages at Marcus Hook and Mantua Creek are the most heavily used of the Federally authorized anchorages. U.S. Coast Guard records on anchorage use revealed that investigations of anchorage modifications could be limited to these two locations. Usage at the other anchorages was so infrequent that it was obvious that no need existed to consider improvements.

388. Examination of vessel characteristics using the anchorage at Mantua Creek indicated that there were no significant problems and that the largest vessels calling there were usually in ballast. Vessels calling at Marcus Hook included a large percentage (60%) of tankers which are constrained by depths in the channel and anchorage. Analysis of historic anchorage usage data showed that Mantua Creek was more frequently used than Marcus Hook, but that both anchorages were empty a significant percentage of the time: 40 percent and 72 percent, respectively. For the period analyzed, no more than three vessels used the Marcus Hook Anchorage at one time and two or fewer vessels used the anchorage 98 percent of the time.

TABLE 23

Cycle 5, Analysis of Realignment of 40' channel at
Benjamin Franklin Bridge
(October 1991 Price Level)

Item	
Channel Width	400'
Initial Dredging	257,000 cy
Maint. Quantity (annual)	4,400 cy
Utility Relocations	None
Associated Features	None

Project Costs	
Project First Costs	$2,012,000
Amortized First Costs	$ 176,000
Operations & Maintenance	$ 123,000
Total Average Annual Cost	$ 299,000

Project Benefits	
Transport. Savings	$43,000 Average Annual Benefits

Benefit/Cost Ratio	0.14

FIGURE 12

DELAWARE RIVER COMPREHENSIVE NAVIGATION STUDY
MAIN CHANNEL DEEPENING

MARCUS HOOK ANCHORAGE & DELAWARE RIVER CHANNEL PROPOSED REALIGNMENT

PHILADELPHIA DISTRICT
CORPS OF ENGINEERS

TABLE 24
Cycle 5, Analysis of Realignment of Delaware River Channel, Realignment of Marcus Hook
(October 1991 Price Level)

	Existing Alignment		Realigned Channel	
Project Costs ($thousands)	42'	45'	42'	45'
Project First Cost	$ 10,133	$ 24,723	$27,463	$29,541
Amortized First Cost	887	2,176	2,407	2,590
Operations & Maintenance	7,859	8,848	7,933	9,009
Total Ave. Annual Cost	8,746	11,024	10,340	11,599
Quantities of material removed:				
Sediment(cy)	145,000	5,222,000	6,394,000	8,831,000
Rock (cy)	15,000	45,100	0	0

Net Savings-
Existing Alignment ($thousands)
42' $(-1,594) Average Annual Costs
45' $(-575) Average Annual Costs

389. No improvements were considered for the Mantua Creek Anchorage since usage patterns suggested no serious problems with authorized or existing dimensions. In developing alternatives for analysis of Marcus Hook, consideration was given to deepening the entire anchorage to depths compatible with main channel depths (42 and 45 feet initially) as well as two schemes to reduce dredging requirements. The Marcus Hook Anchorage and Range area represents the largest single shoal location in the main channel project and plans to minimize dredging were expected to be much more efficient than dredging the entire anchorage. The first alternative reasonably minimized the number of free-swinging spaces to be provided. Although the available usage data did not permit queuing type analysis which related vessel draft and dimensions, duration of anchorage, and number of vessels at any given time, two spaces were considered to be adequate. A second option provided for deepening the entire anchorage for comparison even though no significant difference would result in benefits. Another option gave consideration to mooring dolphins or double anchoring (stern and bow) by vessels to further reduce the area required below that of free-swinging criteria.

390. However, coordination with the Mariners' Advisory Committee and Pilots' Association surfaced several concerns over the last option. Double anchoring systems were considered unreliable since they do not always hold the vessel in place. This would create a serious hazard and oil spill potential, particularly for frequent use by tankers in close proximity to each other. In addition, not all vessels are equipped with stern anchors. The non-structural approach was therefore eliminated. Mooring structures were also viewed as presenting collision potential. Massive, costly structures would be required to resist the mooring forces of river currents . In addition operational costs would be increased by the necessity for tug assistance to anchor and mooring crews. For these reasons the structural version of the option was considered impractical and the full size and two space anchorage plans were analyzed (see Figures 16 and 17).

391. An economic analysis of the Marcus Hook Anchorage showed that anchorage use had declined since the mid-1970's due to 1) a decline in Delaware River commerce, 2) a larger cargo carried per vessel, and 3) a shortening of queues due to an increase in cargo transfer capacity. Two types of benefits were studied:

(a) Improvements to navigation (accident cost prevention); and

(b) Improvements to operating efficiency (lightering and bunkering cost reduction).

392. The economics analysis identified no difference in benefits attributable to the full anchorage deepening plan. Costs were analyzed using the D2M2 model, reflecting the difference in initial and maintenance dredging costs as well as disposal area usage throughout the planning period. Results of the benefit/cost analysis are shown below in Table 22.

393. The analysis of deepening Marcus Hook Anchorage concluded that, when considered incrementally, provision of an anchorage depth compatible with a deeper channel was not economically justified. However, a question remained as to whether it was safe to design a deeper channel with no upstream anchorage of compatible depth (only berths would have suitable depth) or if a minimum capacity anchorage was a necessary, inseparable feature of a channel deepening plan. The District coordinated further with the Delaware River Pilots on this matter and it was concluded that further studies should include a minimum size anchorage area as part of the channel deepening plan.

394. TRIBUTARY PROJECTS. Only one deep-draft tributary project to the main channel, the Delaware River in the vicinity of Camden, was found to have potential to benefit from channel deepening.

FIGURE 14

DELAWARE RIVER
NAVIGATION STUDY
MAIN CHANNEL DEEPENING

MARCUS HOOK ANCHORAGE
DEEPENING OF ENTIRE
ANCHORAGE

PHILADELPHIA DISTRICT,
CORPS OF ENGINEERS

FIGURE 15

DELAWARE RIVER
NAVIGATION STUDY
MAIN CHANNEL DEEPENING

MARCUS HOOK ANCHORAGE
DEEPENING FOR TWO
VESSEL CAPACITY

PHILADELPHIA DISTRICT,
CORPS OF ENGINEERS

TABLE 25
Economic Analysis of Marcus Hook Anchorage Improvements
(October 1991 Price Level)

	Full Size ($thousands)		Partial Size ($thousands)	
	42 ft.	45 ft.42 ft	42 ft.	45ft.
Project First Cost	$12,671	$42,599	$6,624	$29,380
Amortized First Cost	1,101	4,204	581	2,575
Operations and Maintenance	734	2,103	651	1,882
Total Average Annual Cost	1,843	6,307	1,232	4,457
Total Average Annual Benefits	148	267	148	267
Net Benefits	(-1,695)	(-6,040)	(-1,084)	(-4,190)
Benefit/Cost Ratio	0.08	0.04	0.12	0.06

395. Delaware River in the Vicinity of Camden. Deepened access to the Beckett Street Terminal (40 feet) was authorized by Section 3a of the W.R.D.A. of 1988. The bulk berths at Beckett Street Terminal handle significant amounts of dry bulk cargo including scrap and coal which could benefit by further deepening consistent with the main channel. Deepening the trapezoidal access channel to berths 3 and 4 at the facility was included in the main channel deepening analyses.

396. MAIN CHANNEL DEEPENING DELAWARE RIVER, PHILADELPHIA TO THE SEA. Deepening of the entire channel was considered through Philadelphia Harbor up to the upper limit of the Philadelphia to Sea project at Allegheny Avenue. Benefits from channel deepening would accrue for crude oil imports to six of the seven major Delaware River refineries, ore imports to Pier 122 plus coal exports from Pier 124. Dredging through Philadelphia Harbor would also benefit scrap metal and bulk operations at Beckett Street Terminal in Camden. However, none were identified for facilities further upstream. Therefore, the channel deepening options stopped at that terminal.

397. Coordination with the Pilot's Association and Mariners Advisory Committee evaluated and discussed the adequacy of existing channel conditions, the need for modifications based on problems experienced, design parameters and physical conditions, and operational practices. Several key findings resulted from this coordination as discussed in the following paragraphs.

398. The existing channel widths varying from 1000' in Delaware Bay to 800' in the lower river up to the Philadelphia Navy Yard, were confirmed as being adequate and safe. These dimensions resulted from various authorizations through the years after consultation with pilots and vessel captains and no justification exists for deviating from these established widths for two-way traffic. A key concern expressed by the pilots was the need for additional widening at bends as part of the plan development.

399. Previous analyses found that deepening of the Federal anchorages to a depth compatible with a deepened main channel was not economically justified when considered incrementally. However, it was felt that as an integral feature of the plan there was a need to provide a minimal anchorage area at a compatible depth to the main channel so that a safe refuge was available for vessels experiencing mechanical problems or sudden fog. As a result, deepening of two spaces within the Marcus Hook Anchorage was included for all channel deepening plans.

400. Design physical conditions for operation in the Delaware were felt to include a 1.5 knot tidal current, visibility of 1 mile during the day or 2 miles at night, and 20-30 knot winds from the northwest. Thick fog and more severe physical conditions which inhibit vessel movements occur about seven days per year.

401. The pilots indicated that the largest vessels (275,000 DWT tankers) operate with tug assistance during light traffic conditions. No passing/meeting situations are permitted at turns for these vessels. Transits are restricted to daylight conditions.

402. The largest anticipated bulk carrier at that time was 190,000 DWT and proposed Pier 124 modifications would accommodate this vessel. Lesser size tankers and bulk carriers operate day or night with no tug assistance except for turning/docking maneuvers. Since the largest vessels operate infrequently and could be accommodated by restricting transits to daylight and milder physical conditions or through use of tug assistance, they were not considered for design under adverse conditions. The design vessel selected was a 160,000 DWT dry bulk carrier with a beam of 145 feet and a design draft of 58 feet. These vessels can be accommodated as a result of lightering and traversing on the high cycle of the tide.

403. The navigational depths considered ranged from 40' to 45'. An additional 2' was included for all depths to allow for overdepth dredging. Vessel depth allowance parameters were evaluated and found to require a total of five feet in order to allow for squat, trim and freshwater sinkage and safe underkeel clearance.

404. The existing channel alignment has 16 bend widenings in the channel between Delaware Bay and the Philadelphia Harbor. (See Figures 18 & 19). These bend widenings are required for turning

vessels. The width needed at each bend is dependent on the angle of the turn plus the beam, length, and maneuverability of the design vessel. Bend widening was not considered necessary for the Philadelphia Harbor itself due to reduced vessel speed. Vessels operate at speeds up to 12 knots elsewhere in the main channel and bay.

405. During Cycle 5 the D2M2 data files were modified to incorporate new information on shoaling rates, initial construction quantities, disposal area capacities, the acquisition costs and the annual costs for disposal site operation and maintenance, and dredging/transportation costs. Additional modifications were made to reflect changes in the status of disposal sites. Due to the large amount of data storage required to operate the D2M2 model, four major reaches were used to determine the most cost effective mode of transportation and disposal site usage. Table 23 shows the dredging yardage at various depths for the entire project from Brandywine Range in Delaware Bay up to Beckett Street Terminal over the 50 year planning period including initial construction and maintenance. The cubic yardage refers to unconsolidated material with a wet-to-dry ratio of 1.5.

TABLE 26
CYCLE 5, CHANNEL DEEPENING
DREDGED MATERIAL QUANTITIES
(DELAWWARE BAY TO BECKETT ST. TERMINAL)
(TOTAL) (MILLION CUBIC YARDS)

DEPTH	Initial Dredging	50 yr Maintenance Dredging Total
40'	0	298
41'	14	308
42'	23	318
43'	34	328
44'	45	339
45'	59	348

FIGURE 16

DELAWARE RIVER

PHILADELPHIA TO THE SEA

Bend Widening 1 of 2

U.S. ARMY ENGINEER DISTRICT, PHILA.

LEGEND

Channel indicated thus: ═══

NOTE:
Distance in miles below Allegheny Ave., Phila., show along side of channel

DELAWARE RIVER

PHILADELPHIA TO THE SEA

PENNA., N.J. & DEL.

Bend Widening 2 of 2

FIGURE 17

406. The D2M2 model used the most efficient means for the disposal of dredged material. The sites considered all passed both technical and ecological screenings accomplished previously.

407. The economic analysis involved the estimated value of potential project benefits based on transportation cost savings which would result from channel deepening. Transportation cost savings would accrue due to use of larger vessels, reduced costs for lightering, tidal delay reductions, and less tug usage requirements. Benefits were broken down into two categories: a) existing traffic (with future growth) through the Delaware River system, and b) potential diversions from competing ports.

408. Weighted average transportation costs per ton were developed for each of the relevant commodities and trade routes for the 40 ft. (MLW) without condition main channel depth, and with condition alternatives extending to a maximum 45 ft. (MLW) main channel depth.

409. A Multiport Analysis was conducted in accordance with EC 1105-2-129: Guidance on the applicability of the Principles and Guidelines to Deep Draft Navigation Benefit Evaluation which calls for "a systematic determination of routing possibilities, regional port analyses and intermodal networks." The goal of the multiport analysis was to estimate the volume of tonnage which might be diverted to the Delaware River port system from New York, Baltimore, Norfolk/Hampton Roads, New Orleans, and the Texas Gulf Coast ports (i.e., those ports identified as competing), and the resultant transportation cost savings from the diverted tonnage as a result of the Delaware River plan of improvements. The only estimated diversions from other ports was coal moving through Pier 124. Further studies were recommended over the entire depth range up to and including 46 feet, based on the expected change in benefits which were expected to occur with the changing world energy situation which would significantly increase the amount of crude oil imports both to the nation in general and the local refineries in particular.

CYCLE 6 - DISPOSAL COST AND IMPACT ASSESSMENT

410. ASSESSMENT OF DISPOSAL AREA IMPACT. The ultimate selection of a plan of improvement must give consideration to disposal options as well as channel depths, dimensions, and length. In order to further refine the disposal analyses, consideration was given to the effect channel deepening would have on the existing Federal project in general, and the existing Federal disposal areas in particular. Five disposal options were evaluated, which are described as follows:

a. Pumping all material from construction of the modified project and subsequent maintenance of the entire project into upland Federal sites, and allowing local sponsors to

reimburse the Federal government on an in-place volumetric basis.

b. Pumping all material into upland Federal sites, as above but requiring local sponsors to rehandle the required volumes of dried material to a final location provided by the sponsor.

c. Requiring local interests to provide suitable new disposal sites to accommodate the volumes of the initial construction and increased maintenance dredging associated with the project modification; and pumping the required volumes of dredged material into these sites during each dredging cycle.

d. Requiring new sites to be provided by local interests for initial construction and increased maintenance as in (c), however, allowing pumping of material into either the Federal or local sites as appropriate to minimize dredging and mobilization costs, while ensuring the long term volume requirements are met by local sponsors.

e. Deposit material at an aquatic site Delaware Bay with is consideration for beneficial uses such as wetland/island/upland creation, oyster seed bed creation, and sand stockpile.

411. In screening these options it was considered necessary that local sponsors make the Federal government whole for any costs it incurred due to non-Federal use of a Federal disposal area. This includes consideration of costs for diking, maintenance, transportation and disposal and acquisition as affected by the local use. In addition, it was concluded that local use of a Federal site should cause no significant reduction in the remaining life of Federal sites, considering 10% or less to be an acceptable change. However, it was also concluded that local use could not result in an overall reduction in the expected life of a site such that a short-term (about 10 years or less) problem could result and jeopardize the government's ability to maintain the existing project.

412. Consideration was given to use of existing Federal upland disposal areas in option (a) since the sites are well distributed along the length of the main channel and had potential to minimize project costs. The analysis was broken down into 4 separate reaches (see figure 20). However, an analysis of initial construction and maintenance requirements showed that the potential impact on remaining capacities at Federal sites would be very significant, based on a 45' project as shown below:

Reach Reduction	Sites	Reduction in Useful Life	Percent
A.	National Park	21 years	45%
B.	Pedricktown N. Pedricktown S. Oldmans	10 years	24%
C.	Killcohook Penns Neck	11 years	18.5%
D.	Artificial Island	36 years	39%

N
DELAWARE
NEW CASTLE COUNTY
WILMINGTON
DELAWARE COUNTY
PENNSYLVANIA
MARCUS HOOK
CHESTER
CHRISTINA RIVER
NEW CASTLE
SCHUYLKILL RIVER
PHILADELPHIA
DEL CITY
C&D CANAL
OLDMANS #1
PEDRICKTOWN NORTH
PEDRICKTOWN SOUTH
PENNS NECK
NEW JERSEY
NATIONAL PARK
SALEM RIVER
SALEM
B
A
KILLCOHOOK
C
ALLOWAY CR.
ARTIFICIAL ISLAND
D
SALEM COUNTY
CUMBERLAND COUNTY
NEW CASTLE COUNTY
KENT COUNTY
COHANSEY RIVER
TO
BUOY 10
RIVER MILE 7
DELAWARE BAY
LEGEND
EXISTING UPLAND DISPOSAL SITES
D2M2 REACH BOUNDARY
COMPREHENSIVE NAVIGATION STUDY
FIGURE 18
DISPOSAL AREAS FOR CHANNEL DEEPENING

413. Based on this analysis it was evident that option (a) was not acceptable for the Delaware River disposal area and that other options should be considered. It was also concluded that use of this option could interfere with annual maintenance operations due to the large volumes of pumped slurry, limited degree of dike raising (lift) which could be accommodated, and difficulty in dewatering large lifts.

414. Option (b) calls for pumping all material into the upland Federal sites, but rehandling it, when dried, into final locations provided by the sponsors. This option is not well suited to the very large quantities generated by main channel deepening, since it would result in huge volumes of material being excavated and hauled to other locations. It would also interfere with maintenance operations at each site, since there is limited time for excavation after dewatering between annual maintenance pumping cycles. Current maintenance operation utilize low ground pressure equipment to accomplish ditching and dike raisings and are time constrained for these limited activities. This option would also appear to be inefficient, given the volumes of dredging, since large parcels would be needed as a final disposal location and these could likely be developed and pumped directly at less expense.

415. Option (c) requires local interests to provide new disposal sites to accommodate the volumes of initial construction and maintenance for which they are responsible and placement of the appropriate volumes in local sites during each dredging cycle.

416. This would appear to be a relatively inefficient option, given that during maintenance operations the local sponsor would be responsible for the incremental quantity associated with channel deepening. Use of this option could significantly increase mobilization, demobilization, and dredging costs by requiring use of multiple disposal areas in every maintenance cycle including pipeline, mooring barges, and site preparation expenses.

417. Option (d) requires local interests to acquire new sites to accommodate the volumes of initial construction and increased maintenance dredging, allowing operational efficiencies to occur by using Federal and non-Federal sites as appropriate, while ensuring that long-term volume requirements are met by local sponsors. This option has advantages over previous options and can result in an NED plan for the river channels since it provides for operational efficiencies while having little or no effect on ultimate Federal site capacities. There is also an opportunity to enhance site management by increasing the number of sites and allowing longer periods for rest, dewatering, and possibly reuse of material. Additionally, site capacity could be exchanged to result in overall efficiencies between the government and local sponsor and ensure the continued availability of disposal capacity distributed along the length of the river, which would continue to minimize future maintenance costs for the main channel.

418. As part of this consideration, the Reedy Point North and South disposal areas located in Reach C, were identified as having significant remaining capacity with little demand for use on the Chesapeake and Delaware Canal project. It was concluded that they could be considered for use by sponsors for the Delaware River main channel deepening, without any significant effect on project maintenance operations. The capacity at these locations could be exchanged for that in other areas such as Reach A where Federal capacity is more limited.

419. Option (e) to dispose of material at aquatic sites in Delaware Bay or in the Atlantic Ocean is unattractive in comparison to other options due to the haul cost, except for the material in the Delaware Bay channel. This was evident from D2M2 computerized cost analyses conducted in earlier studies. Beneficial use sites and the Buoy 10 site were made available for computer runs in each reach. Only in the bay channel were these options selected as less expensive, than alternative sites within the reach. Maintenance dredging operations have used the overboard disposal site at Buoy 10 on a limited basis for the bay channel since this is closer to the shoaling locations than upland sites or any potential ocean locations. However, based on agency coordination beneficial use options in the Delaware Bay, option (e), viewed as necessary alternatives to extensive use of Buoy 10 Delaware Bay.

420. In conclusion, options (d) and (e) were found to warrant further consideration in developing a disposal plan which reasonably maximized National Economic Development objectives. The impact of dredging volumes for channel deepening were too significant to allow use of the Federal disposal areas on the main channel. However, for the Delaware River use of excess capacity at C&D Canal disposal areas, trade offs between Federal and non-Federal site use and capacities, and beneficial uses in the Delaware Bay warrant consideration.

421. <u>DISPOSAL COST AND IMPACT ASSESSMENT.</u> For the new sites to be considered under option (d) of the previous discussion, an evaluation was made of critical cost factors and in each reach environmental and cultural resource concerns in order to rank and compare the remaining 33 potential disposal sites plus 2 Federal sites.

422. Using cost curves and data developed for the D2M2 model weighted dredging costs per cubic yard were developed for each area as a function of distance from dredging locations. Costs were also developed for diking and acquisition per cubic yard of ultimate site capacity as components of a site cost per cubic yard. This was used to rank sites as high, moderate or low cost based on the following ranges. In the Delaware River and Delaware Bay a low cost site was any site under $4.50 per cubic yard. In order for a site to be ranked moderate in the Delaware River the cost ranged

from $4.50 to $6.50 a cubic yard. Due to the large number of available and probably acceptable sites in the Delaware River ranges the price range was kept narrow. In the Delaware Bay the channel ranges from 5 to over 15 miles from the shore. This forced the moderate cost up between $4.50 to $10.00 in order to attract more environmentally desirable alternatives. Otherwise the cost prohibitive choice of hauling material upriver to a Delaware River site would have to be considered. High costs sites were greater than $6.50 for the Delaware River and greater than $10.00 for the Delaware Bay.

423. The habitat and land cover as well as other critical environmental and cultural values at each site were described and quantified in order to assess the significance of impacts and the probable need for mitigation at each site. Impacts were summarized as high, moderate, and low and mitigation requirements assessed citing acreage and habitat type. Using these comparisons of cost and impact the sites in each reach were classified and screened. All low cost sites in each reach regardless of environmental impact and moderate cost sites with low impact were carried forward. Table 24 and Table 24A shows the results of this analysis. Based on this analysis ten new upland and seven aquatic sites in the Delaware River and the Delaware Bay 19 remaining sites were recommended for consideration in detailed formulation analyses which passed the previous disposal cycle utilized a more detailed incremental costs analysis including incremental mitigation to prepare a final ranking of disposal based on the disposal requirements of the Delaware River Main Channel in the Delaware Bay. Variations of island/marsh creation and upland creation warrant consideration for the aquatic sites. No sites which may have been economically more advantageous were eliminated from consideration at any time in the screening process solely due to environmental factors. Where modification of site boundaries (avoidance) was possible by shifting a border and least costly, this environmentally preferred option was chose.

CYCLE 7 - DISPOSAL AREA SCHEME SELECTION

424. This final analysis of disposal areas utilized a more detailed incremental cost analysis including incremental mitigation to prepare a final ranking of disposal areas based on the disposal requirements of a 45 foot deep full width channel. This is in compliance with Corps Policy Guidance subject, Management of Material Dredged from Navigation Channels dated May 18, 1989. Both initial and ultimate disposal capacity requirements were used in determining the size and in some cases the number of disposal sites considered. Initial costs were evaluated using acquisition costs, mobilization and demobilization costs, and dredging and disposal costs for a given disposal area or areas. To these construction costs were added the costs associated with mitigation

of environmentally sensitive habitat. The total cost of initial construction was converted to an annualized cost and added to the average annual maintenance cost to determine total average annual cost.

425. In the Delaware River reaches 17 separate new sites which passed the previous disposal cycle analysis plus the two Federal disposal sites (Reedy Island North and South) and the 19 remaining bay sites were combined into 19 disposal scenarios. These scenarios are evaluated in Table 28. In addition thin layering was evaluated in Reaches C and D where sufficient river bottom exists beyond 2000 feet of a channel, to handle the disposal requirements of initial construction in these reaches.

426. The two scenarios in reach A, both involve use of a single upland disposal site. Site 17G is slightly less expensive (3%) than site 17O; neither requires mitigation. However, during this time site 17G was being designed for a $1 billion waterfront project called Imperial Landing. Included on this project is a 1,500 slip marina, 4,700 housing units and 2.5 million square feet commercial space, plus a golf course, ferry service, and an equestrian center. The project is before the West Deptford Township planning board and township committee for final approval. Development is expected to begin shortly, and the site will not be available for use as a disposal site. As a result, site 170 would be the best site for use in Reach A.

427. There are six scenarios in Reach B, three involving upland sites and three aquatic. The three upland scenarios were less expensive than aquatic disposal, even without mitigation costs included.

TABLE 27
CYCLE 6 SCREENING OF DISPOSAL AREAS

SITE/ REACH	ACRES	CAPACITY	COST $/C.Y.	LAND USE AND COVER	FISH & WILDLIFE IMPACTS	MITIGATION REQUIREMENTS	CULTURAL RESOURCE IMPACTS	COST RANKING	ENV IMPACT	CONTINUE TO EVALUATE
13F UPLAND REACH A	140	4.9 MCY	7.70	20 ACRES WOODS 120 ACRES CULT. FIELD	MODERATE	NONE	NONE KNOWN	HIGH	MODERATE	NO
17A UPLAND REACH A	130	4.5 MCY	8.00	10 ACRES WOODS 120 ACRES CULT. FIELD	LOW	NONE	NONE KNOWN	HIGH	LOW	NO
17B UPLAND REACH A	120	4.2 MCY	8.00	20 ACRES WOODS 100 ACRES CULT. FIELD	LOW	NONE	NONE KNOWN	HIGH	LOW	NO
17C UPLAND REACH A	120	5.2 MCY	7.50	120 ACRES CULT. FIELD	LOW	NONE	NONE KNOWN	HIGH	LOW	NO
17D UPLAND REACH A	100	3.5 MCY	7.30	5 ACRES WOODS 95 ACRES CULT. FIELD	LOW	NONE	NAT REGISTER SITES	HIGH	MODERATE	NO
17G UPLAND REACH A	295	20.9 MCY	3.10	30 ACRES CULT. FIELD 265 ACRES OF FIELD	LOW	NONE	NONE KNOWN	LOW	LOW	YES
17O UPLAND REACH A	300	11 MCY	3.20	30 ACRES CULT. FIELD 210 ACRES WOODS 30 ACRES LAND FIELD 30 ACRES WETLANDS	MODERATE	30 ACRES WETLANDS	SEVERAL PREHIST. REGISTER SITES	LOW	MODERATE	YES

TABLE 27 (CONT'D)

CYCLE 6 SCREENING OF DISPOSAL AREAS
(Cont'd)

SITE/ REACH	ACRES	CAPACITY	COST $/C.Y.	LAND USE AND COVER	FISH & WILDLIFE IMPACTS	MITIGATION REQUIREMENTS	CULTURAL RESOURCE IMPACTS	COST RANKING	ENV IMPACT	CONTINUE TO EVALUATE
15D UPLAND REACH B	575	40.3 MCY	3.20	200 ACRES ABAN. FIELD 275 ACRES CULT FIELD	LOW	NONE	PREHISTORIC SITES KNOWN	LOW	MODERATE	YES
RACCOON UPLAND REACH B	600	40 MCY	2.40	600 ACRES ABAN. FIELD	LOW	NONE	NONE	LOW	LOW	YES
15E UPLAND REACH B	120	7.6 MCY	3.60	60 ACRES CULT. FIELD 40 ACRES ABAN. FIELD 20 ACRES WETLAND	MODERATE	20 ACRES WETLAND	POSSIBLE	LOW	MODERATE	YES
15F UPLAND REACH B	145	6.5 MCY	4.70	145 ACRES ABAN. FIELD	LOW	NONE	NONE KNOWN	MODERATE	LOW	YES
15G UPLAND REACH B	320	20.0 MCY	3.50	320 ACRES ABAN. FIELD	LOW	NONE	NONE KNOWN	LOW	LOW	YES
15H AQUATIC TO ISLAND (+15') REACH B	455	17 MCY	5.10	75 ACRES SHALLOWS 100 ACRES TIDAL FLATS 280 ACRES DEEP RIVER	MODERATE	75 ACRES SHALLOWS 100 ACRES TIDAL FLATS	NONE	MODERATE	MODERATE	NO
15I AQUATIC TO ISLAND (+15') REACH B	775	21 MCY	5.20	165 ACRES TIDAL FLATS 265 ACRES SHALLOWS 180 ACRES DEEP WATER 65 ACRES WETLANDS	HIGH	165 ACRES TIDAL FLATS 265 ACRES SHALLOWS 65 ACRES WETLANDS	NONE	MODERATE	HIGH	NO

TABLE 27 (CONT'D)

CYCLE 6 SCREENING OF DISPOSAL AREAS
(Cont'd)

SITE/ REACH	ACRES	CAPACITY	COST $/C.Y.	LAND USE AND COVER	FISH & WILDLIFE IMPACTS	MITIGATION REQUIREMENTS	CULTURAL RESOURCE IMPACTS	COST RANKING	ENV IMPACT	CONTINUE TO EVALUATE
15I AQUATIC TO UPLAND (+50') REACH B	775	50 MCY	3.70	165 ACRES TIDAL FLATS 265 ACRES SHALLOWS 180 ACRES DEEP WATER 65 ACRES WETLANDS	HIGH	165 ACRES TIDAL FLATS 265 ACRES SHALLOWS 65 ACRES WETLANDS	NONE	LOW	HIGH	YES
15J AQUATIC TO ISLAND (+15') REACH B	895	27 MCY	4.30	125 ACRES TIDAL FLATS 320 ACRES SHALLOWS 430 DEEP WATER	HIGH	125 ACRES TIDAL FLATS 320 ACRES SHALLOWS	NONE	LOW	HIGH	YES
15J AQUATIC TO UPLAND (+50') REACH B	895	60 MCY	3.70	125 ACRES TIDAL FLATS 320 ACRES SHALLOWS 430 DEEP WATER	HIGH	125 ACRES TIDAL FLATS 320 ACRES SHALLOWS	NONE	LOW	HIGH	YES
16O AQUATIC TO ISLAND (+15') REACH B	1400	50 MCY	4.30	460 ACRES INTERTIDAL 590 ACRES SHALLOWS 100 ACRES DEEP WATER 250 ACRES WETLAND	HIGH	460 ACRE INTERTIDAL 590 ACRES SHALLOWS 250 ACRES WETLAND	NONE	LOW	HIGH	YES
16M UPLAND REACH B	155	5.2 MCY	7.00	155 ACRES CULT. FIELD	LOW	NONE	NONE KNOWN	HIGH	LOW	NO
16Y UPLAND REACH B	220	9.4 MCY	6.90	145 ACRES CULT. FIELD 60 ACRES WOODS 15 ACRES WETLANDS 3000 STREAM	MODERATE	15 ACRES WETLAND	NONE KNOWN	HIGH	LOW	NO
21E UPLAND REACH B	150	5.0 MCY	6.70	150 ACRES CULT. FIELD	LOW	NONE	NONE KNOWN	HIGH	LOW	NO
21F UPLAND REACH B	100	3.7 MCY	7.00	100 ACRES CULT. FIELD	LOW	NONE	NONE KNOWN	HIGH	LOW	NO

TABLE 27 (CONT'D)

CYCLE 6 SCREENING OF DISPOSAL AREAS

SITE/ REACH	ACRES	CAPACITY	COST $/C.Y.	LAND USE AND COVER	FISH & WILDLIFE IMPACTS	MITIGATION REQUIREMENTS	CULTURAL RESOURCE IMPACTS	COST RANKING	ENV IMPACT	CONTINUE TO EVALUATE
21 Y UPLAND REACH B	130	4.5 MCY	7.30	130 ACRES CULT. FIELD	LOW	NONE	NONE KNOWN	HIGH	LOW	NO
22BB UPLAND REACH B	300	10.8 MCY	7.50	200 ACRES CULT. FIELD 40 ACRES WOODS 60 ACRES ABAN. FIELD	MODERATE	NONE	NONE KNOWN	HIGH	MODERATE	NO
21D UPLAND REACH C	100	3.9 MCY	6.80	90 ACRES CULT. FIELD 500' STREAM 10 ACRES WOODS	MODERATE	NONE	NONE KNOWN	HIGH	MODERATE	NO
23C UPLAND REACH C	200	6.9 MCY	6.20	200 ACRES CULT. FIELD	LOW	NONE	NONE KNOWN	MODERATE	LOW	YES
23D UPLAND REACH C	200	6.9 MCY	6.40	200 ACRES CULT. FIELD	LOW	NONE	NONE KNOWN	MODERATE	LOW	YES
25I UPLAND REACH C	140	6.5 MCY	5.70	140 ACRES CULT. FIELD	LOW	NONE	NAT. REGISTER DISTRICT	MODERATE	MODERATE	NO
20A AQUATIC TO ISLAND (+15') REACH C	1170	33 MCY	4.20	70 ACRES SHALLOWS 1100 ACRES DEEP WATER	MODERATE	70 ACRES SHALLOWS	NONE	LOW	MODERATE	YES

TABLE 27 (CONT'D)

CYCLE 6 SCREENING OF DISPOSAL AREAS

SITE/ REACH	ACRES	CAPACITY	COST $/C.Y.	LAND USE AND COVER	FISH & WILDLIFE IMPACTS	MITIGATION REQUIREMENTS	CULTURAL RESOURCE IMPACTS	COST RANKING	ENV IMPACT	CONTINUE TO EVALUATE
20A AQUATIC TO UPLAND (+50') REACH C	1170	98 MCY	3.10	70 ACRESS SHALLOWS 1100 ACRES DEEP WATER	MODERATE	70 ACRES SHALLOWS	NONE	LOW	MODERATE	YES
24E AQUATIC TO ISLAND (+15') REACH C	3535	72 MCY	3.90	3435 ACRES SHALLOWS 100 ACRES DEEP WATER	HIGH	3435 ACRES SHALLOWS	NONE	LOW	HIGH	YES
24G AQUATIC TO ISLAND (+15') REACH C	3500	72 MCY	4.50	3300 ACRES SHALLOWS 200 ACRES DEEP WATER	HIGH	3500 ACRES SHALLOWS	NONE	LOW	HIGH	YES
24O UPLAND REACH D	295	10.6 MCY	6.30	285 ACRES CULT. FIELD 10 ACRES WETLANDS	MODERATE	10 ACRES WETLANDS	NONE KNOWN	MODERATE	MODERATE	NO
25J UPLAND REACH D	145	6.6 MCY	6.40	145 ACRES CULT FIELD	LOW	NONE	NONE KNOWN	MODERATE	LOW	YES
27H AQUATIC TO ISLAND (+15') REACH D	470	5.7 MCY	8.30	460 ACRES SHALLOW 10 ACRES WETLAND	HIGH	460 ACRES SHALLOWS 10 ACRES WETLAND	NONE KNOWN	HIGH	HIGH	NO
27H AQUATIC TO UPLAND (+50') REACH D	470	18.1 MCY	6.10	460 ACRES SHALLOW 10 ACRES WETLAND	HIGH	460 ACRES SHALLOW 10 ACRES WETLAND	NONE KNOWN	MODERATE	HIGH	NO

TABLE 27 (CONT'D)

CYCLE 6 SCREENING OF DISPOSAL AREAS

SITE/ REACH	ACRES	CAPACITY	COST $/C.Y.	LAND USE AND COVER	FISH & WILDLIFE IMPACTS	MITIGATION REQUIREMENTS	CULTURAL RESOURCE IMPACTS	COST RANKING	ENV IMPACT	CONTINUE TO EVALUATE
271 AQUATIC TO ISLAND (+15') REACH D	700	14 MCY	5.50	700 ACRES SHALLOWS	HIGH	700 ACRES SHALLOWS	NONE KNOWN	MODERATE	HIGH	NO
271 AQUATIC TO UPLAND (+50') REACH D	700	45 MCY	4.10	700 ACRES SHALLOWS	HIGH	700 ACRES SHALLOWS	NONE KNOWN	LOW	HIGH	YES

TABLE 27 (CONT'D)
CYCLE 6 SCREENING OF DISPOSAL AREAS
LOWER MIAH MAULL/UPPER BRANDYWINE RANGE

SITE/REACH	ACRES	CAPACITY	COST $/C.Y.	LAND USE WILDLIFE IMPACTS	FISH & WILDLIFE IMPACTS	MITIGATION REQUIREMENTS	CULTURAL RESOURCE IMPACTS	COST RANKING	ENV IMPACT	CONTINUE TO EVALUATE
PN 1 Wetland Restoration Reach E	200	3.8 MCY	9.45	50 Acres of tidal flats 150 acres shallows	Moderate	Pending*	None Known	Moderate	Moderate	Yes
FR 19 Upland Reach E	170	3.3 MCY	20.25	170 Acres cult. filed	Low	None	None Known	High	Low	No
MS 3 Upland Reach E	250	4.8 MCY	20.25	50 Acres woods 200 Acres cult. filed	Low	None	None Known	High	Low	No
MS 12 Upland Reach E	230	4.4 MCY	20.65	160 Acres cult. filed 70 Acres woods	Low	None	None Known	High	Low	No
ML 1 Upland Reach E	190	3.6 MCY	20.00	190 Acres Cult. Field	Low	None	None Known	High	Low	No
ML 2 Upland Reach E	210	4.0 MCY	20.00	200 Acres cult. field 10 acres woods	Low	None	None Known	High	Low	No
ML 4 Upland Reach E	190	3.6 MCY	20.00	160 Acres cult. field 30 acres land field	Low	None	None Known	High	Low	No
I 3 Island Creation Reach E	110	2.1 MCY	7.10	110 Acres shallows	Moderate	Pending*	None Known	Moderate	Moderate	Yes
I 1 Island Creation Reach E	200	3.8 MCY	7.85	200 Acres deepwater	Moderate	Pending*	None Known	Moderate	Moderate	Yes
LC 2 Upland Reach E	210	4.0 MCY	21.35	190 Acres cult. field 20 Acres woods	Low	None	None Known	High	Low	No

* Pending Benthic Testing

TABLE 27 (CONT'D)
CYCLE 6 SCREENING OF DISPOSAL AREAS
LOWER BRANDYWINE RANGE

SITE/REACH	ACRES	CAPACITY	COST $/C.Y.	LAND USE AND COVER	FISH & WILDLIFE IMPACTS	MITIGATION REQUIREMENTS	CULTURAL RESOURCE IMPACTS	COST RANKING	ENV IMPACT	CONTINUE TO EVALUATE
RD 4 Beachfill Reach E	100	1.9 MCY	12.10	100 Acres Sandy Shore Line	Low	None	None Known	Moderate	Low	Yes
OB 4 Overboard Reach E	170	3.3 MCY	4.05	170 Acres Deepwater	Moderate	170 Acres deepwater	None Known	Low	Moderate	Yes
CM 2 Upland Reach E	140	2.7 MCY	13.50	70 Acres woods 40 Acres Cult. Field 30 Acres Filed	Low	None	None Known	Moderate	Low	Yes
CM 4 Beachfill Reach E	100	1.9 MCY	13.05	100 Acres Sandy Shore Line	Low	None	None Known	Moderate	Low	Yes
CM 5/6 Beachfill Reach E	200	3.8 MCY	10.35	200 Acres Sandy Shore Line	Low	None	None Known	Moderate	Low	Yes
MS 18 Wetland Creation Reach E	200	3.8 MCY	15.10	100 Acres of Tidal Flats 100 Acres Shallows	Moderate	Pending*	None Known	High	Moderate	No
MS 19 Sand Stock Pile Reach E	200	3.8 MCY	11.15	200 Acres Shallows	Low	Pending*	None Known	Moderate	Moderate	Yes
L 1 Upland Reach E	100	3.1 MCY	19.95	100 Acres Cult. Field 60 Acres wood	Low	None	None Known	High	Low	No
L 2 Upland Reach E	135	2.6 MCY	19.95	135 Acres Cult. Field	Low	None	None Known	High	Low	No

TABLE 7

CYCLE 6 SCREENING OF DISPOSAL AREAS
LOWER BRANDYWINE RANGE

SITE/REACH	ACRES	CAPACITY	COST $/C.Y.	LAND USE AND COVER	FISH & WILDLIFE IMPACTS	MITIGATION REQUIREMENTS	CULTURAL RESOURCE IMPACTS	COST RANKING	ENV IMPACT	CONTINUE TO EVALUATE
L 3 Upland Reach E	100	1.9 MCY	19.80	100 Acres Cult. Field	Low	None	Several Pre Hist. Reg Sites	High	Low	No
L 4 Overboard Reach E	100	1.9 MCY	14.75	100 Acres Sandy Shoreline	Low	None	None Known	High	Low	Yes
L 5 Sandrock Pile Reach E	200	3.8 MCY	11.10	200 Acres Shallows	Moderate	Pending*	None Known	Moderate	Moderate	Yes
L 6 Beachfill Reach E	100	1.9 MCY	16.85	100 Acres Sandy Shoreline	Low	Pending*	None Known	Moderate	Moderate	No
L 7 Beachfill Reach E	100	1.9 MCY	16.85	100 Acres Sandy Shore Line	Low	Pending*	None Known	High	Moderate	No

* Pending Benthic Testing

TABLE 27 (CONT'D)
CYCLE 6 SCREENING OF DISPOSAL AREAS
LOWER LISTON/UPPER CROSS LEDGE RANGE

SITE/REACH	ACRES	CAPACITY	COST $/C.Y.	LAND USE AND COVER	FISH & WILDLIFE IMPACTS	MITIGATION REQUIREMENTS	CULTURAL RESOURCE IMPACTS	COST RANKING	ENV IMPACT	CONTINUE TO EVALUATE
C 2 Upland Reach E	100	1.9 MCY	15.70	80 Acres Woods 20 Acres Cult. Field	Low	None	None Known	High	Low	No
C 11 Upland Reach E	100	1.9 MCY	10.30	10 Acres Woods 80 Acres Cult. Field	Low	None	None Known	Moderate	Low	Yes
C 13 Island Creation Reach E	160	3.1 MCY	7.50	160 Acres Field	Moderate	None	None Known	Moderate	Moderate	Yes
LC 9 Wetland Creation Restoration Reach E	200	3.8 MCY	7.35	200 Acres Shallows	Moderate	None	None Known	Moderate	Moderate	Yes

TABLE 27 (CONT'D)
CYCLE 6 SCREENING OF DISPOSAL AREAS
LOWER CROSS LEDGE/UPPER MIAH MAULL RANGE

SITE/REACH	ACRES	CAPACITY	COST $/C.Y.	LAND USE AND COVER	FISH & WILDLIFE IMPACTS	MITIGATION REQUIREMENTS	CULTURAL RESOURCE IMPACTS	COST RANKING	ENV IMPACT	CONTINUE TO EVALUATE
F 1 Wetland Creation Reach E	200	3.8 MCY	10.00	40 Acres of Tidal flats 160 Acres of shallows	Moderate	Pending*	None Known	Moderate	Moderate	Yes
F 2 Island Creation Reach E	215	4.1 MCY	9.25	215 Acres shallows	Low	Pending*	None Known	Moderate	Moderate	Yes
F 3 Beachfill Reach E	100	1.9 MCY	12.10	100 Acres Sandy Shoreline	Low	None	None Known	Moderate	Low	Yes
RD 1 Upland Reach E	120	2.32 MCY	31.75	80 Acres Cult. Field 20 Acres Residential 20 Acres wood	Low	None	None Known	High	Moderate	No
LC 10 Sand Stockpile Reach E	200	3.8 MCY	8.25	200 Acres shallows	Low	Pending*	None Known	High	Moderate	No
BP 1 Upland Reach E	160	3.1 MCY	20.75	100 Acres woods 20 Acres Land Field 40 Acres Woods	Moderate	None	None Known	High	Low	No
BP 2 Upland Reach E	170	3.3 MCY	19.75	150 Acres Woods 20 Acres Land Field	Moderate	None	None Known	High	Low	No
CV 1 Beachfill Reach E	100	1.9 MCY	30.00	100 Acres Sandy Shoreline	Low	None	None Known	High	Low	No

* Pending Benthic Testing

TABLE 28
CYCLE 7 DISPOSAL AREA SCHEME SELECTION
(COST IN THOUSANDS DOLLARS)

ITEM	REACH A 170	REACH A 17G	REACH B 15D	REACH B RACCON ISL.	REACH B COMBINATION 15E,F,&G	REACH B 15I/DIKED UPLAND	REACH B 15J/DIKED UPLAND	REACH B 160-ISLAND
ACREAGE (AC)	300	295	575	600	585	775	895	1400
INITIAL COST	$36,504	$35,472	$57,337	$58,976	$61,143	$162,677	$133,534	$236,249
FEDERAL SITE REPLACEMENT	$0	$0	$0	$0	$0	$0	$0	$0
ENVIRONMENTAL CONCERNS/CRITERIA	MINOR WETLANDS	NONE	NONE	NONE	MINOR WETLANDS	NURSERY, SPAWNING AND FORAGING HABITAL	NURSERY, SPAWNING AND FORAGING HABITAL	NURSERY, SPAWNING AND FORAGING HABITAL
FOR:	----	----	----	----	----	MODERATE WETLANDS SHALLOW WATER HABITAT INTERTIDAL HABITAT	SHALLOW WATER HABITAT INTERTIDAL HABITAT	SHALLOW WATER HABITAT INTERTIDAL HABITAT MAJOR WETLANDS
DISPOSAL AREA MITIGATION	30 ACRES WETLANDS AVOIDANCE	NONE	NONE	NONE	CREATE 20 ACRES OF WETLANDS	200 AC INTERTIDAL 310 AC SHALLOWS AVOID WETLANDS	125 AC INTERTIDAL 320 AC SHALLOWS	460 AC INTERTIDAL 390 AC SHALLOWS 250 AC WETLAND
DISPOSAL AREA MITIGATION COSTS	$0	$0	$0	$0	DIKE $132 PLACE MATERIAL $240	DIKE '$73,500 PLACE MATERIAL $6,120	DIKE $94,850 PLACE MATERIAL $5,340	DIKE $168,350 PLACE MATERIAL $13,200
TOTAL INITIAL COSTS	$36,504	$35,472	$57,337	$58,976	$61,515	$242,297	$233,724	$417,799
AMORTIZED FIRST COSTS	$ 3,286	$ 3,194	$ 5,162	$ 5,310	$ 5,538	$ 21,815	$ 21,043	$ 37,615
ANNUAL O&M REQUIREMENTS	40,000 cy.	40,000 cy.	820,000 cy.	820,000 cy.	820,000 cy.	820,000 cy.	820,000 cy.	820,000 cy.
AVG. ANNUAL MAINT. COST	$ 142	$ 142	$ 3,132	$ 3,222	$ 3,572	$ 2,113	$ 2,113	$ 2,113
TOTAL AVG. ANNUAL COST	$ 3,428	$ 3,336	$ 8,294	$ 8,532	$ 9,110	$ 23,928	$ 23,156	$ 39,728

TABLE 28 (CONT'D)

CYCLE 7 DISPOSAL AREA SCHEME SELECTION
(COSTS IN THOUSAND DOLLARS)

ITEM	REACH C 23C/23D AND 241 (REDUCED IS.)	REACH C 23C/23D AND READY IS. NORTH	REACH C 20A/DIKED ISLAND	REACH C 20A/DIKED UPLAND	REACH C 24E/DIKED ISLAND	REACH C 24G/DIKED ISLAND	REACH C TRANSFER TO RACCOON ISLAND	REACH C READY ISLAND NORTH AND SOUTH 23C
ACREAGE (AC)	650	520	1170	350	1450	1400	600	200
INITIAL COST	$132,294	$71,336	$165,305	$80,411	$208,721	$202,156	$52,873	$70,735
FEDERAL SITE REPLACEMENT	$0	$12,650	$0	$0	$0	$0	$0	$36,800
ENVIRONMENTAL CONCERNS/CRITERIA	NURSERY, SPAWNING AND FORAGING HABITAT	NONE	NURSERY, SPAWNING AND FORAGING HABITAT	NURSERY, SPAWNING AND FORAGING HABITAT	NURSERY, SPAWNING AND FORAGING HABITAT	NURSERY, SPAWNING AND FORAGING HABITAT	NONE	NONE
FOR:	SHALLOW WATER HABITAT	----	----	SHALLOW WATER HABITAT	SHALLOW WATER HABITAT	SHALLOW WATER HABITAT	----	----
DISPOSAL AREA MITIGATION	250 ACRES SHALLOWS	NONE	70 ACRES SHALLOWS	50 ACRES SHALLOWS	1450 ACRES SHALLOWS	1400 SHALLOWS AVOID WETLANDS	NONE	NONE
DISPOSAL AREA MITIGATION COSTS	DIKE $570 PLACE MATERIAL $3000	$0	DIKE $310 PLACE MATERIAL $840	DIKE $270 PLACE MATERIAL $600	DIKE $101,500 PLACE MATERIAL $1,740	DIKE $98,000 PLACE MATERIAL $1,680	$0	$0
TOTAL INITIAL COSTS	$135,864	$83,986	$166,455	$81,281	$311,961	$301,836	$52,873	$107,535
AMORTIZED FIRST COSTS	$ 12,232	$ 7,561	$14,986	$ 7,318	$ 28,086	$ 27,175	4,760	$9,682
ANNUAL O&M REQUIREMENTS	420,000 cy.	420,000 cy.	420,000 cy.	420,000 cy.	420,000 cy.	420,000 cy.	420,000 cy.	420,000 cy.
AVG. ANNUAL MAINT. COST	$ 1,704	$ 1,704	$ 1,432	$ 1,432	$ 1,432	$ 1,432	$ 1,704	$ 1,527
TOTAL AVG. ANNUAL COST	$ 13,936	$ 9,265	$16,418	$ 8,750	$ 29,518	$ 28,607	$ 6,464	$ 11,043

TABLE 28 (CONT'D)

CYCLE 7 DISPOSAL AREA SCHEME SELECTION
(COSTS IN THOUSAND DOLLARS)

ITEM	REACH C THIN LAYERING	REACH D READY ISLAND NORTH AND SOUTH	REACH D 271/ISLAND	REACH D 240	REACH D THIN LAYERING
ACREAGE (AC)	5000	0	0	295	5200
INITIAL COST	$ 29,867	$43,444	$ 93,699	$58,124	$ 51,183
FEDERAL SITE REPLACEMENT	$ 38,410	$14,250	$0	$0	$ 8,930
ENVIRONMENTAL CONCERNS/CRITERIA	TURBIDITY	NONE	NURSERY, SPAWNING AND FORAGING HABITAT	NONE	TURBIDITY
FOR:	----	----	SHALLOW WATER HABITAT	----	----
DISPOSAL AREA MITIGATION	NONE	NONE	415 ACRES SHALLOWS	NONE	NONE
DISPOSAL AREA MITIGATION COSTS	$0	$0	DIKE $1180 PLACE MATERIAL $4980	$0	$0
TOTAL INITIAL COSTS	$ 68,637	$57,694	$99,859	$58,124	$60,113
AMORTIZED FIRST COSTS	$ 6,180	$ 5,194	$ 8,990	$ 5,233	$ 5,412
ANNUAL O&M REQUIREMENTS	630,000 cy.	60,000 cy.	60,000 cy.	60,000 cy.	90,000 cy.
AVG. ANNUAL MAINT. COST	$ 2,143	$ 354	$ 354	$ 624	$ 531
TOTAL AVG. ANNUAL COST	$ 8,323	$ 5,548	$ 9,344	$ 5,857	$ 5,943

TABLE 28 (CONT'D)
CYCLE 7 DISPOSAL AREA SCHEME SELECTION
(COSTS IN THOUSAND DOLLARS)
FOR
LOWER LISTON/UPPER CROSS LEDGE RANGE

SITE NAME/ TYPE	C11 UPLAND	C13 ISLAND CREATION	LC9 WETLAND RESTORATION
ACREAGE (AC) INITIAL COST	100 $10,500	160 $8,900	200 $8,900
FEDERAL SITE REPLACEMENT	0	0	0
ENVIRONMENTAL CONCERNS/CRITERIA	None	Nursery, spawning and foraging habitat	Nursery, spawning and foraging habitat
FOR:	------	Shallow water habitat	Shallow water habitat
DISPOSAL AREA MITIGATION	None	None, site selection to avoid critical areas*	None, site selection to avoid critical areas*
DISPOSAL AREA MITIGATION COST	0	0	0
TOTAL INITIAL COSTS	$10,500	$8,900	$8,900
AMORTIZED FIRST COSTS	$932.8	$790.7	$790.7
ANNUAL O&M REQUIREMENTS	58,200cy	58,200cy	58,200cy
AVG. ANNUAL MAINT. COST	$145.5	$145.5	$145.5
TOTAL AVG. ANNUAL COST	$1,078	$936.2	$936.2

* Final site boundary will be based on detailed benthic testing in Preconstruction, Engineering and Design (PED) phase

TABLE 28 (CONT'D)
CYCLE 7 DISPOSAL AREA SCHEME SELECTION
(COSTS IN THOUSAND DOLLARS)
FOR
CROSS LEDGE/UPPER MIAH MAULL RANGE

SITE NAME/ TYPE	LC10/FR28 SAND STOCK PILE	F1 WETLAND CREATION	F2 ISLAND CREATION	F3 BEACHFILL
ACREAGE (AC) INITIAL COST	100 $13,120	280 $27,230	215 $28,030	100 $17,070
FEDERAL SITE REPLACEMENT	0	0	0	0
ENVIRONMENTAL CONCERNS/CRITERIA	Nursery, spawning and foraging habitat	Nursery, spawning and foraging habitat	Nursery, spawning and foraging habitat	NONE
FOR:	Shallow water habitat	Shallow water habitat	Shallow water habitat	-----
DISPOSAL AREA MITIGATION	None, site selection to avoid critical areas*	None, site selection to avoid critical areas*	None, site selection to avoid critical areas*	NONE
DISPOSAL AREA MITIGATION COST	---	---	---	---
TOTAL INITIAL COSTS	$13,120	$27,230	$28,030	$17,070
AMORTIZED FIRST COSTS	$1,165.6	$2,419.1	$2,490.2	$1,516.5
ANNUAL O&M REQUIREMENTS/	2,500cy	2,500cy	2,500cy	2,500cy
AVG. ANNUAL MAINT. COST	$6.3	$6.3	$6.3	$6.3
TOTAL AVG. ANNUAL COST	$1,171.9	$2,496.5	$2,496.5	$1,522.8

* Final site boundary will be based on detailed benthic testing in Preconstruction, Engineering and Design (PED) phase

TABLE 28 (CONT'D)
CYCLE 7 DISPOSAL AREA SCHEME SELECTION
(COSTS IN THOUSAND DOLLARS)
FOR
LOWER MIAN MAULL/UPPER BRANDY WINE RANGE

SITE NAME/ TYPE	I 1 ISLAND CREATION	PM1 WETLAND RESTORATION	I3 ISLAND CREATION
ACREAGE (AC) INITIAL COST	200 $14,800	200 $14,400	110 $14,400
FEDERAL SITE REPLACEMENT	0	0	0
ENVIRONMENTAL CONCERNS/CRITERIA	Nursery, spawning and foraging habitat	Nursery, spawning and foraging habitat	Nursery, spawning and foraging habitat
FOR:	Shallow water habitat	Shallow water habitat	Shallow water habitat
DISPOSAL AREA MITIGATION	None, site selection to avoid critical areas*	None, site selection to avoid critical areas*	None, site selection to avoid critical areas*
DISPOSAL AREA MITIGATION COSTS	0	0	0
TOTAL INITIAL COSTS	$14,800	$14,400	$14,400
AMORTIZED FIRST COSTS	$1,314.8	$1279.3	$1279.3
ANNUAL O&M REQUIREMENTS	900cy	900cy	900cy
AVG. ANNUAL MAINT. COST	$2.3	$2.3	$2.3
TOTAL AVG. ANNUAL COST	$1,317.2	$1,281.6	$1.281.6

* Final site boundary will be based on detailed benthic testing in Preconstruction, Engineering and Design (PED) phase

TABLE 28 (CONT'D)
CYCLE 7 DISPOSAL AREA SCHEME SELECTION
(COSTS IN THOUSAND DOLLARS)
FOR
LOWER BRANDYWINE RANGE

SITE NAME/ TYPE	RD4 BEACHFILL	OB4 OVERBOARD	CM2 UPLAND	MS19 SANDSTOCK PILE	CM4 BEACHFILL	CM5/6 BEACHFILL	L4 BEACHFILL	L5 SANDSTOCK PILE
ACREAGE (AC) INITIAL COST	100 $32,680	170 $33,855	140 $27,570	200 $25,080	100 $32,680	200 $ 32,680	100 $ 32,680	200 $25,080
FEDERAL SITE REPLACEMENT	0	0	0	0	0	0	0	0
ENVIRONMENTAL CONCERNS/CRITERIA	NONE	Blue crab wintering, critical fish wintering area	NONE	Nursery, spawning and foraging habitat	NONE	NONE	NONE	Nursery, spawning and foraging habitat
FOR:	-----	Deep water habitat	-----	Shallow water habitat	-----	-----	-----	Shallow water habitat
DISPOSAL AREA MITIGATION	NONE	Due to large quantities, mitigation by alternative deep water site improvement	NONE	None, site selection to avoid critical areas*	NONE	NONE	NONE	None, site selection to avoid critical areas*
DISPOSAL AREA MITIGATION COST	0	11,285	0	0	0	0	0	0
TOTAL INITIAL COSTS	$32,680	$33.855	$27,570	$25.080	$32,680	32,680	32,680	25,080
AMORTIZED FIRST COSTS	$2903.3	$3,007.7	$2449.3	$2,228.1	$2903.3	29022	29033	2,228.1
ANNUAL O&M REQUIREMENTS	6000cy	6000cy	6000cy	6000cy	6000cy	0	0	0
AVG. ANNUAL MAINT. COST	$15.0	$15.0	$15.0	$15.0	$15.0	15.0	15.0	15.0
TOTAL AVG. ANNUAL COST	$2,918.3	$3,022.7	$2,464.3	$2,243.1	$2918.3	2918.3	2,918.3	2,243.1

* Final site boundary will be based on detailed benthic testing in Preconstruction, Engineering and Design (PED) phase

428. There were 9 scenarios evaluated in Reach C. The 2 candidate upland sites, the 2 existing Federal sites, and 3 aquatic sites were evaluated in 6 combinations. In addition the use of one inexpensive site in Reach B, plus thin layering of initial construction was also evaluated. Transfer of material to the Raccoon Island disposal site was found to be the least expensive, with the added cost of farther transport more than offset by lower disposal area construction costs.

429. In Reach D, four scenarios were evaluated. Two looked at upland disposal, one considered creating an island, and one thin layering. Use of the existing Reedy Island North and Reedy Island South was the least expensive.

430. In conclusion, in the upper Reaches A,B,C, and D 5 upland disposal sites were determined to be the NED sites for disposal of dredged material associated with channel deepening for the Delaware River. These include three new upland sites, (17O, 15D, plus Raccoon Island), plus the existing Reedy Island North and Reedy Island South disposal sites. Only those sites which were most economically advantageous were selected, once environmental and cultural mitigation costs were included and engineering feasibility and institutional acceptability assured.

431. In Reach E, based on the costs shown in Table 25, LC 9 (Port Mahon) or C 13 (Alder Cove) were determined to be the NED disposal plans for the disposal of dredged material associated with Lower Liston/ Upper Cross Ledge Range. Due to the closeness of the cost comparisons, final selection will await the findings of the PED studies. FR 28/ LC 10 (sand stockpiles off of Kitts Hummock and Pickering Beach, shown in table 7-13) was determined to be the NED disposal plan for the disposal of dredged material associated with the Lower Cross Ledge/Upper Miah Maull Range. Table 7-14 shows island creation at I3 (lower Middle Shoal), and wetland restoration at PN 1 (Maurice River Cove area) were determined to be the NED disposal plan for the disposal of dredged material associated with the Lower Miah Maull/Upper Brandywine Range. Again the closeness of the cost comparison will force final selection to wait for the results of the PED studies. Sand stockpiles off of Lewis/ Broadkill, Beach (LS) and Slaughter Beach (MS-19) (Table 7-15) were determined to be the NED disposal plan for the disposal of dredged material associated with the Lower Brandywine Range. Final selection of these options will await completion of the detailed benthic studies to be conducted during the PED phase. If the studies reveal that significant mitigation is required for sand stockpile areas then the beachfill options could become the NED plan.

CYCLE 8 - ASSESSMENT AND EVALUATION OF DETAILED PLANS

432. The final cycle of formulation was accomplished to evaluate alternative channel deepening plans and conduct economic optimization of the project features including channel depth,

disposal area usage, project length, navigation aid requirements, and full width versus asymmetric channel plans. Provision of a two space anchorage was included in the planning. Consideration was also given to environmental and cultural impacts, the need for mitigation, and the potential for wetlands creation under Section 150 of Public Law 94-587.

433. CHANNEL FORMULATION. Three channel options were considered. All would follow the existing channel alignment and would extend from the bay mouth up to Philadelphia Harbor. They are presented in order of relative scope. The first option, a minimum width asymmetric channel, would minimize costs while accounting for predominant import commodities. Previous analyses concluded that only by including all of the oil refineries (except Texaco) can sufficient vessel traffic benefit to justify the costs of dredging a lengthy river channel. By extending the deepened channel about 2 miles upstream from Eagle Point (the uppermost refinery location) to near the Walt Whitman Bridge, Conrail's Pier 122 and the Packer Avenue Terminal could also benefit. The second option, a more efficient asymmetric channel, was suggested by the Delaware River Pilots. The same six refineries and Conrail's Pier 122 would benefit from reduced vessel travel time and operating costs compared to the narrower asymmetric. The third option, a full width channel, would provide for two way traffic. Besides further operating savings to vessels from the six refineries and Conrail's Pier 122, an adjacent Conrail Pier 124 which exports coal would be added as well as container traffic for Packer Avenue Terminal. The channel would be extended two miles further upstream to the Beckett Street, Camden Terminal where both dry bulk imports and exports could benefit. Extending the deepening further upriver to the Beckett Street Terminal was previously found to be the upper limit of the project. This facility would require deepening of the Federal project, Delaware River in the Vicinity of Camden, in order to fully benefit from the main channel deepening.

434. Channel Depths. A range of channel depths up to 46 feet were considered. Further depths have been previously shown to lack economic justification, and that range was considered likely to bracket the optimum depth.

435. Dredging Practices. The present channel is maintained primarily by the use of contracted hydraulic dredges which pump into confined upland disposal areas. When required, advanced maintenance dredging of up to 4 feet overdepth is performed, depending on the rate of shoaling. In addition to the advanced maintenance overdepth, a separate dredging overdepth of 2 feet may occur to account for dredging inaccuracies. High shoaling areas are dredged at least every year but areas of lower shoaling may go several years between dredging. The two foot overdepth allowance is standard practice on large dredging projects. An allowance for up to an including a two foot overdepth dredging takes into account dredging inaccuracies. The inclusion of the overdepth quantities in the total project cost provides for a conservative cost estimate.

436. Starting Conditions. The amount of initial dredging was determined by use of a design section in any location where periodic maintenance has occurred. The remaining locations are either naturally deeper or previously dredged below 40 feet (a common practice in the past for mining sand) and are now relatively stable. By this breakdown, one would not inadvertently bypass a location where a post-dredging survey shows a deep location, only to later require initial dredging due to subsequent shoaling in the period before channel deepening could occur. Disposal areas were developed based on maximizing usable disposal area size in order to minimize project costs. Real estate costs for a lesser sized disposal area would only be marginally reduced, since excess partial parcels would have limited use due to their being uneconomic remnants.

437. Shoaling Analysis. The shoaling analysis performed for the Philadelphia-to-Sea channel deepening utilized an empirical data base of historic hydrographic surveys and maintenance dredging records in order to estimate the incremental maintenance dredging quantities associated with the considered alternative channel depths and alignments. The incremental maintenance dredging quantities were then used to determine the estimated annual operation and maintenance cost component (in addition to the amortized first cost of project construction) of the total average annual cost of the considered alternative.

438. The detailed analysis of shoaling rates was performed for three of the ranges of the Philadelphia-to-Sea project which together require nearly 85 per cent of the total project by length. The period of record used in the analysis of shoaling with respect to channel deepening included 1969 through 1985. During this period there were a number of maintenance dredging contracts in which depths greater than the project depth of 40 feet were obtained either through intentional advance maintenance dredging or unintended dredging beyond "pay" depth. The record of depth as a function of time at representative index stations within each of the four navigation ranges evaluated was used to determine characteristic shoaling rates subsequent to dredging. The estimates of potential future shoaling rates within the Philadelphia-to-Sea channel for alternative depths greater than the existing 40 foot depth were based on the actual shoaling characteristics observed in the critical shoaling reached of the project for dredged depths in excess of 40 feet.

439. Design Vessel. The design vessel selected for the main channel was a 145 foot beam tanker with a length of 951 feet, based on an analysis of over 1,100 bulk vessel movements in 1985 and 1986 plus guidance found in EM 1110-2-1613. Crude oil tankers are the dominant vessel type both in size and numbers, both now and throughout the study period. No colliers or iron ore ships using the Delaware River had vessel beams of over 140 feet in that two year period. The limited number of larger vessels used the channel over that two year period (11 tankers making 29 trips) could still use any of the channel options but would require better weather or limited to daylight transit; this is the present practice for these

larger ships. There has been no subsequent change in tanker vessel size based on coordination with the pilots. For the channel segments above Eagle Point a dry bulk vessel with a length of 830 feet and beam of 128 feet is the selected design vessel. The largest containerized vessel anticipated to use the channel in the future is the post-Penamax vessel with the following approximate characteristics: 55,000 DWT, 4500-5000 TEV's, length of 950 feet and a beam width of 130 feet.

440. Bend Widening. Bend widening would be required for all schemes to facilitate turning of the longer vessels now using the river and to meet current Corps design criteria. Bend widening was accomplished using the Apex Method presented in EM 1110-2-1613.

441. Channel Widths. Channel widths were established using EM 1110-2-1613 for one-way and two-way channels. The factors chosen for design in each channel segment were established as a percentage of beam width as follows:

	Delaware River	Delaware Bay
Ship Clearance Lane	80%	100%
Maneuvering Lane	180%	200%
Bank Clearance Lane	60%	100%

442. Anchorage. Partial deepening of the Marcus Hook Anchorage is included in each plan to provide a safe navigation channel. The pilots have indicated that the risk of vessel accidents and major oil spills would probably double or triple if there was no upstream anchorage at compatible depth with the deepened channel. Given the level of crude oil traffic in the river and frequency of tanker transits, tanker traffic will encounter fog, foul weather, and emergency situations which could prevent completion of a trip using high tide and must have a safe anchorage as part of the project. It is estimated that $3 to $5 million in annual clean up costs might result from major oil spills (without adequate anchorage space) if environmental damage is included, an annual cost of $30 to $50 million is not unreasonable. Criteria in EM 1110-2-1613 for a free swinging anchorage was used in the design.

443. All facilities within the study area have been investigated with regard to the need for both a turning basin and anchorage. Corps design criteria for a turning basin require a circle diameter which is 1.5 times the vessel length. The turning area may include any of the following items: the Federal Navigation Channel including bends, the private berth area of the target dock, portions of the Marcus Hook Anchorage proposed for deepening, any adjacent areas that are naturally deep. A separate area is required only if sufficient turning space cannot be found within the above categories. The ten facilities which would benefit from channel deepening were evaluated. First, the longest vessels using each facility were identified and then the Corps criteria for a turning area were applied. For all of the facilities, existing space is sufficient for turning and maneuvering. Separate turning

areas are not required. Except in four cases, sufficient maneuvering area exists solely within the area in front of the berth and the adjacent Federal channel. The specific results of each evaluation are described below.

1. Sun Oil, Marcus Hook - The largest vessel using Marcus Hook facilities is a 935 foot tanker and requires a turning circle with a 2400 foot diameter. This circle includes the berth area and the 800 foot Federal channel, and extends 100 feet into the Marcus Hook Anchorage. The second largest vessel is an 872 foot tanker. It has a turning circle which can be accommodated without requiring use of the anchorage.

2. BP, Marcus Hook - The same vessels described in Sum Oil, Marcus Hook were evaluated for this facility. The only difference is a 50 foot rather than a 100 foot extension of the largest vessel into Marcus Hook Anchorage.

3. Mobil Oil, Paulsboro - The largest vessel using this facility is a 1445 long tanker. It can turn at any time within the combined channel, berthing area, and expanded bend. This situation allows for increased flexibility because the present practice is to dock the vessel facing upstream, and turn only when the vessel is empty and extends past the existing channel.

4. Chevron, Ft. Mifflin - The largest ship visiting this facility is a 1031 foot long tanker. This vessel can turn at any time within the combined channel and berthing area.

5. Atlantic, Ft. Mifflin - The largest vessel here is also the 1031 foot long tanker. There is insufficient combined channel and berthing area for turning at the dock. However, approximately 2 miles upstream at the Eagle Point Range, sufficient channel width (1150 feet) exists to turn the ship around.

6. Eagle Point, Westville, NJ - An 876 foot tanker is the largest vessel at this facility. The tanker can turn within the combined berth and channel.

7. Conrail - The largest ships at this facility are dry bulk vessels with a maximum length of 892 feet. These vessels can dock and back out within the existing channel with tug assistance.

8. Packer Avenue - The container design vessel for this facility can only turn outside the combined berth/channel area. However, suitable natural depths are available to accomplish the turning without extra dredging. The results summarized above are based on application of Corps criteria. Although Pilot coordination indicated a preference for more (maneuvering/turning) space, only those modifications justified by Corps criteria can be implemented.

444. Beckett Street Terminal Access Channel. The trapezoidal access channel for the bulk berths at Beckett Street Terminal were designed to be consistent with the criteria for the authorized 40'

project which includes approach and departure angles of 450° from the 40' west side of the Delaware River channel.

445. Operating Drafts. The Delaware River pilots establish through the Mariners' Advisory Committee the safe operating practices. Currently, the maximum acceptable ship draft in the 40 foot deep channel is also 40 feet for vessels using the tides. While the Delaware River, Philadelphia to Sea project is authorized to a depth of 40 feet MLW, the effective channel depth is somewhat deeper for several reasons. The river has been fully maintained to provide a 40 foot minimum depth. Additional depth at a given location could be different at a given time as a result of tolerances in the dredging process, natural scour due to currents, agitation of the sediments in the center of the channel due to vessel transits, and periodic sand mining operations. Advance maintenance of 2 to 4 feet is also practiced at selected locations with high shoaling rates. When a given river section does shoal, it does so the fastest along the edges, with the center channel depth (where in present practice ships generally navigate) considerably deeper. Rock outcrops, located in the Marcus Hook Range, cause additional concern over the actual channel depth.

446. In addition to the static vessel draft, four factors must be included to determine required channel depth for a given operating draft. The first, freshwater sinkage, results from the fact that the density of freshwater is 3% less than average ocean saltwater. This means that a vessel with a 39 foot draft in saltwater is one foot deeper in freshwater. The second factor concerns the amount of minimum clearance desired between a ship and the channel bottom. Corps vessel underkeel guidance for channel design calls for 2 feet of clearance for soft channel bottoms and 3 feet for hard/rock channels, a practice also adopted for use in the Delaware. The third factor in computing required channel depth, squat, results because a ship in motion will cause a lowering of the water surface because of the change in velocity and pressure about the vessel, causing it to be lowered with respect to the channel bottom. The amount of lowering depends on several factors, especially the speed of the vessel compared to that of the water and the cross section of the channel and the river itself. For the Delaware River the pilots travel faster in the lower river and bay where the greater channel cross section minimizes the squat and the absence of docks close to the channel minimizes vessel wave damage. Above Wilmington, vessel speeds are reduced. Overall the effect of squat is a 1 to 2 foot requirement in operating draft.

447. One remaining factor, trim is involved in determining channel depth. In the bay, where salinity levels are higher tankers operate with the stern 1 foot lower than the bow; this practice allows for better vessel maneuvering at higher speeds. Shifting of cargo between tanks allows for a return to an even keel upon entering the river.

448. BENEFIT ANALYSIS METHODOLOGY. The analysis quantified transportation benefits from the proposed channel improvements for vessel movements through the Delaware River port system by

comparing the incremental difference in transportation costs for the with and without project conditions. Transportation costs were computed by combining vessel operating costs, projections for commodities, and fleet shift impacts. A multiport analysis was also conducted, and concluded that deepening the Delaware River main channel would not divert traffic from the competing North Atlantic ports. A shift of Canadian container traffic from Halifax to Philadelphia is possible with the recent introduction of the Canada Pacific Railroad, via its subsidiary the D&H Railway, into the Philadelphia area. This would occur under both the without and with project conditions. The estimate of savings in ocean transportation costs from a Delaware River channel deepening proved to be insufficient to offset inland transportation cost advantages at the competing ports of New York, Baltimore, and Norfolk/Hampton Roads for potentially divertible commodity trade routes.

449. Vessel costs at sea and in port were derived from the data contained in OCE Economic Guidance Memorandum #91-4, Fiscal Year 1991, "Vessel Operating Costs", for foreign flag liquid bulk, dry bulk, and container vessels. Deep draft vessel operating costs in the Reference Handbook were compiled based on interviews with vessel operators, shipyards, fuel suppliers, and through research of secondary sources. Port charges, pilot fees, and tug boat costs were site specific to the Delaware River port system. Landside costs, such as the transportation costs of the commodities after leaving the destination port or prior to entering the origin port, were considered identical per ton under the with and without project conditions and were, thus, not included in the transportation cost estimation.

450. Data bases were separately analyzed to determine transportation costs and savings for vessel movements for the following commodities: crude oil greater than 40 foot sailing draft, crude oil less than or equal to 40 foot sailing draft, coal from Pier 124, iron ore, and South Jersey Port Corporation (SJPC) dry bulk commodities and container movements.

451. An analysis of the port depths of trade route partners for the benefitting commodities has incorporated the impact of any constraints at the other end of the trade route. Crude oil movements will not have a constraint at the pertinent foreign ports in West Africa, North Europe, the Caribbean, South Africa, South America, Southeast Asia, China/North Korea, Red Sea/Arabian Gulf, Mediterranean, South Europe, Australia, and Canada since depths are in excess of the maximum considered Delaware River channel depth of 46 feet. Coal movements are constrained by depths less than 40 feet at Pakistan and Venezuela and by the constraint of the Panama Canal for movements to China, Japan, and Australia. The benefitting coal trade routes based on vessel design characteristics and depths at the partner ports are North Europe, Mediterranean, Canada, South America, South Europe, and East Europe. Iron ore movements are unconstrained by the depth at the major beneficiary trade partner port, Seven Islands, in Atlantic Canada. Other, less important, iron ore trade routes without depth constraints are South America, North Europe, South Europe, and

North Africa. Scrap exports from the SJPC terminal to Turkey are provided with a depth of 72 feet at the trade route port. Bituminous steam coal from South America has trade route port depths in excess of 45 feet. Trade route port depths for potentially benefitting container movements (Europe, Mediterrean, East Coast of South America, and Australia/New Zealand) are also not a constraint.

452. The analysis utilized the Waterborne Commerce Statistics Center (WCSC) data base for the last five available years, 1985-1989 for actual historic vessel movements using the current 40 foot (MLW) main channel. An econometric framework using a two-stage least squares multiple regression model was applied to simulate expected cargo tonnage carried by vessels in the fleet if the Delaware River federal navigation channel were to be deepened from the current 40 feet to a maximum with project condition depth of 46 feet.

453. The theoretical basis for the econometric analysis incorporates the recognition that the economic goal of any firm is to maximize profits. The profit function is equal to revenues minus costs. The modelling of potential reductions in transportation costs caused by a navigation improvement is identical to analyzing the effect on a firm's cost function by changing its production function. The purpose of the statistical analysis applied in this report is to estimate a production function of vessel operations using actual voyage data. The production function, expressed as $Q=f(K,L,M)$, represents the utilization of particular combinations of input resources to produce a specific level of quantity output. The output of the production function, Q, or quantity, is defined as the amount of cargo carried (i.e., sailing deadweight tonnage). The input, L, represents labor which is considered fixed in a capital-intensive industry such as shipping. The input, K, represents capital, and is defined as the vessels themselves and can be measured by cargo carrying capacity (design deadweight tonnage and design draft). The input, M, represents change in technology (specifically, a change in the channel constraint to vessels from a channel deepening). The production function model has been expanded to include sailing draft as an exogenous input variable directly related to sailing deadweight tonnage. The addition of this variable helped to reduce the potential problem of heteroscedasticity, which, when present, places more weight on observations which have larger error variances than on those with smaller error variances. The effort of developing an econometric model to represent a production function for ship operators involves estimating a technological process for individual ships. The individual ship's production process will represent the technical constraints faced by ship operators as well as their market constraints since the demand for ocean transportation services is a derived demand, meaning that the demand for other goods and services determines the demand for ocean transportation. Non-economic factors such as port depth adjustments are accomplished exogenous to the two-stage least squares multiple

regression model during the transferral of the predicted data to the transportation cost model evaluation.

454. The amount of tonnage which can be carried by a ship leaving or entering a harbor should be positively correlated to its size. The larger the ship, the greater its capacity for transporting tonnage will also be. Since ship operating firms are assumed to be profit maximizers faced with a demand for their services derived by other markets, their optimal behavior should be characterized by them providing a supply of transportation services at minimum cost. In other words, ship operators should be using the most economically efficient ship available to transport cargo. However, channel dimensions generally constrain ship operators by limiting the amount of cargo which can be loaded upon their vessels. This constraint results in operators using efficient ships at less than their optimal load or optimally using less efficient ships. Either way, ship operators are confronted by higher costs directly caused by these economic inefficiencies. The objective of the statistical analysis was to produce a model to be used as a tool to predict cargo tonnage carried by vessel classes, and, thus, simulate actual operating practices under different channel depths.

455. Exogenous input data from the WCSC data base and Lloyd's Register of Ships included the following: vessel name, design draft (DESDWT), actual sailing draft (SDRAFT), commodity, trade route, export or import classification, design deadweight tonnage (DESDWT), actual sailing deadweight tonnage (SDWT), and dockcode.

456. Predicted tonnage by vessel was estimated for three data bases: crude oil vessels with sailing drafts less than or equal to 40 feet, coal vessels, and iron ore vessels. Crude oil vessels with sailing drafts greater than 40 feet will not have an increase in tonnage carried due to a channel deepening. The operators of these vessels have made a decision currently to lighter at Big Stone Beach Anchorage until the vessel sailing draft is sufficiently reduced to allow for navigation upriver to the pertinent facility. Even with a deeper main channel they will continue to carry the same amount of tonnage, and benefits will be based on savings from reduced lightering requirements. Vessels using SJPC's Beckett Street Terminal are expected to behave optimally by utilizing vessel cargo carrying capacity to the maximum extent allowed by the channel as it is deepened.

457. The data bases were desegregated by trade route and design draft. Average sailing draft, average design deadweight tonnage, average sailing deadweight tonnage, and fleet distribution were computed for each vessel design draft class by trade route. Individual transportation cost models were developed for each design draft vessel class for each trade route.

458. For crude oil vessels with sailing drafts 40 feet, these cost models estimated tons lightered and transportation costs for each channel depth from 40 to 46 feet. By combining commodity projections with the fleet distribution, estimates of total tons lightered for each design draft class by trade route over the project life by decade were made. Total transportation costs,

including the costs of lightering, were then computed for design draft class, trade route, project life decade, and channel depth. Subtracting the total transportation costs of each with project channel depth from the total transportation costs for the without project channel depth resulted in cost savings as a result of the reduced lightering with a deeper channel. Finally, the tons lightered, transportation costs, and transportation savings associated with each channel depth were summed for all trade routes and annualized.

459. The data bases for crude oil <= 40 foot sailing draft, coal, and iron ore movements were analyzed in basically a similar manner to the crude oil >40 foot sailing draft data base. However, a key difference is that tonnage expected to be carried by each vessel for each channel depth was predicted by a two-stage least squares multiple regression statistical model. The very large tankers that are currently not lightering have made a decision, based on the relative shipment size purchased, to load to a sailing draft (i.e., 40 feet or less) that assures that lightering is not required in the Delaware Bay. Economically, the oil companies do not believe it cost-efficient to purchase slightly more crude oil for these shipments and load slightly deeper to, say, 41 or 42 feet, since this would require lightering of only a small amount of the crude into barges in the bay. With a deeper channel, under both current and future practice, these vessels will carry increased tonnage as predicted by the statistical model and will increase their sailing draft to take advantage of the channel improvement (while assuring that lightering of the vessel is still not required based on the sailing draft). A review of the data base for coal and iron ore vessels determined that less than 2% of outgoing Pier 124 vessels had arrived in the Delaware River system carrying iron ore to Pier 122. The infrequency of this type of operation is expected to continue in the future, and will have only a minimal impact on benefits.

460. Individual transportation cost models were developed for each design draft vessel class for each trade route. These cost models estimated the cost per ton based on predicted tonnage from the statistical model for each channel depth from 40 to 46 feet. By combining commodity projections with the fleet distribution, estimates of the total transportation cost for each design draft class by trade route over the project life by decade were made. Subtracting the total transportation costs of each with project channel depth from the total transportation costs for the without project depth results in cost savings from the more efficient movement of tonnage. Finally, the transportation savings for all trade routes were summed and annualized.

461. Two dry bulk commodities will benefit from a channel depth improvement in excess of forty feet at the South Jersey Port Corporation's Beckett Street Terminal. Container vessels also have the potential to benefit for five trade routes. Individual transportation cost models were developed for each design deadweight tonnage vessel class for each trade route. Ship operators are expected to continue to behave optimally by utilizing

chartered vessel cargo carrying capacity to the extent allowed by the channel as it is deepened, since these movements are economical within a small range of marginal costs. Containers incorporate average lightloading into the analysis. The cost models which were developed estimated the cost per ton for each channel depth from 40 to 46 feet. By combining commodity projections with the fleet distribution, estimates of the total transportation costs for each design deadweight tonnage vessel class by trade route was made. The subtraction of the total transportation costs of each with project channel depth from the total transportation costs for the without project channel depth resulted in an annualized estimate of savings from the more efficient movement of tonnage with the channel improvement.

462. MINIMUM WIDTH ASYMMETRIC INBOUND CHANNEL. An asymmetric inbound channel is considered as a separable feature since a majority of potential benefits are obtained from inbound traffic. Under this option only the inbound lane of the channel would be deepened up to the Philadelphia Navy Yard below Walt Whitman Bridge. (Refer to Figure 21.) Channel widths would be 400 feet from Pier 122 to the Navy Yard, 435 feet from the Navy Yard to Bombay Hook and 580 feet in the bay. As part of this option a new set of range lights would be required to mark the centerline of the asymmetric channel. Other features of this option included as part of the plan would be widening of bends to accommodate vessel crab in turns. A two space anchorage would be provided at Marcus Hook within its existing limits at the upstream end. The plan includes utility relocations at two locations for the 45' and 46' depth plans. Dredged material would be placed in the new sites identified as 170 in Reach A, 15 D in Reach B, and Raccoon Island for Reach C. Material from Reach D would be placed in the two Federal disposal sites (Reedy Point North and South) at the entrance to the C&D Canal, exchanging ultimate capacity for that in Reach A where Federal sites are most limited. Disposal of dredged material in Reach E, the bay channel, is to occur through wetland/island creation and sand stockpiling for subsequent use by the non-federal interests. Associated cost include berth dredging at each benefiting facility and bulkhead modifications for one facility at depths of 43 feet and greater.

463. Maintenance dredging would be accomplished according to the current intervals at Federal expense. Material would be placed in Federal and non-Federally provided sites in order to minimize mobilization and pumping costs, while maximizing the capabilities for site management and potential reuse of material. Ultimately the local sponsor would be responsible for the incremental site preparation and disposal area costs attributable to the channel deepening. Maintenance of associated features would be accomplished by the beneficiary facilities.

FIGURE 19

DELAWARE RIVER
COMPREHENSIVE NAVIGATION STUDY
MINIMUM WIDTH
ASYMMETRIC CHANNEL
PHILADELPHIA DISTRICT, CORPS OF ENGINEERS

464. Navigation Practice. With only the inbound lane deepened, vessel operating practices would be different from current practices. No longer could crude oil tankers and import dry bulk carriers (the only ships benefitting from an asymmetric inbound deepening option) normally travel in the channel center except to pass. They would be restricted to a channel 42% to 46% narrower and for safe navigation would travel much slower. This plan results in vessel steaming times of 11 1/2 hours at a minimum, which exceeds the time for running upriver with a single tide. Two measures to overcome this constraint are possible. Deeper draft vessels could be required to wait in the naturally deep upper Delaware Bay for about 3 hours for the return of higher tides, resulting in a 14 hour total trip. The second option would be to add two feet of channel depth to either the upper river or bay channels or portions of both to allow for a continuous 11 1/2 hour trip not hindered by the need to wait for the tide to return. Increasing vessel operating costs by about $3,000 ($1000/hr x 3 hrs.) for over 200 ships per year would be less expensive than the several million yards of added dredging. Therefore, the first option was analyzed.

465. While passing of ships with drafts over 40 feet could not occur, effective coordination between pilots should allow for limited impact on operations. Present practice in the asymmetric Philadelphia Harbor is for shallower vessels to use the 37' east channel irrespective of travel direction and deeper draft vessels use the 40' west channel. Similar practices could occur with this option. In keeping with current practice ships using the deeper channel could align themselves with the northernmost destination in front so that no vessels are delayed by turning and docking movements.

466. Beneficiaries. This option would benefit crude oil and dry bulk imports to Pier 122 only. The Delaware River channel is too long and too heavily used to allow for outbound vessels to alternately use the deeper channel, especially with the timing requirements associated with using the tides.

This option involves deepening for inbound traffic based on Corps design criteria for the channel with no access channel to SJPC's Beckett Street Terminal. With only the inbound traffic lane to be deepened, outgoing vessels would receive no benefits. Also, crude oil, and iron ore incoming vessels would be forced to stay within a narrower channel and travel at a slower speed. This would add, on average, approximately 7 hours additional travel time, plus additional tug and pilot costs, to each trip upriver for Option 2. Consequently, Option 2 would provide reduced transportation cost savings as compared to a full width option. Benefits are presented in Table 31.

TABLE 29

DELAWARE RIVER COMPREHENSIVE NAVIGATION STUDY FILE:BSUM2S1
MAIN CHANNEL DEEPENING INVESTIGATION
OPTION 2
SUMMARY OF AVG ANN BENEFITS
INCORPORATING FY91 OCE VESSEL OPERATING COSTS
8 3/4% DISCOUNT RATE

COMMODITY	41 FEET	42 FEET	43 FEET	44 FEET	45 FEET	46 FEET
CRUDE OIL TRANSPORTATION SAVINGS	$6,219,000	$12,129,000	$17,883,000	$23,203,000	$28,417,000	$33,468,000
IRON ORE TRANSPORTATION SAVINGS	$53,000	$102,000	$147,000	$183,000	$214,000	$233,000
COAL-ALL TRANSPORTATION SAVINGS ELIMINATED SINCE OUTBOUND CHANNEL WILL NOT BE DEEPENED						
SOUTH JERSEY PORT CORPORATION-ALL TRANSPORTATION SAVINGS ELIMINATED SINCE ACCESS CHANNEL WILL NOT BE DEEPENED						
CONTAINERS-ALL TRANSPORTATION SAVINGS ELIMINATED						
TOTAL TRANSPORTATION SAVINGS (CUMULATIVE)	$6,272,000	$12,231,000	$18,030,000	$23,486,000	$28,631,000	$33,701,000

467. MORE EFFICIENT ASYMMETRIC INBOUND CHANNEL. Channel widths for this option are based on recommendations of the Delaware River and Bay Pilots. This channel allows for running with the tide and permits speeds sufficient to stay within a single tidal cycle. The deepened channel in Philadelphia Harbor would be 400' wide and between the Navy Yard and Wilmington would be 435' wide (see Figure 22). In the reach between Wilmington and the Bombay Hook, the deepened channel would be 600 feet wide while in the bay the channel would be 800 feet wide. River geometry and shore facilities are such that present practices are for the pilots to navigate this portion of the river and bay much faster in order to allow for inbound vessel transits to occur within a single tide cycle. Such a speed difference between upper river and the lower river plus bay allows for use of the tide within a single tidal cycle to increase effective channel depth. Similar to the minimum width asymmetric channel, this option requires a duplicate set of range lights to be installed for safe navigation of inbound vessels in order to follow the centerline of the asymmetric channel. Other features of this option would include bend widening, a two space anchorage at Marcus Hook and utility relocations for the 45 foot and 46 foot depth plan. Dredged material disposal would be accomplished similar to the first option. Associated costs for berth dredging and bulkheads would also be required as in the earlier option.

468. Navigation Practice. Vessel operating practice would only change slightly. Deeper vessels would be able to utilize 80% of the existing bay channel and 75% of the river channel below Wilmington. For every foot of increased channel depth a comparable increase in vessel draft could occur for inbound traffic. With a 45' deep channel, 42' draft inbound vessels (freshwater draft) could navigate without using the tide and vessels up to a 45' draft could do so with a tide. Inbound trips using the tide would take about 10 1/2 hours.

469. Beneficiaries. Like the minimum width asymmetric this option would benefit crude oil and dry bulk imports, but not coal vessels. This option developed at the request of the pilots, would deepen only the inbound traffic lane, but to a greater width than Option 2. Also like Option 2, Option 3 does not include an access channel to SJPC's Beckett Street Terminal. Additional travel time per vessel trip over the two-way channel for crude oil, and iron ore incoming vessels would be approximately three hours, thereby, providing transportation cost savings greater than Option 2 but less than Option 1. Benefits are presented in Table 32.

FIGURE 20

DELAWARE RIVER
COMPREHENSIVE NAVIGATION STUDY
MORE EFFICIENT
ASYMMETRIC CHANNEL
PHILADELPHIA DISTRICT, CORPS OF ENGINEERS

TABLE 30

DELAWARE RIVER COMPREHENSIVE NAVIGATION STUDY
MAIN CHANNEL DEEPENING INVESTIGATION
OPTION 3
SUMMARY OF AVG ANN BENEFITS
INCORPORATING FY91 OCE VESSEL OPERATING COSTS
@ 3/4% DISCOUNT RATE

COMMODITY	41 FEET	42 FEET	43 FEET	44 FEET	45 FEET	46 FEET
CRUDE OIL TRANSPORTATION SAVINGS	$6,926,000	$13,509,000	$19,918,000	$25,844,000	$31,651,000	$37,276,000
IRON ORE TRANSPORTATION SAVINGS	$90,000	$174,000	$251,000	$312,000	$365,000	$397,000
COAL-ALL TRANSPORTATION SAVINGS ELIMINATED SINCE OUTBOUND CHANNEL WILL NOT BE DEEPENED						
SOUTH JERSEY PORT CORPORATION-ALL TRANSPORTATION SAVINGS ELIMINATED SINCE ACCESS CHANNEL WILL NOT BE DEEPENED						
CONTAINERS-ALL TRANSPORTATION SAVINGS ELIMINATED						
TOTAL TRANSPORTATION SAVINGS (CUMULATIVE)	$7,016,000	$13,683,000	$20,169,000	$26,156,000	$32,016,000	$37,673,000

470. FULL WIDTH CHANNEL. Under this option the inbound and outbound lanes would be deepened consistent with the existing project dimensions; 1000' from Delaware Bay to Bombay Hook and then 800' up to the Philadelphia Navy Yard below the Walt Whitman Bridge. Refer to Figure 23.

471. Through Philadelphia Harbor up to Beckett Street Terminal, the 400'-500' west side channel would be deepened from its current 40' depth. A trapezoidal access channel would be provided to the bulk berths at Beckett Street Terminal, modifying the 40' access channel authorized by the W.R.D.A. of 1988, which modified sections of the east side Delaware River channel and the Delaware River in the Vicinity of Camden project. Oil tanker movements are limited to the wider channel reaches, while the narrower channel accommodates the smaller dry bulk vessels calling at the Conrail facilities and Beckett Street Terminal, as well as container vessels at the intermodal transfer facility. The 400' channel is used by both inbound and outbound vessels in a one-way manner using communications among the vessel pilots and Philadelphia Maritime Exchange to avoid conflicts. Shallower draft traffic utilizes the parallel eastern channels to avoid conflicts with the deep draft vessels confined to the western channel. This practice would continue to be used in order to minimize dredging requirements, and one-way usage of the 400' wide channel is adequate for the level of traffic. The overall project length would be 102 miles.

472. Included as part of the plan would be widening of bends to accommodate vessel crab in turns. A two space anchorage would be provided at Marcus Hook within its existing limits at the upstream end. The plan includes utility relocations at two locations for the 45' and 46' depth plans. No navigation aids would require modification for this option. Dredged material would be placed in the new sites identified as 170 in Reach A, 15 D in Reach B, and Raccoon Island for Reach C. Material from Reach D would be placed in the two Federal disposal sites (Reedy Point North and South) at the entrance to the C&D Canal, exchanging ultimate capacity for that in Reach A where Federal sites are most limited. Disposal areas were developed based on maximizing usable disposal area size in order to minimize project costs. Real estate costs for a lesser sized disposal area would only be marginally reduced, since excess partial parcels would have limited use due to their being uneconomic remnants. Disposal of dredged material in Reach E, the bay channel, is to occur through wetland/island creation and sand stockpiling for subsequent use by the non-federal interests. Associated costs include berth dredging at each benefitting facility and bulkhead modifications for one facility at depths of 43 feet and greater.

473. Maintenance dredging would be accomplished according to the current intervals at Federal expense. Material would be placed in Federal and non-Federally provided sites in order to minimize mobilization and pumping costs, while maximizing the capabilities for site management and potential reuse of material. Ultimately the local sponsor would be responsible for the incremental site preparation and disposal area costs attributable to the channel

deepening. Maintenance of associated features would be accomplished by the beneficiary facilities.

FIGURE 21
DELAWARE RIVER
COMPREHENSIVE NAVIGATION STUDY
FULL WIDTH CHANNEL
PHILADELPHIA DISTRICT, CORPS OF ENGINEERS

474. Navigation Practice. With both inbound and outbound lanes deepened, vessel operating practice would continue as it does now. Vessels would navigate in the center of the channel when possible to maximize speeds but could use both lanes in a passing situation. For every foot of increased channel depth, a comparable increase in maximum vessel operating drafts could occur for both inbound and outbound traffic. With a 45' deep channel, 42' (freshwater) draft vessels could navigate without using the tide and vessels up to a 45' draft could do so with a tide. Inbound trips using the tide would still take about 7 1/2 hours while outbound trips would take the same 10 1/2 hours.

475. Beneficiaries. The main beneficiary of channel deepening would be crude oil tankers docking at six refineries. In addition colliers and iron ore vessels using Piers 122 and 124 could also be loaded deeper. Scrap, and bituminous coal shipments at the Beckett Street Terminal are also expected to benefit as well as container vessels. The estimation of benefits for Option 1, the full width channel with an access channel to SJPC's Beckett Street Terminal, involved combining the transportation costs per ton by channel depth estimated for each pertinent vessel class by trade route by commodity with the annualized level of commodity projections. No induced tonnage will result from the proposed channel improvements. Benefits are presented in Table 33.

476. COMPARISON OF DETAILED PLANS. The following analyses were conducted to identify and measure the likely economic, environmental and social impacts expected to result from implementation of the alternative plans. The impacts were evaluated to determine the contributions, both beneficial and adverse, of the alternative plans. Interest during construction was computed using a schedule defining cost, by individual year over the total construction period, broken out by individual cost category, i.e., initial project costs, associated costs, real estate cost, relocations, navigation aids, and PED costs. All associated and PED costs as well as some real estate costs will not accrue interest during construction. The Single Payment Compound Amount Factor was applied to bring costs for each individual year forward to the project base year in order to place costs on an equal basis with the annualized project benefits. The analysis is structured incrementally, analyzing first the narrowest asymmetric channel, then the more efficient asymmetric channel and last the full width, longer channel.

477. Minimum Width Asymmetric Channel Inbound (Option II) A comparison of costs and benefits associated with constructing this option from depths of 41 feet to 46 feet is presented in Table 34. Project benefits come from crude oil imports to six refineries and iron ore imports to Pier 122. Net benefits are maximized with a 45 foot channel depth for this option.

Delaware River Comprehensive Navigation Study:
Main Channel Deepening

Table 31. Annualized Benefits For Option 1 (with Beckett Street Terminal)
September 1991 Price Level, 8 3/4% Discount rate

Commodity	Channel Depth: 41	42	43	Average Annual Benefits 44	45	46
Crude oil vessels with sailing drafts greater than 40 feet	$5,333,000	$10,533,000	$15,641,000	$20,525,000	$25,430,000	$30,244,000
Crude oil vessels with sailing drafts less than or equal to 40 feet	$2,068,000	$3,902,000	$5,642,000	$7,090,000	$8,390,000	$9,587,000
Subtotal-Crude Oil Imports	$7,401,000	$14,435,000	$21,283,000	$27,615,000	$33,820,000	$39,831,000
Coal vessels-Exports	$95,000	$176,000	$240,000	$284,000	$311,000	$321,000
Iron Ore vessels-Imports	$117,000	$226,000	$326,000	$406,000	$475,000	$517,000
SJPC:						
Scrap to Turkey	$1,488,000	$2,159,000	$3,096,000	$4,280,000	$4,917,000	$4,917,000
Coal from Colombia	$58,000	$64,000	$99,000	$134,000	$160,000	$160,000
Subtotal-SJPC	$1,546,000	$2,223,000	$3,195,000	$4,414,000	$5,077,000	$5,077,000
Containers	$871,000	$1,720,000	$2,032,000	$2,251,000	$2,895,000	$2,895,000
TOTAL-CUMULATIVE	$10,030,000	$18,780,000	$27,076,000	$34,970,000	$42,578,000	$48,641,000
INCREMENTAL	$10,030,000	$8,750,000	$8,296,000	$7,894,000	$7,608,000	$6,063,000

TABLE 32
DELAWARE RIVER COMPREHENSIVE NAVIGATION STUDY
MAIN CHANNEL DEEPENING INVESTIGATION
OPTION 3
SUMMARY OF AVG ANN BENEFITS
INCORPORATING FY91 OCE VESSEL OPERATING COSTS
8 3/4% DISCOUNT RATE

COMMODITY	41 FEET	42 FEET	43 FEET	44 FEET	45 FEET	46 FEET	
CRUDE OIL							
TRANSPORTATION SAVINGS	$6,926,000	$13,509,000	$19,918,000	$25,844,000	$31,651,000	$37,276,000	
IRON ORE							
TRANSPORTATION SAVINGS	$90,000	$174,000	$251,000	$312,000	$365,000	$397,000	
COAL-ALL TRANSPORTATION SAVINGS ELIMINATED SINCE OUTBOUND CHANNEL WILL NOT BE DEEPENED							
SOUTH JERSEY PORT CORPORATION-ALL TRANSPORTATION SAVINGS ELIMINATED SINCE ACCESS CHANNEL WILL NOT BE DEEPENED							
CONTAINERS-ALL TRANSPORTATION SAVINGS ELIMINATED							
TOTAL TRANSPORTATION SAVINGS (CUMULATIVE)	$7,016,000	$13,683,000	$20,169,000	$26,156,000	$32,016,000	$37,673,000	
TOTAL TRANSPORTATION SAVINGS (INCREMENTAL)	$7,016,000	$6,667,000	$6,486,000	$5,987,000	$5,860,000	$5,657,000	
OPTION 1:							
CRUDE OIL							
TRANSPORTATION SAVINGS	$7,401,000	$7,034,000	$6,848,000	$6,332,000	$6,205,000	$6,011,000	$39,831,000
IRON ORE							
TRANSPORTATION SAVINGS	$117,000	$109,000	$100,000	$80,000	$69,000	$42,000	$517,000

478. More Efficient Asymmetric Inbound Channel (Option III). A comparison of the costs and benefits associated with constructing and operating this option from depths of 41 feet to 46 feet is presented in Table 34. Project benefits come from increased navigational efficiencies to the same six refineries and one iron ore facility as in Option II. Net benefits are maximized with a 45 feet channel depth. In addition as shown on Table 35, for each proposed depth the net NED benefits for Option III exceed those for Option II therefore further formulation analysis will proceed with Option III as the inbound asymmetric plan.

479. Outbound Lane Optimization. Consistent with incremental plan formulation methodology, a comparison of the additional costs and benefits associated with constructing and operating a two-way channel (Option I) was developed as an incrementally added plan to the asymmetric inbound channel (Option III). This incremental optimization is presented as Table 36. Project benefits come from increased navigational efficiencies to the same six refineries and one iron ore facility as in Options II and III, from coal exports from Pier 122, from container benefits and from bulk imports and exports from the Beckett Street facility. Net benefits are maximized with a 45 foot channel depth.

480. Length Optimization. A sensitivity analysis was conducted for the optimum plan to assure that the last increment of channel length was justified. A shorter project ending at the Conrail Ore piers below the Walt Whitman Bridge (Table 37) was compared to the longer project which accesses Beckett Street Terminal (Table 38). The results are summarized in Table 39 which demonstrates that the project increment to Beckett Street Terminal is incrementally justified and optimizes at the 45' depth.

481. Continuation of Length Optimization. Another sensitivity analyses was performed for the increment between the most northern refinery and the Walt Whitman Bridge; facilities located in the channel segment include Conrail's Piers 122 and 124 and the Packer Avenue general cargo and container facility. This showed that this segment is also incrementally justified and optimizes at the 45' depth (Refer to tables 40 and 41).

TABLE [illegible]
INCREMENTAL OPTIMIZATION OF ASYMMETRIC CHANNELS
OPTIONS II vs. III

CHANNEL DEPTH	ANNUAL COSTS ($000'S)			ANNUAL BENEFITS ($000'S)			NET
	#3	#2	DIFF.	#3	#2	DIFF.	
41 FT	9,919	9,805	114	7,016	6,272	744	630
42 FT	11,817	11,056	761	13,683	12,231	1,452	691
43 FT	15,079	14,109	970	20,169	18,030	2,139	1,169
44 FT	19,566	18,090	1,476	26,156	23,486	2,670	1,194
45 FT	24,525	22,450	2,075	32,016	28,631	3,385	1,310
46 FT	32,804	30,086	2,718	37,673	33,701	3,972	1,254

TABLE 34
OPTIMIZATION OF OUTBOUND CHANNEL

CHANNEL DEPTH	ANNUAL COSTS ($000'S)			ANNUAL BENEFITS ($000'S)			NET (6-3)
	#1 W/ BECKETT (1)	#3 (2)	DIFF. (1-2)	#1 W/ BECKETT (4)	#3 (5)	DIFF. (4-5)	
41 FT	11,119	9,919	1,200	10,030	7,016	3,014	1,814
42 FT	14,150	11,817	2,333	18,780	13,683	5,097	2,764
43 FT	19,161	15,079	4,082	27,076	20,169	6,907	2,825
44 FT	25,685	19,566	6,118	35,131	26,156	8,975	2,857
45 FT	32,113	24,525	7,587	42,776	32,016	10,760	3,173
46 FT	40,847	32,804	8,043	48,874	37,673	11,201	3,158

TABLE 36
OPTION 1 (FULL CHANNEL WIDTH, WITHOUT BECKETT STREET)
ANNUALIZATION OF COSTS AND ECONOMIC OPTIMIZATION
8 3/4% DISCOUNT RATE, SEPT 1991 P. L.

	41 FT	42 FT	43 FT	44 FT	45 FT	46 FT
INITIAL PROJECT COSTS	$74,790,000	$99,160,000	$135,640,000	$191,620,000	$243,460,000	$303,370,000
ASSOC. COSTS	$7,348,000	$9,238,000	$19,708,000	$21,193,000	$22,560,000	$23,892,000
REAL ESTATE	$19,827,000	$19,827,000	$19,827,000	$19,827,000	$19,827,000	$19,827,000
RELOCATIONS	$0	$0	$0	$0	$3,130,000	$5,760,000
NAVIGATION AIDS	$856,000	$856,000	$856,000	$856,000	$856,000	$856,000
PED COSTS	$10,000,000	$10,000,000	$10,000,000	$10,000,000	$10,000,000	$10,000,000
TOTAL FIRST COSTS	$112,821,000	$139,081,000	$186,031,000	$243,496,000	$299,833,000	$363,705,000
CRF, 50 YRS	0.0888400	0.0888400	0.0888400	0.0888400	0.0888400	0.0888400
AVG ANN FIRST COST	$10,023,000	$12,356,000	$16,527,000	$21,632,000	$26,637,000	$32,312,000
AVG ANN O&M (FROM W/O PROJECT DEPTH)	$220,000	$440,000	$670,000	$890,000	$1,110,000	$1,330,000
TOTAL AVG ANN COSTS (W/O IDC)	$10,243,000	$12,796,000	$17,197,000	$22,522,000	$27,747,000	$33,642,000
AVG ANN IDC COSTS	$599,000	$934,000	$1,376,000	$2,370,000	$3,481,000	$5,631,000
TOTAL AVG ANN COSTS	$10,842,000	$13,730,000	$18,573,000	$24,892,000	$31,228,000	$39,273,000
AVG ANN BENEFITS OVER PROJECT LIFE	$8,484,000	$16,557,000	$23,881,000	$30,556,000	$37,501,000	$43,564,000
AVG ANN BENEFITS DURING CONSTRUCTION	$0	$0	$0	$161,000	$198,000	$233,000
TOTAL AVG ANN BENEFITS	$8,484,000	$16,557,000	$23,881,000	$30,717,000	$37,699,000	$43,797,000
BENEFIT-COST RATIO	0.78	1.21	1.29	1.23	1.21	1.12
NET BENEFITS	($2,358,000)	$2,827,000	$5,308,000	$5,825,000	$6,471,000	$4,524,000

TABLE 36
OPTION 1 (FULL CHANNEL WIDTH, WITH BECKETT STREET)
ANNUALIZATION OF COSTS AND ECONOMIC OPTIMIZATION
8 3/4% DISCOUNT RATE, SEPT 1991 P. L.

	41 FT	42 FT	43 FT	44 FT	45 FT	46 FT
INITIAL PROJECT COSTS	$76,820,000	$101,910,000	$139,370,000	$195,690,000	$248,480,000	$314,540,000
ASSOC. COSTS	$7,781,000	$9,723,000	$20,247,000	$21,785,000	$23,205,000	$24,590,000
REAL ESTATE	$19,827,000	$19,827,000	$19,827,000	$19,827,000	$19,827,000	$19,827,000
RELOCATIONS	$0	$0	$0	$0	$3,130,000	$5,760,000
NAVIGATION AIDS	$856,000	$856,000	$856,000	$856,000	$856,000	$856,000
PED COSTS	$10,000,000	$10,000,000	$10,000,000	$10,000,000	$10,000,000	$10,000,000
TOTAL FIRST COSTS	$115,284,000	$142,316,000	$190,300,000	$248,158,000	$305,498,000	$375,573,000
CRF, 50 YRS	0.0888400	0.0888400	0.0888400	0.0888400	0.0888400	0.0888400
AVG ANN FIRST COST	$10,242,000	$12,643,000	$16,906,000	$22,046,000	$27,140,000	$33,366,000
AVG ANN O&M (FROM W/O PROJECT DEPTH)	$270,000	$540,000	$800,000	$1,070,000	$1,340,000	$1,610,000
TOTAL AVG ANN COSTS (W/O IDC)	$10,512,000	$13,183,000	$17,706,000	$23,116,000	$28,480,000	$34,976,000
AVG ANN IDC COSTS	$607,000	$967,000	$1,455,000	$2,569,000	$3,633,000	$5,871,000
TOTAL AVG ANN COSTS	$11,119,000	$14,150,000	$19,161,000	$25,685,000	$32,113,000	$40,847,000
AVG ANN BENEFITS OVER PROJECT LIFE	$10,030,000	$18,780,000	$27,076,000	$34,970,000	$42,578,000	$48,641,000
AVG ANN BENEFITS DURING CONSTRUCTION	$0	$0	$0	$161,000	$198,000	$233,000
TOTAL AVG ANN BENEFITS	$10,030,000	$18,780,000	$27,076,000	$35,131,000	$42,776,000	$48,874,000
BENEFIT-COST RATIO	0.90	1.33	1.41	1.37	1.33	1.20
NET BENEFITS	($1,089,000)	$4,630,000	$7,915,000	$9,446,000	$10,663,000	$8,027,000

TABLE 36 A.
OPTION 2
ANNUALIZATION OF COSTS AND ECONOMIC OPTIMIZATION
8 3/4% DISCOUNT RATE, SEPT 1991 P. L.

	41 FT	42 FT	43 FT	44 FT	45 FT	46 FT
INITIAL PROJECT COSTS	$59,180,000	$68,970,000	$89,340,000	$124,310,000	$160,680,000	$225,970,000
ASSOC. COSTS	$7,862,000	$10,005,000	$20,536,000	$21,959,000	$23,830,000	$29,163,000
REAL ESTATE	$19,827,000	$19,827,000	$19,827,000	$19,827,000	$19,827,000	$19,827,000
RELOCATIONS	$0	$0	$0	$0	$3,130,000	$5,760,000
NAVIGATION AIDS	$6,837,300	$6,837,300	$6,837,300	$6,837,300	$6,837,300	$6,837,300
PED COSTS	$10,000,000	$10,000,000	$10,000,000	$10,000,000	$10,000,000	$10,000,000
TOTAL FIRST COSTS	$103,706,300	$115,639,300	$146,540,300	$182,933,300	$224,304,300	$297,557,300
CRF, 50 YRS	0.0888400	0.0888400	0.0888400	0.0888400	0.0888400	0.0888400
AVG ANN FIRST COST	$9,213,000	$10,273,000	$13,019,000	$16,252,000	$19,927,000	$26,435,000
AVG ANN O&M (FROM W/O PROJECT DEPTH)	$90,000	$190,000	$280,000	$380,000	$470,000	$560,000
TOTAL AVG ANN COSTS (W/O IDC)	$9,303,000	$10,463,000	$13,299,000	$16,632,000	$20,397,000	$26,995,000
AVG ANN IDC COSTS	$502,000	$593,000	$810,000	$1,458,000	$2,053,000	$3,091,000
TOTAL AVG ANN COSTS	$9,805,000	$11,056,000	$14,109,000	$18,090,000	$22,450,000	$30,086,000
AVG ANN BENEFITS OVER PROJECT LIFE	$6,272,000	$12,231,000	$18,030,000	$23,486,000	$28,631,000	$33,701,000
AVG ANN BENEFITS DURING CONSTRUCTION	$0	$0	$0	$0	$0	$0
TOTAL AVG ANN BENEFITS	$6,272,000	$12,231,000	$18,030,000	$23,486,000	$28,631,000	$33,701,000
BENEFIT-COST RATIO	0.64	1.11	1.28	1.30	1.28	1.12
NET BENEFITS	($3,533,000)	$1,175,000	$3,921,000	$5,396,000	$6,181,000	$3,615,000

TABLE 37
INCREMENTAL OPTIMIZATION OF
BECKETT REACH

CHANNEL DEPTH	ANNUAL COSTS ($000'S)			ANNUAL BENEFITS ($000'S)			NET (6-3)
	#1 W/ BECK. (1)	#1 W/ O BECK. (2)	DIFF. (1-2)	#1 W/ BECK. (4)	#1 W/O BECK. (5)	DIFF. (4-5)	
41 FT	11,119	10,842	277	10,030	8,484	1,546	1,269
42 FT	14,150	13,730	420	18,780	16,557	2,223	1,803
43 FT	19,161	18,573	588	27,076	23,881	3,195	2,607
44 FT	25,685	24,892	793	35,131	30,717	4,414	3,622
45 FT	32,113	31,228	885	42,776	37,699	5,077	4,193
46 FT	40,847	39,273	1,574	48,874	43,797	5,077	3,503

TABLE 38
LENGTH OPTIMIZATION: DREDGING ONLY TO COASTAL REFINERY
ANNUALIZATION OF COSTS
8 3/4% DISCOUNT RATE, SEPT 1991 P.L.

	41 FT	42 FT	43 FT	44 FT	45 FT	46 FT
INITIAL PROJECT COSTS	$74,100,000	$98,430,000	$134,690,000	$190,340,000	$241,790,000	$301,180,000
ASSOC. COSTS	$4,899,000	$6,457,000	$16,515,000	$17,502,000	$18,497,000	$19,479,000
REAL ESTATE	$19,827,000	$19,827,000	$19,827,000	$19,827,000	$19,827,000	$19,827,000
RELOCATIONS	$0	$0	$0	$0	$3,130,000	$5,760,000
NAVIGATION AIDS	$856,000	$856,000	$856,000	$856,000	$856,000	$856,000
PED COSTS	$10,000,000	$10,000,000	$10,000,000	$10,000,000	$10,000,000	$10,000,000
TOTAL FIRST COSTS	$109,682,000	$135,570,000	$181,888,000	$238,525,000	$294,100,000	$357,102,000
CRF, 50 YRS	0.0888400	0.0888400	0.0888400	0.0888400	0.0888400	0.0888400
AVG ANN FIRST COST	$9,744,000	$12,044,000	$16,159,000	$21,191,000	$26,128,000	$31,725,000
AVG ANN O&M (FROM W/O PROJECT DEPTH)	$214,000	$428,000	$652,000	$866,000	$1,080,000	$1,295,000
TOTAL AVG ANN COSTS (W/O IDC)	$9,958,000	$12,472,000	$16,811,000	$22,057,000	$27,208,000	$33,020,000
AVG ANN IDC COSTS	$593,400	$927,100	$1,366,400	$2,354,100	$3,457,100	$5,591,300
TOTAL AVG ANN COSTS	$10,551,400	$13,399,100	$18,177,400	$24,411,100	$30,665,100	$38,611,300

TABLE 39

LENGTH OPTIMIZATION - SEGMENT BETWEEN
NORTHERN MOST REFINERY & WALT WHITMAN BRIDGE

CHANNEL DEPTH	ANNUAL COSTS ($000's) #1 W/O BECK	NORTHERN MOST REFINERY	Diff	ANNUAL BENEFITS ($000's) #1 W/O BECK	NORTHERN MOST REFINERY	Diff	NET
41 FT	10,842	10,551	291	8,484	7,401	1,083	792
42 FT	13,730	13,399	331	16,557	14,435	2,122	1,791
43 FT	18,573	18,177	396	23,881	21,283	2,598	2,202
44 FT	24,892	24,410	482	30,717	27,615	3,102	2,620
45 FT	31,228	30,644	564	37,699	33,820	3,879	3,315
46 FT	39,273	38,611	622	43,797	39,831	3,966	3,304

TRADE OFF ANALYSIS

482. The information presented previously indicates that all depths have positive net National Economic Development (NED) benefits. Although adverse environmental impacts associated with dredging and disposal increase with both depths and width, the net difference in impacts between the smallest scale plan, and the largest scale plan is considered to be relatively small, when compared to that already occurring with the existing channel.

RATIONALE FOR SELECTED PLAN

483. The process used to determine the selected plan considered the degree of study objective fulfillment, economic justification, and environmental considerations. The main planning objectives were to provide adequate and safe navigation channels to accommodate vessels travelling along the Delaware River while satisfying the national objective of maximizing net benefits. Based on the comparison of alternatives presented, the 45 foot full-width plan with access to Beckett Street Terminal fulfills the planning objectives, is economically justified, maximizes net benefits and qualifies as the NED plan.

RISK AND UNCERTAINTY ANALYSIS

484. Situations of risk are conventionally defined as those in which the potential outcomes can be described in reasonably well known probability descriptions. In situations of uncertainty, potential outcomes cannot be described in objectively known probability distributions. Risk and uncertainty arise from measurement uncertainty or inaccuracies and from the underlying variability of complex natural, social, and economic situations. It is the purpose of this section to characterize to the extent possible the different degrees of risk and uncertainty.

485. A number of parameters were identified as having risk and uncertainty associated with the outcome of the planning analysis. A sensitivity analysis was conducted to vary these key parameters and determine what impact this would have on project justification and optimization. The parameters which were varied are discussed below.

486. <u>DISCOUNT RATE.</u> Table 42 is a summary for Option 1 (full width channel) of average annual benefits for three discount rates, 8 5/8%, 8 7/8%, and 10%. Benefits would be only 6% lower for the 10% discount rate in comparison to the 8 3/4% discount rate for the full range of improvements considered. The optimal depth would still be 45 feet, for 8 5/8% and 8 7/8% as shown on Table 43 and 44 and 44 feet for 10%, as shown on Table 45.

TABLE 40
OPTION 1 (WITH BECKETT STREET)
SENSITIVITY ANALYSIS:DISCOUNT RATES

8 3/4% DISCOUNT RATE:

	Channel Depth:					
Commodity	41	42	43	44	45	46
Crude Oil Imports	$7,401,000	$14,435,000	$21,283,000	$27,615,000	$33,820,000	$39,831,000
Coal vessels-Exports	$95,000	$176,000	$240,000	$284,000	$311,000	$321,000
Iron Ore vessels-Imports	$117,000	$226,000	$326,000	$406,000	$475,000	$517,000
SJPC	$1,546,000	$2,223,000	$3,195,000	$4,414,000	$5,077,000	$5,077,000
Containers	$871,000	$1,720,000	$2,032,000	$2,251,000	$2,895,000	$2,895,000
TOTAL-CUMULATIVE	$10,030,000	$18,780,000	$27,076,000	$34,970,000	$42,578,000	$48,641,000

8 5/8% DISCOUNT RATE:

	Channel Depth:					
Commodity	41	42	43	44	45	46
Crude Oil Imports	$7,505,000	$14,637,000	$21,581,000	$28,002,000	$34,294,000	$40,389,000
Coal vessels-Exports	$95,000	$176,000	$240,000	$284,000	$311,000	$321,000
Iron Ore vessels-Imports	$119,000	$229,000	$331,000	$412,000	$482,000	$525,000
SJPC	$1,548,000	$2,226,000	$3,200,000	$4,421,000	$5,085,000	$5,085,000
Containers	$874,000	$1,725,000	$2,038,000	$2,258,000	$2,904,000	$2,904,000
TOTAL-CUMULATIVE	$10,141,000	$18,993,000	$27,390,000	$35,377,000	$43,076,000	$49,224,000

6 7/8% DISCOUNT RATE:

	Channel Depth:					
Commodity	41	42	43	44	45	46
Crude Oil Imports	$7,299,000	$14,236,000	$20,989,000	$27,233,000	$33,353,000	$39,281,000
Coal vessels-Exports	$95,000	$176,000	$240,000	$284,000	$311,000	$321,000
Iron Ore vessels-Imports	$115,000	$223,000	$321,000	$400,000	$468,000	$509,000
SJPC	$1,544,000	$2,220,000	$3,190,000	$4,407,000	$5,069,000	$5,069,000
Containers	$868,000	$1,715,000	$2,026,000	$2,244,000	$2,886,000	$2,886,000
TOTAL-CUMULATIVE	$9,921,000	$18,570,000	$26,766,000	$34,568,000	$42,087,000	$48,066,000

10% DISCOUNT RATE:

	Channel Depth:					
Commodity	41	42	43	44	45	46
Crude Oil Imports	$6,881,000	$13,420,000	$19,786,000	$25,673,000	$31,442,000	$37,030,000
Coal vessels-Exports	$95,000	$176,000	$240,000	$284,000	$311,000	$321,000
Iron Ore vessels-Imports	$101,000	$196,000	$282,000	$352,000	$411,000	$448,000
SJPC	$1,511,000	$2,172,000	$3,122,000	$4,314,000	$4,962,000	$4,962,000
Containers	$839,000	$1,657,000	$1,958,000	$2,169,000	$2,789,000	$2,789,000
TOTAL-CUMULATIVE	$9,427,000	$17,621,000	$25,388,000	$32,792,000	$39,915,000	$45,550,000

TABLE 41
OPTION 1 (FULL CHANNEL WIDTH, WITH BECKETT STREET)
ANNUALIZATION OF COSTS AND ECONOMIC OPTIMIZATION
SENSITIVITY: 8 5/8% DISCOUNT RATE

F:AAC1W

	41 FT	42 FT	43 FT	44 FT	45 FT	46 FT
INITIAL PROJECT COSTS	$76,820,000	$101,910,000	$139,370,000	$195,690,000	$248,480,000	$314,540,000
ASSOC. COSTS	$7,781,000	$9,723,000	$20,247,000	$21,785,000	$23,205,000	$24,590,000
REAL ESTATE	$19,827,000	$19,827,000	$19,827,000	$19,827,000	$19,827,000	$19,827,000
RELOCATIONS	$0	$0	$0	$0	$3,130,000	$5,760,000
NAVIGATION AIDS	$856,000	$856,000	$856,000	$856,000	$856,000	$856,000
PED COSTS	$10,000,000	$10,000,000	$10,000,000	$10,000,000	$10,000,000	$10,000,000
TOTAL FIRST COSTS	$115,284,000	$142,316,000	$190,300,000	$248,158,000	$305,498,000	$375,573,000
CRF, 50 YRS	0.0876504	0.0876504	0.0876504	0.0876504	0.0876504	0.0876504
AVG ANN FIRST COST	$10,105,000	$12,474,000	$16,680,000	$21,751,000	$26,777,000	$32,919,000
AVG ANN O&M (FROM W/O PROJECT DEPTH)	$270,000	$540,000	$800,000	$1,070,000	$1,340,000	$1,610,000
TOTAL AVG ANN COSTS (W/O IDC)	$10,375,000	$13,014,000	$17,480,000	$22,821,000	$28,117,000	$34,529,000
AVG ANN IDC COSTS	$589,760	$937,990	$1,411,350	$2,490,960	$3,523,040	$5,694,870
TOTAL AVG ANN COSTS	$10,964,760	$13,951,990	$18,891,350	$25,311,960	$31,640,040	$40,223,870
AVG ANN BENEFITS OVER PROJECT LIFE	$10,141,000	$18,993,000	$27,390,000	$35,377,000	$43,076,000	$49,224,000
AVG ANN BENEFITS DURING CONSTRUCTION	$0	$0	$0	$163,000	$201,000	$236,000
TOTAL AVG ANN BENEFITS	$10,141,000	$18,993,000	$27,390,000	$35,540,000	$43,277,000	$49,460,000
BENEFIT-COST RATIO	0.92	1.36	1.45	1.40	1.37	1.23
NET BENEFITS	($824,000)	$5,041,000	$8,499,000	$10,228,000	$11,637,000	$9,236,000

TABLE 42
OPTION 1 (FULL CHANNEL WIDTH, WITH BECKETT STREET) F:AAC1W
ANNUALIZATION OF COSTS AND ECONOMIC OPTIMIZATION
SENSITIVITY: 8 7/8% DISCOUNT RATE

	41 FT	42 FT	43 FT	44 FT	45 FT	46 FT
INITIAL PROJECT COSTS	$76,820,000	$101,910,000	$139,370,000	$195,690,000	$248,480,000	$314,540,000
ASSOC. COSTS	$7,781,000	$9,723,000	$20,247,000	$21,785,000	$23,205,000	$24,590,000
REAL ESTATE	$19,827,000	$19,827,000	$19,827,000	$19,827,000	$19,827,000	$19,827,000
RELOCATIONS	$0	$0	$0	$0	$3,130,000	$5,760,000
NAVIGATION AIDS	$856,000	$856,000	$856,000	$856,000	$856,000	$856,000
PED COSTS	$10,000,000	$10,000,000	$10,000,000	$10,000,000	$10,000,000	$10,000,000
TOTAL FIRST COSTS	$115,284,000	$142,316,000	$190,300,000	$248,158,000	$305,498,000	$375,573,000
CRF, 50 YRS	0.0900323	0.0900323	0.0900323	0.0900323	0.0900323	0.0900323
AVG ANN FIRST COST	$10,379,000	$12,813,000	$17,133,000	$22,342,000	$27,505,000	$33,814,000
AVG ANN O&M (FROM W/O PROJECT DEPTH)	$270,000	$540,000	$800,000	$1,070,000	$1,340,000	$1,610,000
TOTAL AVG ANN COSTS (W/O IDC)	$10,649,000	$13,353,000	$17,933,000	$23,412,000	$28,845,000	$35,424,000
AVG ANN IDC COSTS	$626,240	$996,010	$1,498,650	$2,645,040	$3,740,960	$6,047,130
TOTAL AVG ANN COSTS	$11,275,240	$14,349,010	$19,431,650	$26,057,040	$32,585,960	$41,471,130
AVG ANN BENEFITS OVER PROJECT LIFE	$9,921,000	$18,570,000	$26,766,000	$34,568,000	$42,087,000	$48,066,000
AVG ANN BENEFITS DURING CONSTRUCTION	$0	$0	$0	$159,000	$195,000	$230,000
TOTAL AVG ANN BENEFITS	$9,921,000	$18,570,000	$26,766,000	$34,727,000	$42,282,000	$48,296,000
BENEFIT-COST RATIO	0.88	1.29	1.38	1.33	1.30	1.16
NET BENEFITS	($1,354,000)	$4,221,000	$7,334,000	$8,670,000	$9,696,000	$6,825,000

TABLE 43
OPTION 1 (FULL CHANNEL WIDTH, WITH BECKETT STREET) F:AAC1W
ANNUALIZATION OF COSTS AND ECONOMIC OPTIMIZATION
SENSITIVITY: 10% DISCOUNT RATE

	41 FT	42 FT	43 FT	44 FT	45 FT	46 FT
INITIAL PROJECT COSTS	$76,820,000	$101,910,000	$139,370,000	$195,690,000	$248,480,000	$314,540,000
ASSOC. COSTS	$7,781,000	$9,723,000	$20,247,000	$21,785,000	$23,205,000	$24,590,000
REAL ESTATE	$19,827,000	$19,827,000	$19,827,000	$19,827,000	$19,827,000	$19,827,000
RELOCATIONS	$0	$0	$0	$0	$3,130,000	$5,760,000
NAVIGATION AIDS	$856,000	$856,000	$856,000	$856,000	$856,000	$856,000
PED COSTS	$10,000,000	$10,000,000	$10,000,000	$10,000,000	$10,000,000	$10,000,000
TOTAL FIRST COSTS	$115,284,000	$142,316,000	$190,300,000	$248,158,000	$305,498,000	$375,573,000
CRF, 50 YRS	0.1008590	0.1008590	0.1008590	0.1008590	0.1008590	0.1008590
AVG ANN FIRST COST	$11,627,000	$14,354,000	$19,193,000	$25,029,000	$30,812,000	$37,880,000
AVG ANN O&M (FROM W/O PROJECT DEPTH)	$270,000	$540,000	$800,000	$1,070,000	$1,340,000	$1,610,000
TOTAL AVG ANN COSTS (W/O IDC)	$11,897,000	$14,894,000	$19,993,000	$26,099,000	$32,152,000	$39,490,000
AVG ANN IDC COSTS	$796,480	$1,266,770	$1,920,600	$3,364,080	$4,757,920	$7,691,010
TOTAL AVG ANN COSTS	$12,693,480	$16,160,770	$21,913,600	$29,463,080	$36,909,920	$47,181,010
AVG ANN BENEFITS OVER PROJECT LIFE	$9,427,000	$17,621,000	$25,388,000	$32,792,000	$39,915,000	$45,550,000
AVG ANN BENEFITS DURING CONSTRUCTION	$0	$0	$0	$150,000	$184,000	$217,000
TOTAL AVG ANN BENEFITS	$9,427,000	$17,621,000	$25,388,000	$32,942,000	$40,099,000	$45,767,000
BENEFIT-COST RATIO	0.74	1.09	1.16	1.12	1.09	0.97
NET BENEFITS	($3,266,000)	$1,460,000	$3,474,000	$3,479,000	$3,189,000	($1,414,000)

487. OPTIMISTIC AND PESSIMISTIC TONNAGE. Tables 46 and 47 bracket the average annual benefits with optimistic and pessimistic tonnage scenarios of plus and minus 25% of the most likely scenario. The optimal depth for the former scenario would be 46 feet, and for the latter scenario would be 43 feet, as shown on Tables 48 and 49, respectively.

488. BASE YEAR TONNAGE. Average annual benefits are presented in Table 50 for base year levels of tonnage. For Option 1, benefits would be 10% lower and the optional depth would still be 45 feet as shown in Table 51.

489. STUDY YEAR TONNAGE. Average annual benefits are presented in Table 52 for study year tonnage levels. Benefits would be 44% lower for that tonnage level and the channel improvement would not be justified, as shown in Table 53.

490. CLOSED OIL REFINERY. Assuming a scenario in which an average-sized benefitting refinery were to close, Table 54 shows the impact. For Option 1, benefits would be 13% lower than determined in the study analysis, but the optimal depth would remain at 45 feet, as shown in Table 55.

491. COAL SHIFT. Table 56 analyzes the impact of the coal exports moving through Pier 124 shifting to Baltimore. For Option 1, benefits would be only 0.7% lower and the optimal depth would be 45 feet, as shown in Table 57.

492. OPTION II vs OPTION I. As the result of agency concerns over the viability of Option III (wide asymmetric) an outbound lane optimization was analyzed as an increment over Option II (narrow asymmetric). This test, as shown in Table 58, also confirmed 45' full width as the NED plan.

TABLE 44
FULL WIDTH CHANNEL
OPTIMISTIC SCENARIO BENEFITS

COMMODITY	CHANNEL DEPTH: 41	42	43	44	45	46
Crude Oil Imports	$9,251,000	$18,044,000	$26,604,000	$34,519,000	$42,275,000	$49,789,000
Coal vessels-Imports	$119,000	$220,000	$300,000	$355,000	$389,000	$401,000
Iron Ore vessels-Imports	$146,000	$283,000	$408,000	$508,000	$594,000	$646,000
SJPC	$1,933,000	$ 2,779,000	$ 3,994,000	$ 5,518,000	$ 6,346,000	$ 6,346,000
Containers	$1,089,000	$ 2,150,000	$ 2,540,000	$ 2,814,000	$ 3,619,000	$ 3,619,000
TOTAL-CUMULATIVE	$12,538,000	$23,476,000	$33,846,000	$43,714,000	$53,223,000	$60,801,000

TABLE 45
FULL WIDTH CHANNEL
PESSIMISTIC SCENARIO BENEFITS

COMMODITY	CHANNEL DEPTH: 41	42	43	44	45	46
Crude Oil Imports	$5,551,000	$10,826,000	$15,962,000	$20,711,000	$25,365,000	$29,873,000
Coal vessels-Imports	$ 71,000	$132,000	$180,000	$213,000	$ 233,000	$ 241,000
Iron Ore vessels-Imports	$ 88,000	$170,000	$245,000	$305,000	$ 356,000	$ 388,000
SJPC	$1,160,000	$ 1,667,000	$ 2,396,000	$ 3,311,000	$ 3,808,000	$ 3,808,000
Containers	$ 653,000	$ 1,290,000	$ 1,524,000	$ 1,688,000	$ 2,171,000	$ 2,171,000
TOTAL-CUMULATIVE	$7,523,000	$14,085,000	$20,307,000	$26,228,000	$31,933,000	$36,481,000

TABLE 46
OPTION 1 (FULL CHANNEL WIDTH, WITH BECKETT STREET)
ANNUALIZATION OF COSTS AND ECONOMIC OPTIMIZATION
SENSITIVITY: OPTIMISTIC SCENARIO

F:AAC1W

	41 FT	42 FT	43 FT	44 FT	45 FT	46 FT
INITIAL PROJECT COSTS	$76,820,000	$101,910,000	$139,370,000	$195,690,000	$248,480,000	$314,540,000
ASSOC. COSTS	$7,781,000	$9,723,000	$20,247,000	$21,785,000	$23,205,000	$24,590,000
REAL ESTATE	$19,827,000	$19,827,000	$19,827,000	$19,827,000	$19,827,000	$19,827,000
RELOCATIONS	$0	$0	$0	$0	$3,130,000	$5,760,000
NAVIGATION AIDS	$856,000	$856,000	$856,000	$856,000	$856,000	$856,000
PED COSTS	$10,000,000	$10,000,000	$10,000,000	$10,000,000	$10,000,000	$10,000,000
TOTAL FIRST COSTS	$115,284,000	$142,316,000	$190,300,000	$248,158,000	$305,498,000	$375,573,000
CRF, 50 YRS	0.0888400	0.0888400	0.0888400	0.0888400	0.0888400	0.0888400
AVG ANN FIRST COST	$10,242,000	$12,643,000	$16,906,000	$22,046,000	$27,140,000	$33,366,000
AVG ANN O&M (FROM W/O PROJECT DEPTH)	$270,000	$540,000	$800,000	$1,070,000	$1,340,000	$1,610,000
TOTAL AVG ANN COSTS (W/O IDC)	$10,512,000	$13,183,000	$17,706,000	$23,116,000	$28,480,000	$34,976,000
AVG ANN IDC COSTS	$608,000	$967,000	$1,455,000	$2,568,000	$3,632,000	$5,871,000
TOTAL AVG ANN COSTS	$11,120,000	$14,150,000	$19,161,000	$25,684,000	$32,112,000	$40,847,000
AVG ANN BENEFITS OVER PROJECT LIFE	$12,538,000	$23,476,000	$33,846,000	$43,714,000	$53,223,000	$60,801,000
AVG ANN BENEFITS DURING CONSTRUCTION	$0	$0	$0	$201,000	$248,000	$291,000
TOTAL AVG ANN BENEFITS	$12,538,000	$23,476,000	$33,846,000	$43,915,000	$53,471,000	$61,092,000
BENEFIT-COST RATIO	1.13	1.66	1.77	1.71	1.67	1.50
NET BENEFITS	$1,418,000	$9,326,000	$14,685,000	$18,231,000	$21,359,000	$20,245,000

TABLE 47
OPTION 1 (FULL CHANNEL WIDTH, WITH BECKETT STREET)
ANNUALIZATION OF COSTS AND ECONOMIC OPTIMIZATION
SENSITIVITY: PESSIMISTIC SCENARIO

F:AAC1W

	41 FT	42 FT	43 FT	44 FT	45 FT	46 FT
INITIAL PROJECT COSTS	$76,820,000	$101,910,000	$139,370,000	$195,690,000	$248,480,000	$314,540,000
ASSOC. COSTS	$7,781,000	$9,723,000	$20,247,000	$21,785,000	$23,205,000	$24,590,000
REAL ESTATE	$19,827,000	$19,827,000	$19,827,000	$19,827,000	$19,827,000	$19,827,000
RELOCATIONS	$0	$0	$0	$0	$3,130,000	$5,760,000
NAVIGATION AIDS	$856,000	$856,000	$856,000	$856,000	$856,000	$856,000
PED COSTS	$10,000,000	$10,000,000	$10,000,000	$10,000,000	$10,000,000	$10,000,000
TOTAL FIRST COSTS	$115,284,000	$142,316,000	$190,300,000	$248,158,000	$305,498,000	$375,573,000
CRF, 50 YRS	0.0888400	0.0888400	0.0888400	0.0888400	0.0888400	0.0888400
AVG ANN FIRST COST	$10,242,000	$12,643,000	$16,906,000	$22,046,000	$27,140,000	$33,366,000
AVG ANN O&M (FROM W/O PROJECT DEPTH)	$270,000	$540,000	$800,000	$1,070,000	$1,340,000	$1,610,000
TOTAL AVG ANN COSTS (W/O IDC)	$10,512,000	$13,183,000	$17,706,000	$23,116,000	$28,480,000	$34,976,000
AVG ANN IDC COSTS	$608,000	$967,000	$1,455,000	$2,568,000	$3,632,000	$5,871,000
TOTAL AVG ANN COSTS	$11,120,000	$14,150,000	$19,161,000	$25,684,000	$32,112,000	$40,847,000
AVG ANN BENEFITS OVER PROJECT LIFE	$7,523,000	$14,085,000	$20,307,000	$26,228,000	$31,933,000	$36,481,000
AVG ANN BENEFITS DURING CONSTRUCTION	$0	$0	$0	$121,000	$149,000	$175,000
TOTAL AVG ANN BENEFITS	$7,523,000	$14,085,000	$20,307,000	$26,349,000	$32,082,000	$36,656,000
BENEFIT-COST RATIO	0.68	1.00	1.06	1.03	1.00	0.90
NET BENEFITS	($3,597,000)	($65,000)	$1,146,000	$665,000	($30,000)	($4,191,000)

TABLE 48
FULL WIDTH CHANNEL
BASE YEAR TONNAGE BENEFITS

COMMODITY	CHANNEL DEPTH: 41	42	43	44	45	46
Crude Oil Imports	$6,881,000	$13,422,000	$19,789,000	$25,676,000	$31,445,000	$37,034,000
Coal vessels-Imports	$ 95,000	$176,000	$240,000	$284,000	$ 311,000	$ 321,000
Iron Ore vessels-Imports	$ 94,000	$181,000	$261,000	$325,000	$ 380,000	$ 413,000
SJPC	$1,214,000	$ 1,746,000	$ 2,509,000	$ 3,466,000	$ 3,987,000	$ 3,987,000
Containers	$ 607,000	$ 1,198,000	$ 1,415,000	$ 1,568,000	$ 2,016,000	$ 2,016,000
TOTAL-CUMULATIVE	**$8,891,000**	**$16,723,000**	**$24,214,000**	**$31,319,000**	**$38,139,000**	**$43,771,000**

TABLE 49
OPTION 1 (FULL CHANNEL WIDTH, WITH BECKETT STREET)
ANNUALIZATION OF COSTS AND ECONOMIC OPTIMIZATION
SENSITIVITY: BASE YEAR TONNAGE

F:AAC1W

	41 FT	42 FT	43 FT	44 FT	45 FT	46 FT
INITIAL PROJECT COSTS	$76,820,000	$101,910,000	$139,370,000	$195,690,000	$248,480,000	$314,540,000
ASSOC. COSTS	$7,781,000	$9,723,000	$20,247,000	$21,785,000	$23,205,000	$24,590,000
REAL ESTATE	$19,827,000	$19,827,000	$19,827,000	$19,827,000	$19,827,000	$19,827,000
RELOCATIONS	$0	$0	$0	$0	$3,130,000	$5,760,000
NAVIGATION AIDS	$856,000	$856,000	$856,000	$856,000	$856,000	$856,000
PED COSTS	$10,000,000	$10,000,000	$10,000,000	$10,000,000	$10,000,000	$10,000,000
TOTAL FIRST COSTS	$115,284,000	$142,316,000	$190,300,000	$248,158,000	$305,498,000	$375,573,000
CRF, 50 YRS	0.0888400	0.0888400	0.0888400	0.0888400	0.0888400	0.0888400
AVG ANN FIRST COST	$10,242,000	$12,643,000	$16,906,000	$22,046,000	$27,140,000	$33,366,000
AVG ANN O&M (FROM W/O PROJECT DEPTH)	$270,000	$540,000	$800,000	$1,070,000	$1,340,000	$1,610,000
TOTAL AVG ANN COSTS (W/O IDC)	$10,512,000	$13,183,000	$17,706,000	$23,116,000	$28,480,000	$34,976,000
AVG ANN IDC COSTS	$608,000	$967,000	$1,455,000	$2,568,000	$3,632,000	$5,871,000
TOTAL AVG ANN COSTS	$11,120,000	$14,150,000	$19,161,000	$25,684,000	$32,112,000	$40,847,000
AVG ANN BENEFITS OVER PROJECT LIFE	$8,891,000	$16,723,000	$24,214,000	$31,319,000	$38,139,000	$43,771,000
AVG ANN BENEFITS DURING CONSTRUCTION	$0	$0	$0	$150,000	$184,000	$217,000
TOTAL AVG ANN BENEFITS	$8,891,000	$16,723,000	$24,214,000	$31,469,000	$38,323,000	$43,988,000
BENEFIT-COST RATIO	0.80	1.18	1.26	1.23	1.19	1.08
NET BENEFITS	($2,229,000)	$2,573,000	$5,053,000	$5,785,000	$6,211,000	$3,141,000

TABLE 50
FULL WIDTH CHANNEL
STUDY YEAR TONNAGE BENEFITS

COMMODITY	CHANNEL DEPTH: 41	42	43	44	45	46
Crude Oil Imports	$4,462,000	$ 8,703,000	$12,831,000	$16,648,000	$20,389,000	$24,013,000
Coal vessels-Imports	$ 110,000	$ 203,000	$ 277,000	$ 328,000	$ 359,000	$ 370,000
Iron Ore vessels-Imports	$ 48,000	$ 93,000	$ 134,000	$ 166,000	$ 195,000	$ 212,000
SJPC	$ 347,000	$ 499,000	$ 718,000	$ 992,000	$ 1,141,000	$ 1,141,000
Containers	$ 505,000	$ 997,000	$ 1,178,000	$ 1,305,000	$ 1,679,000	$ 1,679,000
TOTAL-CUMULATIVE	$5,472,000	$10,495,000	$15,138,000	$19,439,000	$23,763,000	$27,415,000

TABLE 51
OPTION 1 (FULL CHANNEL WIDTH, WITH BECKETT STREET)
ANNUALIZATION OF COSTS AND ECONOMIC OPTIMIZATION
SENSITIVITY: STUDY YEAR TONNAGE

F:AAC1W

	41 FT	42 FT	43 FT	44 FT	45 FT	46 FT
INITIAL PROJECT COSTS	$76,820,000	$101,910,000	$139,370,000	$195,690,000	$248,480,000	$314,540,000
ASSOC. COSTS	$7,781,000	$9,723,000	$20,247,000	$21,785,000	$23,205,000	$24,590,000
REAL ESTATE	$19,827,000	$19,827,000	$19,827,000	$19,827,000	$19,827,000	$19,827,000
RELOCATIONS	$0	$0	$0	$0	$3,130,000	$5,760,000
NAVIGATION AIDS	$856,000	$856,000	$856,000	$856,000	$856,000	$856,000
PED COSTS	$10,000,000	$10,000,000	$10,000,000	$10,000,000	$10,000,000	$10,000,000
TOTAL FIRST COSTS	$115,284,000	$142,316,000	$190,300,000	$248,158,000	$305,498,000	$375,573,000
CRF, 50 YRS	0.0888400	0.0888400	0.0888400	0.0888400	0.0888400	0.0888400
AVG ANN FIRST COST	$10,242,000	$12,643,000	$16,906,000	$22,046,000	$27,140,000	$33,366,000
AVG ANN O&M (FROM W/O PROJECT DEPTH)	$270,000	$540,000	$800,000	$1,070,000	$1,340,000	$1,610,000
TOTAL AVG ANN COSTS (W/O IDC)	$10,512,000	$13,183,000	$17,706,000	$23,116,000	$28,480,000	$34,976,000
AVG ANN IDC COSTS	$608,000	$967,000	$1,455,000	$2,568,000	$3,632,000	$5,871,000
TOTAL AVG ANN COSTS	$11,120,000	$14,150,000	$19,161,000	$25,684,000	$32,112,000	$40,847,000
AVG ANN BENEFITS OVER PROJECT LIFE	$5,472,000	$10,495,000	$15,138,000	$19,439,000	$23,763,000	$27,415,000
AVG ANN BENEFITS DURING CONSTRUCTION	$0	$0	$0	$97,000	$119,000	$140,000
TOTAL AVG ANN BENEFITS	$5,472,000	$10,495,000	$15,138,000	$19,536,000	$23,882,000	$27,555,000
BENEFIT-COST RATIO	0.49	0.74	0.79	0.76	0.74	0.67
NET BENEFITS	($5,648,000)	($3,655,000)	($4,023,000)	($6,148,000)	($8,230,000)	($13,292,000)

TABLE 52
FULL WIDTH CHANNEL
BENEFITS WITH AVERAGE SIZED REFINERY CLOSED

COMMODITY	CHANNEL DEPTH: 41	42	43	44	45	46
Crude Oil Imports	$6,167,000	$12,029,000	$17,736,000	$23,012,000	$28,183,000	$33,192,000
Coal vessels-Imports	$ 95,000	$ 176,000	$ 240,000	$ 284,000	$ 311,000	$ 321,000
Iron Ore vessels-Imports	$ 117,000	$ 226,000	$ 326,000	$ 406,000	$ 475,000	$ 517,000
SJPC	$1,546,000	$ 2,223,000	$ 3,195,000	$ 4,414,000	$ 5,077,000	$ 5,077,000
Containers	$ 871,000	$ 1,720,000	$ 2,032,000	$ 2,251,000	$ 2,895,000	$ 2,895,000
TOTAL-CUMULATIVE	**$8,796,000**	**$16,374,000**	**$23,529,000**	**$30,367,000**	**$36,941,000**	**$42,002,000**

TABLE 53

OPTION 1 (FULL CHANNEL WIDTH, WITH BECKETT STREET)
ANNUALIZATION OF COSTS AND ECONOMIC OPTIMIZATION
SENSITIVITY: AVERAGE-SIZED REFINERY CLOSED

F:AAC1W

	41 FT	42 FT	43 FT	44 FT	45 FT	46 FT
INITIAL PROJECT COSTS	$76,820,000	$101,910,000	$139,370,000	$195,690,000	$248,480,000	$314,540,000
ASSOC. COSTS	$7,781,000	$9,723,000	$20,247,000	$21,785,000	$23,205,000	$24,590,000
REAL ESTATE	$19,827,000	$19,827,000	$19,827,000	$19,827,000	$19,827,000	$19,827,000
RELOCATIONS	$0	$0	$0	$0	$3,130,000	$5,760,000
NAVIGATION AIDS	$856,000	$856,000	$856,000	$856,000	$856,000	$856,000
PED COSTS	$10,000,000	$10,000,000	$10,000,000	$10,000,000	$10,000,000	$10,000,000
TOTAL FIRST COSTS	$115,284,000	$142,316,000	$190,300,000	$248,158,000	$305,498,000	$375,573,000
CRF, 50 YRS	0.0888400	0.0888400	0.0888400	0.0888400	0.0888400	0.0888400
AVG ANN FIRST COST	$10,242,000	$12,643,000	$16,906,000	$22,046,000	$27,140,000	$33,366,000
AVG ANN O&M (FROM W/O PROJECT DEPTH)	$270,000	$540,000	$800,000	$1,070,000	$1,340,000	$1,610,000
TOTAL AVG ANN COSTS (W/O IDC)	$10,512,000	$13,183,000	$17,706,000	$23,116,000	$28,480,000	$34,976,000
AVG ANN IDC COSTS	$608,000	$967,000	$1,455,000	$2,568,000	$3,632,000	$5,871,000
TOTAL AVG ANN COSTS	$11,120,000	$14,150,000	$19,161,000	$25,684,000	$32,112,000	$40,847,000
AVG ANN BENEFITS OVER PROJECT LIFE	$8,796,000	$16,374,000	$23,529,000	$30,367,000	$36,941,000	$42,002,000
AVG ANN BENEFITS DURING CONSTRUCTION	$0	$0	$0	$134,000	$165,000	$194,000
TOTAL AVG ANN BENEFITS	$8,796,000	$16,374,000	$23,529,000	$30,501,000	$37,106,000	$42,196,000
BENEFIT-COST RATIO	0.79	1.16	1.23	1.19	1.16	1.03
NET BENEFITS	($2,324,000)	$2,224,000	$4,368,000	$4,817,000	$4,994,000	$1,349,000

TABLE 54
FULL WIDTH CHANNEL
BENEFITS WITH COAL MOVED TO BALTIMORE

COMMODITY	CHANNEL DEPTH: 41	42	43	44	45	46
Crude Oil Imports	$7,401,000	$14,435,000	$21,283,000	$27,615,000	$33,820,000	$39,831,000
Coal vessels-Imports	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0
Iron Ore vessels-Imports	$ 117,000	$ 226,000	$ 326,000	$ 406,000	$ 475,000	$ 517,000
SJPC	$1,546,000	$ 2,223,000	$ 3,195,000	$ 4,414,000	$ 5,077,000	$ 5,077,000
Containers	$ 871,000	$ 1,720,000	$ 2,032,000	$ 2,251,000	$ 2,895,000	$ 2,895,000
TOTAL-CUMULATIVE	$9,935,000	$18,604,000	$26,836,000	$34,686,000	$42,267,000	$48,320,000

TABLE 55
FULL WIDTH CHANNEL OPTIMIZATION WITH COAL

OPTION 1 (FULL CHANNEL WIDTH, WITH BECKETT STREET)
ANNUALIZATION OF COSTS AND ECONOMIC OPTIMIZATION
SENSITIVITY: COAL TO BALTIMORE

F:AAC1W

	41 FT	42 FT	43 FT	44 FT	45 FT	46 FT
INITIAL PROJECT COSTS	$76,820,000	$101,910,000	$139,370,000	$195,690,000	$248,480,000	$314,540,000
ASSOC. COSTS	$7,781,000	$9,723,000	$20,247,000	$21,785,000	$23,205,000	$24,590,000
REAL ESTATE	$19,827,000	$19,827,000	$19,827,000	$19,827,000	$19,827,000	$19,827,000
RELOCATIONS	$0	$0	$0	$0	$3,130,000	$5,760,000
NAVIGATION AIDS	$856,000	$856,000	$856,000	$856,000	$856,000	$856,000
PED COSTS	$10,000,000	$10,000,000	$10,000,000	$10,000,000	$10,000,000	$10,000,000
TOTAL FIRST COSTS	$115,284,000	$142,316,000	$190,300,000	$248,158,000	$305,498,000	$375,573,000
CRF, 50 YRS	0.0888400	0.0888400	0.0888400	0.0888400	0.0888400	0.0888400
AVG ANN FIRST COST	$10,242,000	$12,643,000	$16,906,000	$22,046,000	$27,140,000	$33,366,000
AVG ANN O&M (FROM W/O PROJECT DEPTH)	$270,000	$540,000	$800,000	$1,070,000	$1,340,000	$1,610,000
TOTAL AVG ANN COSTS (W/O IDC)	$10,512,000	$13,183,000	$17,706,000	$23,116,000	$28,480,000	$34,976,000
AVG ANN IDC COSTS	$608,000	$967,000	$1,455,000	$2,568,000	$3,632,000	$5,871,000
TOTAL AVG ANN COSTS	$11,120,000	$14,150,000	$19,161,000	$25,684,000	$32,112,000	$40,847,000
AVG ANN BENEFITS OVER PROJECT LIFE	$9,935,000	$18,604,000	$26,836,000	$34,686,000	$42,267,000	$48,370,000
AVG ANN BENEFITS DURING CONSTRUCTION	$0	$0	$0	$134,000	$165,000	$194,000
TOTAL AVG ANN BENEFITS	$9,935,000	$18,604,000	$26,836,000	$34,820,000	$42,432,000	$48,564,000
BENEFIT-COST RATIO	0.89	1.31	1.40	1.36	1.32	1.19
NET BENEFITS	($1,185,000)	$4,454,000	$7,675,000	$9,136,000	$10,320,000	$7,717,000

TABLE 58
OPTIMIZATION OF OUTBOUND LANE
OPTION #1 vs ASYMMETRIC #2

CHANNEL DEPTH	ANNUAL COSTS ($000'S)			ANNUAL BENEFITS			NET
	#1	#2	DIFF.	#1	#2	DIFF.	
41 FT	11,119	9,805	1,314	10,030	6,272	3,758	2,444
42 FT	14,150	11,056	3,094	18,780	12,231	6,549	3,455
43 FT	19,161	14,109	5,052	27,076	18,030	9,046	3,994
44 FT	25,685	18,090	7,594	35,131	23,486	11,645	4,051
45 FT	32,113	22,450	9,662	42,776	28,631	14,145	4,483*
46 FT	40,847	30,086	10,761	48,874	33,701	15,173	4,412

482. Navigation Practice. Navigation practice has changed considerably since 1954, when the last channel modifications for the Delaware River, Philadelphia to Sea project occurred. Initially vessels did not use the tide and vessel operating drafts were limited to 30 feet, since the 40 foot channel could be effectively maintained to a depth of only 36 feet. At present the channel is fully maintained to a 40 foot depth. Vessels which do not use the tides are loaded up to a depth of 37 feet and by using tides vessel drafts can reach 40 feet. Maximum use of the channel in terms of vessel operating draft now occurs.

483. RIVER DEPTHS. Effective river depths vary as a result of tides and weather conditions. Low tides fall 2 feet or more below the plane of mean low water an average of five times a year and 1 foot or more below the plane of mean low water an average of 34 times a year. The extreme low tides occur in the Delaware River when strong northwest winds prevail for periods of from one to three days. Similar variations in high tide also occur. Tidal variations are monitored by the pilots and transit times adjusted accordingly to assure safe underkeel and overhead clearance. Although no changes in operating practice are anticipated, the level of project outputs is sensitive to navigation practice, as is

demonstrated by the variations in benefits for the alternative plans considered.

495. Shoaling Analysis The shoaling analysis performed for the channel deepening utilized an empirical data base of historic hydrographic surveys and maintenance dredging records in order to estimate the incremental maintenance dredging quantities associated with the considered alternative channel depths and alignments. Detailed analysis of shoaling rates was performed for four of the ranges of the project which together require nearly 90 per cent of the average annual maintenance dredging by volume along less than 10 per cent of the total project by length. The period of record used in the analysis of shoaling with respect to channel deepening included 1969 which is the earliest year with current dredging and disposal practices fully in place through 1985. During this period there were a number of maintenance dredging contracts in which depths greater than the project depth of 40 feet were obtained either through intentional advance maintenance dredging or unintended dredging beyond "pay" depth. The record of depth as a function of time at representative index stations was used to determine characteristic shoaling rates subsequent to dredging. The estimates of potential future shoaling rates within the Philadelphia-to-Sea channel for alternative depths greater than the existing 40 foot depth were based on the actual shoaling characteristics observed in the critical shoaling reaches of the project for dredged depths in excess of 40 feet.

496. The risk and uncertainty associated with the shoaling and maintenance dredging analysis is related to a number of factors, including the natural year-to-year variability of sedimentation rates within the dredged channel of the project, the frequency and depth of maintenance dredging performed in the period of record used in the analysis, and the approach of utilizing an empirical data base rather than a modeling approach. The risk and uncertainty involved in the shoaling rate estimates are potential problems only if the tentatively selected plan is constructed and subsequent shoaling rates are significantly greater than projected. This is considered unlikely based on the amount of data and records evaluated, including advance maintenance. If there is less or no increase in shoaling rate and required maintenance dredging, then actual dredging costs for the Federal government would be less than projected and disposal site usage and costs would also be less, resulting in extended site capacity. Since disposal site area requirements were developed based primarily on initial construction, there is little risk that less disposal area acquisition would be needed due to uncertainty in shoaling projections.

497. Disposal Site Selection. Analyses of existing Federal disposal area capacity indicated that, even assuming dike heights are raised, insufficient capacity exists to maintain the 40 foot channel throughout the study period using the existing sites in the

upper river. Either two new upland disposal sites will be needed for disposal of material from the channel between Philadelphia and Wilmington, or material will have to be transported to downriver sites at increased expense. Enough capacity exists in disposal areas along the lower river to last past the year 2055 if dike raising continues. Based on recent experience, about 10 years would be required to obtain all necessary environmental clearances, complete detailed designs, and prepare the sites for first use. With suburban expansion likely to continue, suitable replacement upland disposal sites will be more difficult to locate and more costly in the future. Any constraint of dike heights will make disposal a more critical problem. Provision of additional sites for the tentatively selected plan will accelerate the acquisition process compared to needs for the existing channel maintenance and minimize the uncertainty of future disposal costs for the existing Federal project as well as the modification, while maximizing the effectiveness of site management and potential for reuse.

498. Sea Level Rise. The National Research Council study (Responding to Changes in Sea Level Engineering Implications, 1987) considers the effects of sea level rise on various coastal and estuarine features including navigation channels. According to this study the present best estimates of local relative sea level changes is 2.0 mm per Year or about 4 inches over 50 Years. This level of change is insufficient to alter the recommended plan.

COORDINATION

499. Coordination has been conducted with various Federal, state, and local agencies from initiation through formulation. More intense coordination was conducted with the various port interests including the Mariners' Advisory Committee, the Delaware River Port Authority, the Delaware River and Bay Authority, and the Joint Executive Committee. Coordination has also been accomplished with project users and potential beneficiaries. Federal and state regulatory agencies were involved in the screening of potential disposal areas and were consulted to asses environmental concerns and views on impacts. A formal public meeting was held during reconnaissance studies and was used along with several newsletters to facilitate public input.

500. A notice of intent to prepare a Draft Environmental Impact Statement (DEIS) was published in the Federal Register on May 4, 1989. A notice of availability for that DEIS was published in the Federal Register on July 13, 1990. Based on comments received on the DEIS it was determined that an amendment was necessary to provide additional information regarding the environmental impacts of the proposed project. Significant issues addressed in that amendment included the chemical characteristics of the sediments proposed for dredging, potential changes in salinity patterns of the Delaware Estuary as a result of channel deepening, potential

impacts to groundwater resources in the project areas, the feasibility of an oil pipeline system to limit the need for a navigation channel within the Delaware River, the impact of rock blasting on fishery resources in the vicinity of Marcus Hook, PA, and an analysis of alternatives to the use of the existing open water disposal site in Delaware Bay. A notice of intent to prepare that DEIS amendment was published in the Federal Register on June 12, 1991. A notice of availability for that amendment was published in the Federal Register on December 6, 1991.

501. Several informational workshops have been held involving members of the Delaware River Estuary Committee and the Water Resource Association of the Delaware River Basin as well as other navigational interests. Correspondence on the staff along with responses to comments on the Draft Report/EIS can be found in Appendix A.

SELECTED PLAN

502. The preceding section summarized plan formulation and identified the best plan to resolve the navigation problems of the study area. The following paragraphs present a description of that plan, including its accomplishments, effects, design, construction, and operation and maintenance aspects.

PROJECT DESCRIPTION

503. The selected plan as shown on Plate 1 consists of a navigation project extending from deep water in the Delaware Bay to the Beckett Street Terminal in Philadelphia Harbor, a distance of about 102.5 miles. The selected plan provides for a full width channel with a 45 foot MLW depth and an allowable dredging overdepth of two feet. The channel side slopes are 3 horizontal to 1 vertical. Channel dimensions below Walt Whitman Bridge are based on a 160,000 D.W.T. tanker with a length of 931 feet, beam of 145 feet, and operating draft of 45 feet. The design vessel for Philadelphia Harbor and Beckett Street Terminal access is a 100,000 D.W.T. dry bulk vessel with a length of 830 feet and beam of 128 feet. The selected channel dimensions allow for navigation practices similar to existing conditions which allow full use of the tide range by inbound vessels. The channel width would range from 400 feet in Philadelphia Harbor to 800 feet from Philadelphia Navy Yard to Bombay Hook and then 1000 feet in the Delaware Bay. The plan includes all appropriate bend widening as well as provision of a two space anchorage of compatible depth at Marcus Hook anchorage. The project also includes utility relocations, aids to navigation, and lands, easements, rights-of-way and disposal areas as required for the initial construction and maintenance of the project. The main channel dimensions are summarized as follows:

Location	Length Miles	Width (feet)
Delaware Bay	44.3	1000
Delaware River, Bombay Hook to Phila. Navy Yard	55.7	800
Phila. Harbor	2.5	400

504. In addition, the plan includes deepening access at a 45' depth to the bulk berths at Beckett Street Terminal in Camden, a public terminal operated by the South Jersey Port Corporation.

505. DREDGED MATERIAL DISPOSAL PLAN. The initial dredging quantity necessary to increase channel depths from the currently authorized 40 foot channel has two components, Federal and non-Federal. The Federal project quantity refers to the channel and anchorage, the non-Federal or associated quantity refers to the berth areas. Quantities are listed in Table 59.

TABLE 57

DISPOSAL QUANTITIES
45 FOOT PLAN

Initial Dredging - cubic yards

Federal Channel	Non-Federal Berth Area	Total
50,100,000	2,423,300	52,523,300

Maintenance Dredging - An additional 756,000 cubic yards per year

506. The disposal plan selected includes use of Site 17-O for initial construction in the upper Delaware River (Reach A), use of site 15D for construction in Reach B, initial construction in Reach C using the Raccoon Island disposal area, use of the Reedy Island North and South Federal sites in Reach D with the remainder going to the Raccoon Island site. Beneficial use of initial dredge material from the bay channel is to occur through wetland/island creation and sand stockpiling for subsequent use by the locals. Dredged material from maintenance would be placed in both Federal and non-Federal sites to minimize dredging and disposal costs for both the present 40' project and additional maintenance with channel deepening. This is the NED plan for dredged material disposal and includes sufficient disposal area capacity by the non-Federal sponsor to fully accommodate initial and maintenance dredging quantities. When required, advanced maintenance dredging of the channel up to 49 feet below mean low water will occur depending on the rate of shoaling. This is a continuation of

existing project maintenance practice since benefits for the proposed deepening are based on maximum utilization of the 45' channel and utilization of high tide stages. Approval for Advance Maintenance was granted by NAD for the Delaware River, Philadelphia to the Sea Project on 19 June 1981. Advance maintenance dredging is needed in critical area to assure maintenance of the proposed depth. The high shoaling areas will continue to be dredged at least every year, where areas of less shoaling will go several years between dredging. In addition, due to dredging inaccuracies up to two feet of overdredging will also continue to occur. The two foot overdepth allowance is standard practice on large dredging projects. An allowance for up to and including a two foot overdepth dredging takes into account dredging inaccuracies. The inclusion of the overdepth quantities in the total project cost provides for a conservative cost estimate.

507. The selected plan requires the acquisition of 3 new upland disposal areas as discussed in the Geotechnical Appendix. Areas 17-0, 15-D, and Raccoon Island will be used for initial and maintenance dredged quantities of the Federal channel. All of the new upland sites have been used in the past as dredged material disposal areas and contain 5 to 15 feet of fine-grained sediment which acts as an impermeable blanket. All of the areas overlie the Potomac-Raritan-Magothy formation. Due to the limited pending time of water and minimum head in the disposal area, as well as the stratigraphy and nature of the sediments beneath the disposal areas, it is improbable that any substantial quantity of water will escape through the foundation into the sole source aquifer. Any water that does not flow directly back into the river through the sluice will reach the river via the shallow surface aquifers that underlie the areas. In addition, the drinking water aquifers of the Potomac-Raritan-Magothy are separated by multiple clay layers as mentioned previously.

PROJECT COSTS

508. Project costs are comprised of initial costs and future operation and maintenance costs as outlined below.

509. INITIAL CONSTRUCTION COSTS. Estimates were prepared for initial dredging of the Federal and Non-Federal associated portions of the recommended plan. Dredging of the Federal and Non-Federal associated portions of the project will be done independently of each other. The estimates assume that Reaches AA (between Beckett Street and Piers 122/124), A, B of the Federal portion of the project will be done by hydraulic dredge and pumping into disposal areas acquired for the project. Due to the long pumping distances, Reaches C, and D will be done by hopper dredges pumping into disposal areas. For Reach E the use of hydraulic dredge and pumping to Wetlands restoration and aquatic sand stockpiling was computed. Cost estimates developed for Reach E takes into account environmental windows that may be encountered during the bottom

dumping portion of the project. The estimates assumed the dredging of the associated portion of the project will be done by a local dredging contractor hauling the dredged material to a private disposal site consistent with long term history of such work and the quantity in the part of all required permits. Cost estimates were also prepared for disposal area preparation. The disposal area work consists of site clearing, raising or building dikes and constructing sluices. All disposal area work will be done prior to initial dredging. The total initial costs for channel improvements from the bay mouth to Philadelphia Harbor are estimated at $245,656,000 dollars excluding LERRD and associated costs. Dredging operations for initial construction would occur over five years and would be separate from maintenance operations for the presently authorized project. The summary of initial first costs is shown in Tables 60 to 61.

510. MAINTENANCE COSTS. Estimates were prepared for maintenance dredging of the recommended plan. The unit costs were developed based on cost data taken from the Maintenance Dredging, Philadelphia to the Sea Project which is currently bid every year. The cost estimates assume that reaches AA, A, and B will be done by hydraulic dredge while reaches C, D, and E will be done by hopper dredge. Disposal area cost estimates were developed to account for the miscellaneous dike raising during the life of the project. Maintenance costs reflect September 1991 price levels. The incremental maintenance costs for the channel deepening project is estimated at $1,340,000 annually. Costs include maintenance dredging for the 50 year project life, and disposal area preparation. The summary of maintenance costs for the 40' existing project and the total after constructed 45' selected plan are shown in Tables 65 and 66.

511. Maintenance of the Federal channel would be a Federal responsibility, and continue to occur on an annual basis. The difference between the two (40' vs 45') would be the net cost of maintenance for the selected plan.

512. DISPOSAL. The three upland disposal sites provided by the non-federal interests for initial construction would be used throughout the 50 year project life for maintenance dredging disposal, along with Federal disposal sites, used for maintenance of the existing 40 foot project plus Reedy Point north and south disposal sites. The proposed aquatic sites in Delaware Bay will be used for initial construction only. Any Federal disposal areas that are used by the Local sponsor must be reimburse on a like for like yearly basis. While ownership and operation would remain with the local sponsor, the decision on site utilization will be retained by the Corps of Engineers via a permanent easement. As part of the final project Local Cooperation Agreement, details will

TABLE 59

DELAWARE RIVER COMPREHENSIVE NAVIGATION STUDY

INITIAL DREDGING
(PRICE LEVEL SEPTEMBER 1991)

		ESTIMATED COST	CONTINGENCY	TOTAL COST
12.-.-.-	DREDGING			
12.0.A.-	MOBILIZATION, DEMOBILIZATION AND PREPARATORY WORK	$10,924,880	$571,293	$11,496,173
12.0.2.-	PIPELINE DREDGING	$91,682,696	$9,435,231	$101,117,927
12.0.3.-	HOPPER DREDGING	$64,113,679	$4,487,257	$68,600,936
12.0.4.-	WETLANDS, PLANTING	$5,200,000	$1,300,000	$6,500,000
12.0.5.-	MECHANICAL DREDGING	$18,043,800	$9,021,900	$27,065,700
	SUBTOTAL, DREDGING	$189,965,055	$24,815,681	$214,780,736
	TOTAL CONSTRUCTION COST	$189,965,055	$24,815,681	$214,780,736
30.-.-.-	PLANNING, ENGINEERING AND DESIGN	$14,900,000	$2,235,000	$17,135,000
31.-.-.-	CONSTRUCTION MANAGEMENT	$6,000,000	$900,000	$6,900,000
	TOTAL PROJECT COSTS	$210,865,055	$27,950,681	$238,815,736
	(ROUNDED)			$238,800,000

TABLE 59

DELAWARE RIVER COMPREHENSIVE NAVIGATION STUDY

INITIAL DISPOSAL AREAS
(PRICE LEVEL SEPTEMBER 1991)

		ESTIMATED COST	CONTINGENCY	TOTAL COST
01.-.-.-	LAND AND DAMAGES			
01.M.-.-	REAL ESTATE RECEIPTS/PAYMENTS	$17,241,000	$2,586,150	$19,827,150
	SUBTOTAL, LANDS AND DAMAGES	$17,241,000	$2,586,150	$19,827,150
12.-.-.-	DREDGING			
12.0.A.-	MOBILIZATION, DEMOBILIZATION AND PREPARATORY WORK	$320,000	$16,000	$336,000
12.0.1.-	DISPOSAL AREAS	$5,849,135	$584,914	$6,434,049
	SUBTOTAL, DREDGING	$6,169,135	$600,914	$6,770,049
	TOTAL CONSTRUCTION COST	$23,090,135	$3,187,064	$26,597,199
30.-.-.-	PLANNING, ENGINEERING AND DESIGN	$1,730,000	$259,500	$1,989,500
31.-.-.-	CONSTRUCTION MANAGEMENT	$800,000	$120,000	$920,000
	TOTAL PROJECT COSTS	$8,699,135	$980,414	$9,679,549
	(ROUNDED)	$8,699,000	$980,000	$9,680,000

TABLE 60

DELAWARE RIVER COMPREHENSIVE NAVIGATION STUDY

UTILITY RELOCATIONS
(PRICE LEVEL SEPTEMBER 1991)

		ESTIMATED COST	CONTINGENCY	TOTAL COST
02.- -.-	RELOCATIONS			
02.3.-	CEMENTERIES, UTILITIES & STRUCTURES, CONSTRUCTION ACTIVITIES			
02.3.A.-	MOBILIZATION, DEMOBILIZATION AND PREPARATORY WORK	$26,750	$6,688	$33,438
02.3.2.-	UTILITIES			
02.3.2.R	PRIMARY POWER LINES	$1,974,150	$493,538	$2,467,688
	SUBTOTAL, RELOCATIONS	$2,000,900	$500,225	$2,501,125
	TOTAL CONSTRUCTION COST	$2,000,900	$500,225	$2,501,125
30 -.-.-	PLANNING, ENGINEERING AND DESIGN	$300,135	$75,033	$375,168
31.-.-.-	CONSTRUCTION MANAGEMENT	$223,300	$26,812	$250,112
	TOTAL PROJECT COSTS	$2,524,335	$602,070	$3,126,405
	(ROUNDED)			$3,126,000

TABLE 61

DELAWARE RIVER COMPREHENSIVE NAVIGATION STUDY – ASSOCIATED COSTS

NAVIGATION AIDS
(PRICE LEVEL SEPTEMBER 1991)

		ESTIMATED COST	CONTINGENCY	TOTAL COST
12.– –.–	DREDGING			
12.0.6.–	NAVIGATION AIDS			
12.06.B	NAVIGATION AIDS	$722,250	$72,225	$794,475
	SUBTOTAL, DREDGING	$722,250	$72,225	$794,475
	TOTAL CONSTRUCTION COST	$722,250	$72,225	$794,475
30.–.–.–	PLANNING, ENGINEERING AND DESIGN	$36,400	$3,640	$40,040
31.–.–.–	CONSTRUCTION MANAGEMENT	$18,200	$2,730	$20,930
	TOTAL PROJECT COSTS	$776,850	$78,595	$855,445
	(ROUNDED)	$777,000	$79,000	$855,000

TABLE 2

DELAWARE RIVER COMPREHENSIVE NAVIGATION STUDY

ASSOCIATED COSTS
(PRICE LEVEL SEPTEMBER 1991)

		ESTIMATED COST	CONTINGENCY	TOTAL COST
02.-.-.-	RELOCATIONS			
	CEMENTERIES, UTILITIES & STRUCTURES,			
02.3.-	CONSTRUCTION ACTIVITIES			
02.3.3.-	STRUCTURES			
02.3.3.5	BULKHEADS	$7,908,700	$1,186,305	$9,095,005
	SUBTOTAL, RELOCATIONS	$7,908,700	$1,186,305	$9,095,005
12.-.-.-	DREDGING			
12.0.A.-	MOBILIZATION, DEMOBILIZATION AND PREPARATORY WORK	$1,177,423	$176,613	$1,354,036
12.0.3.-	HOPPER DREDGING	$8,614,235	$1,292,135	$9,906,370
	SUBTOTAL, DREDGING	$9,791,658	$1,468,749	$11,260,407
	TOTAL CONSTRUCTION COST	$17,700,358	$2,655,054	$20,355,412
30.-.-.-	PLANNING, ENGINEERING AND DESIGN	$1,416,029	$212,404	$1,628,433
31.-.-.-	CONSTRUCTION MANAGEMENT	$1,062,021	$159,303	$1,221,325
	TOTAL PROJECT COSTS	$20,178,408	$3,026,761	$23,205,169
	(ROUNDED)			$23,205,000

TABLE 63

MAINTENANCE DREDGIN 45' FULL WIDT H CHANNEL
(ANN UAL COST)
(PRICE LEV EL SEPTEMBER 1991)

		ESTIMATED COST	CONTINGENC	TOTAL COST
12.-.-.-	DREDGING			
12.0.A.-	MOBILIZATION, DEMOBILIZATION AND PREPARATORY WORK	$1,152,000	$172,800	$1,324,800
12.0.1.-	DISPOSAL AREAS	$505,000	$75,750	$580,750
12.0.2.-	PIPELINE DREDGING	$6,038,800	$897,820	$6,936,620
12.0.3.-	HOPPER DREDGING	$4,419,200	$661,880	$5,081,080
		=========	=======	=========
	SUBTOTAL, DREDGING	$12,115,000	$1,808,250	$13,923,250
		=========	=======	=========
	TOTAL CONSTRUCTION COST	$12,115,000	$1,808,250	$13,923,250
30.-.-.-	PLANNING, ENGINEERING AND DESIGN	$300,000	$45,000	$345,000
31.-.-.-	CONSTRUCTION MANAGEMENT	$150,000	$22,500	$172,500
		=========	=======	=========
	TOTAL PROJECT COSTS	$12,565,000	$1,884,750	$14,440,750
	(ROUNDED)			$14,441,000

TABLE 64

MAINTENANCE DREDGIN EXISTING 40' CHANNEL
(ANN UAL COST)
(PRICE LEV EL SEPTEMBER 1991)

		ESTIMATED COST	CONTINGENC	TOTAL COST
12.-.-.-	DREDGING			
12.0.A.-	MOBILIZATION, DEMOBILIZATION AND PREPARATORY WORK	$1,152,000	$172,800	$1,324,800
12.0.1.-	DISPOSAL AREAS	$415,000	$62,250	$477,250
12.0.2.-	PIPELINE DREDGING	$5,376,000	$802,400	$6,178,400
12.0.3.-	HOPPER DREDGING	$4,006,100	$596,915	$4,603,015
	SUBTOTAL, DREDGING	$10,949,100	$1,634,365	$12,583,465
	TOTAL CONSTRUCTION COST	$10,949,100	$1,634,365	$12,583,465
30.-.-.-	PLANNING, ENGINEERING AND DESIGN	$300,000	$45,000	$345,000
31.-.-.-	CONSTRUCTION MANAGEMENT	$150,000	$22,500	$172,500
	TOTAL PROJECT COSTS			$13,100,965
	(ROUNDED)			$13,101,000

be specified to ensure both the project sponsor and the Federal Government incur equitable costs. Disposal of dredged material from berths would continue to be deposited at private rather than project disposal areas.

513. Real Estate studies involved coordination with the Corps of Engineers, Baltimore District, Real Estate Division (CENAB-RE). Integral to this work effort, as outlined in draft ER 405-1-12 dated January 1991, is the preparation of a Baseline Cost Estimate for Real Estate in M-Cases format and Real Estate Supplement. This involves a detailed accounting of property ownership and acquisition activities of impacted project lands, preparation of a Gross Appraisal, and assessment of LERRD requirements. CENAP-RE Cooperation Agreement (LCA) in cooperation with the local sponsor, study manager., project manager and all other affiliated or concerned agencies. The sponsor has been responsible for providing the pertinent data and information to assist Government personnel in the identification of all property and potentially impacted properties within the study area.

514. Contingencies: The estimated cost for each major subdivision or feature of the recommended project includes an item for "contingencies". The item for "contingencies" is an allowance against some adverse or unanticipated condition not susceptible to exact evaluation from the data at hand but which must be expressed or represented in the cost estimate. The contingency allowances used in the development of the cost estimates for the selected project were estimated as a lump sum or approximate percentage. The contingency allowances used in the cost estimates reflect the following uncertainties and concerns exposed during the feasibility study:

a. Mobilization, Demobilization and Preparatory Work: Contingencies in this line item reflect concerns about availability of dredges and locations of the available dredges. A contingency factor of 5% for dredges and for rock excavation a contingency factor of 15% was used to reflect in addition to the above mentioned concerns, the specialized rock blasting equipment required.

b. Pipeline Dredging: Contingencies for the line item reflect concerns about pumping distances and production rates when dredging new/undisturbed materials. In addition contingencies reflect concerns about the fluctuation of fuel prices, surveys and labor costs. Hence for Reaches AA, A and B a contingency factor of 7% of the initial dredging was used. In addition for Reach E a contingency factor of 15% of the initial dredging was used to reflect the uncertainty that may arise at the proposed disposal site.

c. Hopper Dredging: Contingencies for the line item reflect concerns about pumping distances and production rates when dredging

new/undisturbed materials. In addition environmental windows that may be encountered during the bottom dumping portion of the project. Hence for Reaches C and D a contingency allowance of 7% of the initial dredging was used.

d. Rock Excavation: Contingencies for this line item reflect concerns about the availability of the equipment; drill pattern and depth of drilling; type of material; and instrumentation and monitoring during blasting. A contingency factor of 50% was used for rock excavation.

e. Disposal Areas: Contingencies for this line item reflect the uncertainty whether all disposal areas will be available and ready for the initial construction stages of the project. A contingency factor of 10% was used.

515. Planning, Engineering, and Design: Preconstruction, Engineering and Design (P,E & D) related costs for the Federal portion of the recommended plan during the initial dredging stage were estimated as a lump sum item based on similar Corps of Engineers projects. P,E & D costs include local cooperative agreements, environmental and regulatory activities, design related engineering, general design memorandum, plans and specifications, engineering during construction, A/E liability actions, cost engineering, construction and supply contract award activities and Project management. P,E & D estimated lump sums for Reaches AA, A and B was $1,420,000; for Reaches C and D was $1,610,000; and for Reach E was $1,390,000. P,E & D for the associated portion of the recommended plan during the initial dredging project were estimated at 8% of the direct construction cost.

516. Construction Management. Construction Management (S & A) related costs for the Federal portion of the recommended plan during the initial dredging stage were estimated as a lump sum in the amount of $600,000 based on similar Corps of Engineers projects. S & A costs include contract administration, review of shop drawings, inspection and quality assurance, project office operation, contractor initiated claims and litigations, government initiated claims and litigations, and project management. S & A related costs for the associated portion of the project were estimated at 6% of the direct construction cost.

PROJECT OPERATION

517. The Philadelphia District, Corps of Engineers would maintain the Federal channels and anchorage in accordance with the project dimensions, providing advance maintenance in high shoaling areas as required. Dredging would be performed on an annual basis in the Delaware River and a 5 year cycle in Delaware Bay, similar to existing practice. The Delaware River Port Authority as sponsor would provide and operate the non-Federal disposal areas in

cooperation with the Philadelphia District, Corps of Engineers, in order to maximize the overall efficiency of dredging and disposal operations. Maintenance of navigation aids would continue to be performed by the U.S. Coast Guard.

518. Berth dredging and facility maintenance would be accomplished by each beneficiary facility. Berth dredging is now performed utilizing an existing Department of the Army Permit. Berth material is placed in an upland diked disposal area established by a private dredging concern for this purpose. State and Federal permit conditions in place are designed to minimize water quality effects from dredging, disposal, and bulkhead modifications. The use of hopper dredging will further limit water quality impacts. Deepened berths are all currently at depths of 40 feet and generally dredged on a regular basis; these facts taken together would limit benthic effects. Seasonal dredging restrictions on bucket dredging now occur and studies are being initiated in regards to hydrualic/hopper dredging to better determine what effects if any would occur to anadromous fish passage and finfish spawning/nursery development. Modification of this Departmenet of the Army permit has been handled in a routine manner, therefore based on past experiences no difficulties are anticipated in modifying this permit for 45 foot dredging nor obtaining appropriate state permits. Port facility operations would continue as currently conducted with individual facilities maximizing economic outputs through operations, expansion, or upgrading of facilities in response to economic conditions. The Pilots' Association for the Bay and River Pilot's Association for the Bay and Delaware River will continue to coordinate/monitor traffic in cooperation with the Philadelphia Maritime Exchange.

PLAN ACCOMPLISHMENTS

519. The selected plan would provide net benefits of $11,019,000 to national economic development. The degree to which the selected plan fulfilled planning objectives was evaluated by comparing the impacts of the alternative depths. Those items evaluated include the following:

- Provide Adequate and Safe Navigation Channels. Although there have been no reported damages related to the existing Federal project, the deeper channel, bend widening and anchorage improvements provided by this plan will provide for the safe transit of vessels. These changed improvements will lesson the chances of large oil spills occurring

- Increases the Efficiency of Movement of Waterborne Commerce. The measures provided by this plan would improve the efficiency of

vessel movements by reducing lightering and the need for lightloading, therefore reducing the possibility of oil spill occurring during lightering operations.

- Identify and Evaluate Acceptable Disposal Sites and Techniques. The disposal scheme selected for the plan of improvement represents the most cost effective method of disposal.

- Protection of Finfish and Wildlife Resources. By observing the seasonal restraints for dredging operations impacts to finfish and wildlife resources will be minimized.

PROJECT EFFECTS

520. Project effects can be separated into impacts associated with dredging and impacts associated with dredged material disposal. Impacts related to dredging can include water quality degradation, loss of benthic organisms, disturbance to fishery resources, and impacts to cultural resources.

521. Water quality impacts include increased turbidity, a potential decrease in dissolved oxygen, and release of chemical contaminants into the water column. The first two are localized, short-term impacts that generally do not cause irreversible ecological harm. A sediment testing program was conducted during the summer of 1991 to characterize the chemical quality of sediments in the existing, Philadelphia to the Sea navigation channel. A total of 46 sediment cores were collected in the channel and in channel bend widening locations throughout the project area, and analyzed for a variety of chemical constituents as specified by the U.S. Environmental Protection Agency. Chemical constituents included metals, pesticides, polychlorinated biphenyls (PCB's) and polynuclear aromatic hydrocarbons (PAH's). Sediment samples were analyzed using both bulk and elutriate analysis procedures. PCB's were only detected in one sample at a concentration of 1.72 parts per million (ppm). Pesticides were detected in two samples at concentrations below 1 ppm. PCB's were not detected in any sediment elutriates, while pesticides were detected in only three elutriates at concentrations ranging between 0.0026 and 0.0063 ppm. PAH's were detected in several channel bend locations throughout the project area. Concentrations of PAH's in sediments were low, ranging between less than 1 and 12.23 ppm. PAH's were only detected in one sediment elutriate at a concentration of 0.013 ppm. Metals were found, were widely distributed throughout the project area. While some high readings were observed, the overall metal content of channel sediments was within reasonable limits. Concentrations of metals in sediment elutriates were low throughout the project area. Concentrations of

metals that were found were generally below 0.1 ppm. These test results do not indicate any significant concerns relative to water quality during dredging or dredged material disposal operations. A more detailed discussion of the 1991 sediment testing program is provided in the Environmental Impact Statement Amendment. Testing would be continued throughout the life of the project to identify problems, if they should arise.

522. Another concern related to water quality is the upstream movement of salinity due to a change in channel geometry. To address this concern, the Delaware River Basin Commission (DRBC) employed their Transient Salinity Intrusion Model (TSIM). This model is used extensively by the DRBC for simulation of various scenarios for drought management and reservoir operation planning. For this effort, salinity distribution was modelled for two discrete navigation channel geometries, the existing 40-foot depth and the proposed 45-foot depth. A worst case analysis was run by using the hydrology observed during the 1960's drought of record (1961-1966), estimated depletive water use in 1986, and the current operation of Delaware River Basin reservoirs. Based on the results of the model runs, it is concluded that the predicted changes in Delaware Estuary salinity patterns, from a five-foot deepening of the existing navigation channel, would not result in a perceptible decline in estuarine productivity or adversely impact water supplies in the vicinity of Philadelphia, PA. The predicted upstream movement in salinity would be minor in comparison to yearly fluctuations in salinities resulting from variations in river flow. An average shift in salinities ranging from 250 yards in upper Delaware Bay to 800 yards in the vicinity of Marcus Hook, PA would not be sufficient to effect species distribution or reduce productivity. In the freshwater portion of the estuary, above Marcus Hook, a predicted shift ranging between 800 yards to as much as 1.5 miles could occur. Salinities in this area are too low to impact freshwater organisms. Because of the natural salinity cycle within the estuary, salinities would only intrude further up-river than under existing conditions during October or November, which is the time of year when salinities are highest. Significant biological functions such as spawning, nursery activities, and plant growth do not occur at this time of year. It is also likely that the predicted upstream movement in salinity is exaggerated because the hydrology of the drought of record was used to calculate the change. It is expected that salinity increases would be even less than predicted during normal water years. With respect to water supplies in the vicinity of the Philadelphia-Camden metropolitan area, the main concern is protection of the Potomac-Raritan-Magothy aquifer system in the Camden, NJ area. A maximum 30-day average chloride concentration of 180 mg/l at River Mile 98 is the current standard set for protecting this aquifer system from salinity intrusion. The predicted 30-day average chloride concentrations at River Mile 98 were well below this standard throughout the drought of record. The DRBC has indicated that they plan on lowering this standard to

150 mg/l when additional reservoir storage is available to insure that the standard can be maintained. This more restrictive salinity standard was also met with a deepened channel throughout the drought of record, except in the simulation for November 1964. The 30-day average chloride concentration at River Mile 98 for this month violated the proposed standard by two mg/l. This one violation in a worst case analysis was considered acceptable since this more restrictive standard is dependent on additional reservoir storage, which was not included in this effort. A more detailed discussion of these analyses is provided in the Environmental Impact Statement Amendment.

523. Dredging would also result in the loss of benthic organisms in the immediate path of the dredge. More mobile organisms, such as crabs, can escape the path of the dredge provided that dredging occurs during their active portion of the year. Sessile organisms, such as worms and mollusks, would not be able to leave the dredging area. These organisms would be removed with the sediments and would not be expected to survive. Benthic recolonization does begin to occur shortly after completion of dredging, however, periodic maintenance dredging requirements can continue to disrupt the area. The extent of recolonization subsequent to dredging depends on several factors including the resulting substrate type, the amount of light penetration due to depth and/or turbidity, frequency of dredging, and long-term changes in water quality. The existing navigation channel is currently maintained to a depth of 40 feet at mean low water (mlw) through periodic dredging of shoaling areas. Deepening this channel to 45 feet at mlw would not significantly alter substrate type, light penetration, long-term turbidity levels, or water quality. While initial construction of a 45-foot deep channel would impact benthic organisms in areas that are not now maintained through dredging, these areas would recolonize. Maintenance of the new channel is not expected to impact benthos significantly more than current maintenance dredging operations.

524. Dredging operations can also impact the seasonal migration of anadromous species of fish. Seasonal dredging restrictions have been developed and are employed to minimize impacts to migratory species at appropriate times of the year. No bucket dredging and/or overboard disposal would be conducted during spring and autumn migration. In addition coordination is continuing with the Delaware Basin Fish and Wildlife Management Cooperative over the potential additional requirements.

525. The removal of rock from the channel in the vicinity of Marcus Hook, PA. also has the potential to impact aquatic organisms. Explosive devices would be required to blast this rock out of the channel. Blasting would occur between December and mid-March, which is in accordance with the Delaware Basin Fish and Wildlife Management Cooperative's proposed seasonal restrictions on construction activities in that portion of the river. Blasting at

this time of the year would avoid impacts to spawning, nursery, and migrational periods. Blasting techniques that would be employed to minimize impact to fish would include the use of directional charges that focus the force of the blast down into the rock, the use of appropriately sized charges, and the use of scare charges to clear fish from the impact area prior to detonation.

526. The Potomac-Raritan-Magothy formation contain the most important and productive aquifers in southern New Jersey and is referred to as the regions ole source aquifer. The thickness of the combined formations is as much as 500 feet. Many industries and public water companies in the region obtain groundwater from this formation. There are four major aquifers within the formation. In the vicinity of the projects disposal areas the uppermost aquifer is 50 to 120 feet below the surface, the second ranges from 105 feet to 250 feet, the third from 300 feet to 390 feet, and the lowermost aquifer if 400 feet to 500 feet below the surface. The upper water bearing zone is usually artisan and is separated from the surface sediments by clay beds with a minimum ten-feet thickness in the vicinity of the disposal areas. Communities along the river obtain their water from the basal part of the lower aquifer. Impermeable clay layers separate all of the water bearing zones. There is no potential for intrusion from future disposal through the existing disposal areas sediments and all clay layers of the Potomac-Raritan-Magothy formation.

527. Groundwater flow is generally toward the main river in a typical river basin. However, the groundwater regime in the project area, specially the New Jersey side of the river, has been disturbed by urbanization. The information has been documented in numerous reports. The U.S.G.S. Atlas HA-697 dated 1986 estimates a leakage of 70 MDG from the Delaware River into the Potomac-Raritan-Magothy aquifer system in the project area. A reversal of the natural groundwater flow due to overpumping of the aquifer has occurred. Prior to municipal and industrial pumping, water flow in the aquifer was towards the river. Where large groundwater withdrawals have locally reversed the original aquifer flow patterns, aquifer recharge by river water results. This is due to the face that permeable sand and gravel in the river ar in direct contact with the sediments which comprise the Potomac-Raritan-Magothy system. 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 largely maintained by the pumping rate of private and public wells, any deepening of the channel will not increase the intrusion.

528. Upland disposal areas will be utilized to provide 50 years of capacity for the selected plan 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 river edge, have similar subsurface conditions, contain varied amounts of fine-

grained dredged materia, and overlie the sole source aquifer. A typical area is Pedricktown disposal area. The area is located in the northwestern corner of Oldmans Township, Salem County, approximately 3 miles south the site 15D. The 1000+ acre facility has ben used for disposal of dredged material from the Delaware River since 1960. Presently the original ground ;is overlain by 20 to 40 feet of dredged material. Groundwater, discharge water, river sediment, and dredged slurry, have been tested to determine what effect the operation has on the surrounding area. To date, no detrimental effects have been realized. The new disposal areas will operate in the same manner as Pedricktown and therefore will not become a future source of groundwater contamination.

529. An investigation of New Jersey municipal water supply wells was conducted in the project area. Wells within two miles of the Delaware River channel or the disposal areas were considered. Thirty municipal wells are in operation from Westville Boro south of Pennsville Township. A table containing, total depth, screen depth and length, and aquifer is provided for each will in the Geotechnical Appendix. Of the thirty wells, 25 area screened in the Potomac-Raritan-Magothy formation. The remaining five withdrawal from the shallower Cape May formation, 40' to 60' below the surface. These wells are located in Penns Grove approximately two miles from Pedricktown South disposal area, which will be used for the 45' project maintenance, and currently is being used for the contaminant levels established by EPA and NJDEP in any of the wells, with the exception of high iron and manganese concentrations in the Salem County Wells. Published reports on ground water characteristics of the Potomac-Raritan-Magothy system and analysis of public and private wells in the vicinity of the site indicate high concentrations of iron and manganese. The high concentrations are attributed to natural conditions resulting from geological formations.

530. The selected plan for the Delaware River includes the use of three new upland sites for the disposal of dredged material. These sites have all been previously used in whole or in part for disposal purposes, and are considered disturbed. The use of these sites would result in the initial loss of existing vegetation. Raccoon Island is predominantly vegetated with common reed. Site 15D, in addition to being vegetated with common reed, is planted with corn and soybeans. Loss of this vegetation is not considered significant as it provides low quality wildlife habitat. Site 170 is more diverse with forested, shrubland and oldfield habitats, along with areas dominated by common reed. This site does provide a variety of upland habitat types, but is still considered a disturbed area. Disposal sites typically revegetate between disposal operations. The dominant species is common reed, however, a variety of wetland species can be found in poorly drained wet areas or areas with ponded water. The value of this type of habitat to wildlife is similar to the value of the existing habitat at the selected sites.

531. Based on the analysis done in Delaware Bay, LC 9 (Port Mahon) or C 13 (Alder Cove) were determined to be the NED disposal plans for the disposal of dredged material associated with Lower Liston/Upper Cross Ledge Range. Due to the closeness of the cost comparisons, final selection will await the findings of the PED studies. FR 28/ LC 10 (sand stockpiles off the Kitts Hummock and Pickering Beach) was determined to be the NED disposal plan for the disposal of dredged material associated with the Lower Cross Ledge/Upper Miah Maull Range. If benthic studies, conducted during the PED phase, reveal that significant mitigation is required for sand stockpile areas then beachfill options could become the NED plan. The placement of similar material on ocean and bay beaches in the past has not resoluted in any long-term ecological or aesthetic impacts. Island creation at I 3 (lower Middle Shoal), and wetland restoration at PN 1 (Maurice River Cove area) were determined to be the NED disposal plan for the disposal of dredged material associated with the Lower Miah Maull/Upper Brandywine Range. Again the closeness of the cost comparison will force final selection to wait for the results of the PED studies. Sand stockpiles off of Lewis, Broadkill, and Slaughter Beach (LS, MS 19) were determined to be the NED disposal plan for the disposal of dredged material associated with the Lower Brandywine Range. Final selection of these options will await completion of the detailed benthic studies to be conducted during the PED phase. If the studies reveal that significant mitigation is required for sand stockpile areas then beachfill options could become the NED plan.

532. Impacts to significant cultural resources as a result of implementing the proposed project can occur as a result of either dredging activities or disposal activities. Of the three sites selected for the disposal of dredged material, two are previously used and do not contain cultural resources that would be adversely impacted by the placement of additional fill. The third site, 170, was investigated in 1976 and was found to contain potentially significant prehistoric and historic resources. Further investigation will be necessary to develop measures to avoid or minimize adverse impacts to these resources. Necessary funds to complete data inventory and recovery have been included for PED implementation. Dredging activities have the potential to impact significant historic resources (principally in the form of shipwrecks), primarily as a result of widening the bends at the intersections of some of the ranges, but also as a result of deepening the navigation channel in areas which have been naturally deep and which therefore might contain shipwrecks. Further investigations will be conducted in the next phase of study to address and resolve this issue. Based on the survey information collected to date, the cost of cultural resource mitigation for known sites within project boundaries is $225,000. This cost is for sites identified in the 170 dredged material disposal area. Additional cultural resource surveys are necessary, and will be conducted during the PED phase of planning. It will not be possible to determine the final cultural resource mitigation cost

until completion of this work.Further information can be found in Section 5 of the Environmental Impact Statement.

RELATIONSHIP TO ENVIRONMENTAL STATUTES

533. Preparation of this Final Environmental Imapct Statement has included numerous coordination/scoping meetings with appropriate Federal and State resource agencies. An interagency scoping meeting for preparation of the DEIS was held on June 22, 1989. That meeting was attended by personnel representing the U.S. Fish and Wildlife Service, the U.S. Environmental Protection Agency, the National Marine Fisheries Service, the Delaware River Basin Commission, the State environmental agencies of Pennsylvania, New Jersey and Delaware, and the State Historic Preservation Officers of these States. Scoping for the DEIS amendment included a series of meetings with Regions II and III of the U.S. Environmental Protection Agency, the New Jersey Department of Environmental Protection and Energy, the Delaware Department of Natural Resources and Environmental Control and the Delaware Estuary Program.

534. In accordance with the Fish and Wildlife Coordination Act, a planning aid report and a section 2(b) report were obtained from the U.S. Fish and Wildlife Service. Letters of comment were also obtained from the U.S. Environmental Protection Agency, the National Marine Fisheries Service and the State environmental agencies of Pennsylvania, New Jersey and Delaware. These reports and letters are included in the comment/response section of the main report.

535. Based on the information developed during preparation of this Environmental Impact Statement, and the application of appropriate measures to minimize project impacts, it was determined in accordance with Section 307(c) of the Coastal Zone Management Act of 1972 that the proposed project complies with an will be conducted in a manner that is consistent with the approved Coastal Zone Management Programs of Pennsylvania, New Jersey and Delaware. Letters of concurrence with our statement of Coastal Zone consistency have been provided by the three States, and are included in the comment/response section of the main report.

536. The Philadelphia District of the U.S. Army Corps of Engineers is involved with the on-going Delaware Estuary Program. District personnel serve on the Management Committee and the Science and Technical Advisory Committee (STAC). The District has made project presentations to the Management Committee, the STAC and the Citizens Advisory Committee (CAC). The Delaware Estuary Program is leading towards preparation of a Comprehensive Management Plan to efficiently manage the resources of the Delaware Estuary. While this plan has not yet been prepared, the Corps will remain involved to insure the Corps' activities are consistent and supportive of the program.

537. In order to implement the requirements of Section 404 of the Clean Water Act, an exemption is being sought under Section 404(r) as part of the Congressional authorization process. A Section 404(b)(1) evaluation has been prepared and is included in Appendix B of the main report. This evaluation concludes 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.

538. Table 1-1 provides a list of Federal environmental quality statues applicable to this statement, and their compliance status relative to the current stage of project review. Compliance will be met for all environmental quality protection statutes and environmental review requirements with distribution of this Final Environmental Impact Statement for review and comment. Aside from the approvals discussed above, no other permits or approvals are required for implementation of the proposed plan of improvement.

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

Federal Statues	Proposed Plan
Archaeological and Historical Preservation Act, as amended	Full Compliance
Clean Air Act, as amended	Full Compliance
Clean Water Act of 1977	Full Compliance
Coastal Zone Management Act of 1972, as amended	Full Compliance
Endangered Species Act of 1973, as amended	Full Compliance
Estuary Protection Act	Full Compliance
Federal Water Project Recreation Act, as amended	N/A
Land and Water Conservation Fund Act, as amended	N/A
Fish and Wildlife Coordination Act	Full Compliance
Marine Protection, Research and Sanctuaries Act	Full Compliance
National Historic Preservation Act, as amended	Full Compliance

National Environmental Policy Act, as amended		Full Compliance
Rivers and Harbors Act		Full Compliance
Watershed Protection and Flood Prevention Act		N/A
Wild and Scenic Rivers Act, as amended		N/A
Executive Orders, Memorandum, etc.		
EO 11988	Floodplain Management	Full Compliance
EO 11990	Protection of Wetlands	Full Compliance
EO 12114	Environmental Effects of Major Federal Actions	Full Compliance
Analysis of Impacts on Prime and Unique Farmlands		N/A
<u>State and Local Policies</u>		
Coastal Area Management Amendments 1974		Full Compliance

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

Full - All requirements of the statute, E.O., or other policy and related regulations have been met for this stage of project review.

Partial - Some requirements of the statue, 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 not applicable.

ECONOMIC EVALUATION

539. All costs for the construction, operation and maintenance of the tentatively selected plan are based on a September 1991 price level and 8-3/4 percent discount rate. Operation and maintenance dredging costs were calculated using a project life of 50 years. Benefits were based on projections of existing commodities. A

comparison of project benefits and costs for the selected plan is shown in Table 70.

540. Average Annual Benefits During Construction Period. As part of the selected plan, a smaller "temporary" channel (similar to the Option 2 asymmetric channel) will be constructed to provide access for incoming crude oil vessels to the two Marcus Hook, Pa. refineries prior to the project base year. Benefits will begin to accrue for the last 3 months of construction. Benefits for the two refineries, were reduced to allow for increased operating costs from additional travel time as well as increased tug and pilot costs which will result from the narrower channel to be temporarily provided. The benefits were brought forward to the project base year applying the Single Payment Compound Amount Factor in a comparable manner to the method applied to compute interest during construction for construction costs, and generated an average annual value of $198,000. The other project beneficiaries will not accrue benefits until full project construction is completed.

TABLE 65

COMPARISON OF BENEFITS AND COSTS
FOR SELECTED PLAN

	Delaware River, Philadelphia Harbor to the Sea
Total Project First Cost	$278,293,000
Associated First Cost	$ 23,205,000
Project Economic Cost	$305,498,000
Interest During Construction	$ 40,887,000
Total Investment Costs	$346,385,000
Interest and Amortization	$ 30,773,000
Annual Operations and Maintenance	$ 1,340,000
Total Average Annual Costs	$ 32,113,000
Average Annual Benefits Over Project Life	$ 42,578,000
Average Annual Benefits During Construction Period	$ 198,000
Total Average Annual Benefits	$ 42,776,000
Benefit Cost Ratio	1.33
Net Benefits	$ 10,663,000

COST APPORTIONMENT

541. Public Law 99-662 (Water Resource Development Act of 1986) has established the basis for the Federal and non-Federal sharing of responsibilities in the construction, and operation and maintenance of Federal water resources projects. Under the terms of Public Law 99-662, the non-Federal interests would pay at the outset of construction, 25 percent of the total costs of construction of General Navigation Features (GNF) which consists of

the access channel. In addition, the non-Federal interests are to provide any lands, easements, rights-of-way, relocations and dredged material disposal areas (LERRD) or the costs thereof. The non-Federal sponsor is responsible for the associated costs of the project. The sponsor is also responsible for an additional 10 percent of the cost of GNF, less credit for lands, easements, rights-of-way, relocations and dredged material disposal areas which can be repaid with interest over a period not to exceed 30 years. The sponsor will provide equivalent capacity at his Raccoon Island and 170 disposal sites to offset the dredged disposal quantities placed at the Federally owned Reedy North and South sites. This arrangement will minimize the number of new sites required for initial construction and postpone the need for acquisition by the Federal government of disposal sites for the existing project which remains solely a Federal responsibility.

542. 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 access channel, and navigation aids are a Federal responsibility. Maintenance for associated features is a non-Federal responsibility. Cost sharing arrangements for the selected plan are displayed on Table 66.

543. The ultimate Total project cost, including LERRD is $278,193,000 as shown in the following table. This includes the Federal Channel and Anchorage, Aids to Navigation, Disposal Areas, and Relocation Costs. The Federal government is responsible for 75% of the Federal Channel and Anchorage which together comprise the General Navigation features (GNF). In addition the federal government is solely responsible for 25% of the costs for general navigation features and the full costs of lands, easements, rights-of-way, relocations and dredged material disposal areas (LERRD). In addition 10% of the GNF less credit for LERRD. However, since the LERRD exceeds 10% of the GNF no additional contribution is required. Associated costs are solely a non-Federal responsibility.

TABLE 66

COST SHARING FOR THE SELECTED PLAN
(45 ft. Channel)

PROJECT COSTS	
General Navigation Features: Federal Channel and Anchorage	$244,800,000 (A)
Aids to Navigation	856,000
LERRD (Disposal Area Costs Real Estate & Dike Construction)	29,507,000
LERRD (Relocation Costs)	3,130,000
TOTAL PROJECT COST	278,293,000
ASSOCIATED COSTS	23,205,000

COST SHARING

	FEDERAL COSTS	NON-FEDERAL COSTS	TOTAL
GNF	$183,600,000 (75% x A)	$ 61,200,000 (25% x A)	$244,800,000
Long Term Repayment	$-24,480,000 (-10% x A)	$+24,480,000 (+10% x A)	- -
Navigation Aids	856,000	N/A	856,000
LERRD (Relocation)	N/A	$ 3,130,000	$ 3,130,000
LERRD (Disposal Areas)	N/A	$ 29,507,000	$29,507,000
Credit of LERRD	+24,480,000	-24,480,000	-
ULTIMATE COSTS	$184,456,000	$ 93,837,000	$278,293,000

Note: September 1991 Price Level; Discount Rate = 8 3/4%

LOCAL COOPERATION

544. Federal participation in the proposed project is contingent upon provisions that the project sponsor furnish assurances that they will comply with Section 221 of the River and Flood Control Act (Public Law 91-611) and, prior to construction, enter into a Local Cooperation Agreement as per the Water Resources Act of 1986 (PL 99-662). Items of Local Cooperation to be satisfied by the time of construction include the following:

- Provide and maintain the associated features at local expense and adequate public terminal and transfer facilities open to all on equal terms and such depths from the Federal channel line to and between the wharves at the terminal (berthing areas) as may be required for the accommodation of vessels at the terminal, consistent with the Federal project;

- Provide without cost to the United States of all lands, easements, rights-of-way, and relocation necessary for the construction, and subsequent operation and maintenance of the project including suitable areas, determined by the Chief of Engineers to be required in the general public interest for initial and subsequent disposal of spoil and necessary retaining dikes, bulkheads, and embankments therefore, or the costs of such retaining works.

- Holding and saving the United States free from damages due to the construction or operation and maintenance of the project, except for damages due to the fault or negligence of the United States or its contractors

- Provide to the Federal Government the non-Federal share of all other costs of construction of such project

- Compliance with applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1978 (P.L. 91-646) and implementing regulations.

- Compliance with Section 601 of the Civil Rights Act of 1964 (P.L. 83-352).

545. The Delaware River Port Authority is the agency empowered by law to provide the non-Federal cooperation required for the project.

546. The sponsor is aware of the above requirements. A sample model of the Local Cooperation Agreement was provided to the sponsor in a letter dated October 6, 1989. A letter of intent to enter into such an agreement was provided by the sponsor on November 1, 1991. (Refer to Appendix A).

FINANCIAL ANALYSIS.

547. Based on preliminary information, the deepening of the Delaware River channel would be funded as part of a larger plan supported by the governors and Legislatives of New Jersey and Pennsylvania to improve the overall management of the Delaware River Ports through unification, expanding the role of the Delaware River Port Authority. Port improvements would be financed through a combination of cash on hand, bonds, and user charges. The exact combination to be determined in a manner most advantageous to DRPA, laid on fianacial situation at the time of construction.

PLAN IMPLEMENTATION

548. The steps necessary to complete the selected plan are as follows:

- The Division Engineer issues a public notice announcing study recommendations and the report is sent to the Board of Engineers for Rivers and Harbors.

- The Board reviews the report and comments in response to the notice and sends its recommendations to the Chief of Engineers who solicits review and comment by the Governor and interested Federal and state agencies. The final report will then be forwarded by the Chief of Engineers to the Secretary of the Army.

- The Secretary of the Army will review the report and obtain the views of the Office of Management and Budget (OMB) to determine the relationship of the plan to the programs of the President. Upon approval, the Secretary will then transmit the report to Congress.

- Detailed engineering and design will begin if the review finds the project favorable and the plan of improvement is approved by the Secretary of the Army.

549. Funding for construction will be allocated from the general budget. At that time, the project sponsor will be called upon to satisfy the requirements of local cooperation, including execution of a contract stating the local cooperation requirements and their legal and financial capability to provide them. After all necessary financial requirements and local cooperation items have been met, a construction contract will be awarded and carried to completion.

ENVIRONMENTAL IMPACT STATEMENT

550. The following section contains the Final Environmental Impact Statement.

CONCLUSIONS

551. Currently, the authorized channel dimensions present constraints to the efficient movement of bulk vessels (liquid, dry and scrap). Inadequate depths have caused bulk shippers to rely on costly non-structural alternatives such as lightloading, lightering and waiting for tides. In addition, the upcoming fleet of container vessels now on order, would benefit from a deeper channel. The modification plan selected and presented in this report will reduce the problems of lightloading and lightering which hinder efficient movement of commodities through the project areas while limiting impacts on the environment, and qualifies as the NED plan.

RECOMMENDATIONS

552. I recommend that the existing Federal navigation project for the Delaware River, Philadelphia to the Sea and Delaware River in the vicinity of Camden be improved with such modifications thereof as in the discretion of the Commander, HQUSACE, may be advisable, to include:

- Deepening of the existing Federal channel to a depth of 45 feet MLW to provide for a channel from deep water in Delaware Bay to the Beckett Street Terminal in Philadelphia Harbor.

- Channel widths ranging from 400 feet in Philadelphia Harbor, 800 feet from the Philadelphia Navy Yard to Bombay Hook, Delaware, and then 1000 feet in Delaware Bay.

- Provisions for a two space anchorage at a depth of 45 feet MLW at Marcus Hook Anchorage.

- Deepening to 45 feet MLW the existing access to the bulk berths at Beckett Street Terminal.

- Utility relocations, bend widening, and appropriate navigation aids as required.

553. The first cost to the United States is presently estimated at $184,456,000, with annual operations, maintenance and replacement costs for the United States estimated at $1,340,000.

554. This recommendation is made with the provision that, prior to the commencement of construction, the non-Federal sponsor will comply with all requirements of law concerning non-Federal sponsorship of the project.

555. These recommendations contained herein reflect the information available at this time and current Departmental policies governing formulation of individual projects. They do not reflect program and budgeting priorities inherent in the formulation of a national Civil Works construction program nor the perspective of higher review levels within the Executive Branch. Consequently, the recommendations may be modified before they are transmitted to the Congress as proposals for authorization and implementation funding.

KENNETH H. CLOW
Lieutenant Colonel, Corps of Engineers
Commanding

CENAD-DE (CENAP/Feb 92) (1105-2-10c) 1st End Cotroneo/ss/7088
SUBJECT: Delaware River Comprehensive Navigation Study - Main Channel Deepening Interim Feasibility Report and Environmental Impact Statement

Commander, North Atlantic Division, Corps of Engineers, ATTN: CENAD-PL-F, 90 Church Street, New York, NY 10007-2979 19 February 1992

FOR COMMANDER, Board of Engineers for Rivers and Harbors,
ATTN: (CEBRH-BR/Resident Member), Kingman Building, Fort Belvoir, Virginia 22060-5576

I concur in the District Commander's conclusions and recommendations.

GERALD C. BROWN
Brigadier General, USA
Commanding

FINAL ENVIRONMENTAL IMPACT STATEMENT

D

Final
Environmental Impact Statement
Delaware River
Comprehensive Navigation Study
Main Channel Deepening

The responsible lead agency is the U.S. Army Corps of Engineers, Philadelphia District.

Abstract:
This study evaluates existing conditions affecting waterborne commerce on the Delaware River, and recommends a plan of improvement that is most suited to meeting the needs of current and future users of the Delaware River Ports. Based on economic and environmental analyses, a two way, full-width channel with a depth of 45 feet below mean low water (mlw) was selected as the recommended plan of improvement. From the Beckett Street Terminal located in Camden, New Jersey through Philadelphia Harbor, the 400-500 foot width west side channel, now at a depth of 40 feet below mlw, would be deepened while the east side channel would remain 37 feet deep. Between the Philadelphia Navy Yard and Delaware Bay the existing channel would be deepened for its full 800-foot width. In the bay the full 1,000-foot width channel would be deepened. As part of this plan, the trapezoidal access channel to Beckett Street Terminal's bulk berths would also be deepened. This would modify the Delaware River in the Vicinity of Camden project. The Marcus Hook anchorage would be partially deepened. This plan would provide deeper access to the major import and export facilities along the main channel, including six oil refineries, the Conrail coal and iron ore facilities at Piers 122 and 124, and Beckett Street Terminal in Camden, New Jersey. Alternative channel modifications to the selected plan are channels of various widths, ranging in depth between 41 feet and 46 feet below mean low water, and no action. Candidate upland dredged material disposal sites selected for this project are sites 170, 15D, and Raccoon Island. Existing Federal sites proposed for use are Reedy Point North and South. These sites were found to be suitable from both environmental and economic perspectives. In Delaware Bay, beneficial use options, including wetland restoration, island creation and sand stockpiling for future beach nourishment efforts, are proposed.

In order to implement the requirements of Section 404 of the Clean Water Act, an exemption is being sought under Section 404(r) as part of the Congressional authorization process in lieu of obtaining a Section 401 Water Quality Certificate from the states in which the disposal of dredged material is taking place. A Section 404(b)(1) evaluation has been prepared and is included in the main report. This evaluation concludes that the proposed action would not result in any significant environmental impacts relative to the areas of concern under Section 404.

PLEASE SEND YOUR COMMENTS
TO THE DISTRICT ENGINEER BY:

For further information on
this statement, please contact:
Mr. Jerry J. Pasquale
Environmental Resources Branch
Telephone: (215) 597-6840

U.S. Army Engineer District, Philadelphia
U.S. Custom House, 2nd & Chestnut Streets
Philadelphia, Pennsylvania 19106-2991

Table of Contents

Page

Abstract i

List of Tables v

List of Figures ix

1.0 Summary 1-1
1.1 Major Conclusions and Findings 1-1
1.2 Areas of Controversy 1-2
1.3 Relationship to Environmental Statutes 1-3

2.0 Needs and Objectives of Action 2-1
2.1 Study Authority 2-1
2.2 Study Objectives 2-1
2.3 Existing Project 2-2
2.4 Problems, Needs and Public Concerns 2-9

3.0 Alternatives 3-1
3.1 Plans Eliminated from Further Study 3-1
3.1.1 Main Channel Deepening Delaware River, Philadelphia to the Sea (50 foot alternative) 3-1
3.1.2 Main Channel Deepening Delaware River, Philadelphia to Trenton 3-1
3.1.3 Channel Realignment at the Benjamin Franklin Bridge 3-2
3.1.4 Channel Realignment at Marcus Hook, Pennsylvania 3-2
3.1.5 Anchorage Modification-Delaware River, Philadelphia to the Sea 3-7
3.1.6 Feasibility of an Oil Pipeline System as an Alternative to Channel Deepening 3-8
3.2 No Action 3-10
3.3 Navigation Improvements Considered in Detail 3-11
3.3.1 Option 1. Full Width Two Way Channel Deepening 3-11
3.3.2 Option 2. Minimum Width Asymmetric Channel 3-12
3.3.3 Option 3. More Efficient Asymmetric Channel 3-12
3.4 Alternative Dredged Material Disposal Plans. 3-13
3.4.1 Dredged Material Disposal Plans Screening Analysis 3-13
3.4.2 No Action 3-14
3.4.3 Candidate Dredged Material Disposal Areas Considered in Detail for the Proposed Deepening Project (Reaches A through D) 3-25
3.4.4 An Analysis of Alternatives to the Buoy 10 Disposal Area in Delaware Bay (Reach E) 3-28
3.5 Tentatively Selected Plan 3-76

Table of Contents (Continued)

Page

3.6 Mitigation Measures 3-81
3.7 Comparative Impacts of Alternatives 3-83

4.0 Affected Environment 4-1
4.1 Study Area 4-1
4.1.1 Location 4-1
4.1.2 Socio-economics 4-4
4.2 Physical Resources 4-5
4.2.1 Climate 4-5
4.2.2 Geology 4-5
4.2.3 Groundwater 4-6
4.2.4 Hydrology 4-8
4.2.5 Water Quality 4-10
4.2.6 Sediment Quality 4-16
4.3 Ecological Resources 4-17
4.3.1 Wetlands 4-17
4.3.2 Phytoplankton 4-22
4.3.3 Zooplankton 4-23
4.3.4 Benthic and Planktonic Macroinvertebrate 4-24
4.3.5 Finfish 4-29
4.3.6 Ichthyoplankton 4-38
4.3.7 Wildlife 4-38
4.3.8 Threatened and Endangered Species 4-40
4.4 Cultural Resources 4-41
4.4.1 Paleogeography of the Delaware Valley and Estuary 4-41
4.4.2 Prehistoric Peoples in the Delaware Valley 4-41
4.4.3 Historic Settlement of the Delaware Valley 4-42
4.4.4 Shipping and Shipbuilding 4-44
4.4.5 Navigational Hazards and Improvements 4-45
4.4.6 Cultural Resources Investigations 4-46
4.5 Candidate Dredged Material Disposal Sites 4-47
4.5.1 Ecological Description 4-47
4.5.2 Cultural Resources Description 4-49

5.0 Environmental Effects 5-1
5.1 Effects of Plan Implementation on Environmental Resources 5-1
5.1.1 Groundwater 5-1
5.1.2 Hydrology/Estuarine Salinity Patterns 5-15
5.1.3 Water Quality/Sediment Contamination 5-36
5.1.4 Delaware River and Bay Wetlands and Shallows 5-81
5.1.5 Dredged Material Disposal Sites with Regard to On-Site Wetlands 5-81
5.1.6 Phytoplankton, Zooplankton and Planktonic Macroinvertebrate 5-94

Table of Contents (Continued)

5.1.7 Benthic Macroinvertebrate 5-94
5.1.8 Finfish 5-95
5.1.9 Wildlife 5-100
5.1.10 Threatened and Endangered Species 5-101
5.1.11 Vegetation 5-102
5.1.12 Cultural Resources 5-102
5.2 Socio-economic Effects 5-112
5.3 Mitigation 5-113
5.4 Unavoidable Adverse Environmental Effects 5-115
5.5 Short-term Uses of the Environment and Long-term Productivity 5-116
5.6 Irreversible and Irretrievable Commitments of Resources 5-116
5.7 Cumulative Effect 5-116

6.0 List of Preparers 6-1

7.0 Public Involvement 7-1

8.0 References 8-1

9.0 Index 9-1

List of Tables

Table		Page
1-1	Compliance with Environmental Quality Protection Statutes and Other Environmental Review Requirements	1-6
3-1	Analysis of Realignment of Delaware River Channel, Realignment of Marcus Hook (October 1989 Price Level)	3-7
3-2	Candidate Dredged Material Disposal Sites Considered in Detail	3-15
3-3	Disposal Options for Delaware Bay	3-32
3-4	Cycle 2 - Engineering Screening of Disposal Areas	3-42
3-5	Cycle 3 - Institutional/Environmental Screening	3-55
3-6	Disposal Options for Lower Liston/Upper Cross Ledge Range	3-64
3-7	Disposal Options for Lower Cross Ledge/Upper Miah Maull Range	3-64
3-8	Disposal Options for Lower Miah Maull/Upper Brandy Wine Range	3-65
3-9	Disposal Options for Lower Brandy Wine Range	3-65
3-10	Remaining Disposal Options for Lower Liston/Upper Cross Ledge Range	3-66
3-11	Remaining Disposal Options for Lower Cross Ledge/ Upper Miah Maull Range	3-66
3-12	Remaining Disposal Options for Lower Miah Maull/ Upper Brandy Wine Range	3-67
3-13	Remaining Disposal Options for Lower Brandy Wine Range	3-67
3-14	Cycle 7 Disposal Area Scheme Selection for Lower Liston/Upper Cross Ledge Range	3-70
3-15	Cycle 7 Disposal Area Scheme Selection for Cross Ledge/Upper Miah Maull Range	3-71
3-16	Cycle 7 Disposal Area Scheme Selection for Lower Miah Maull/Upper Brandy Wine Range	3-72
3-17	Cycle 7 Disposal Area Scheme Selection for Lower Brandy Wine Range	3-73

List of Tables (Continued)

3-18 Delaware River Comprehensive Navigation Study Sediment Analysis for Reach E Disposal 3-79

3-19 Comparative Impacts of Alternative Channel Plans 3-84

3-20 Comparative Impacts of Dredged Material Disposal Alternatives 3-85

4-1 Summary of 1988 and 1989 Water Quality Data Collected by the Delaware River Basin Commission for Water Quality Zone 3. 4-11

4-2 Summary of 1988 and 1989 Water Quality Data Collected by the Delaware River Basin Commission for Water Quality Zone 4 4-12

4-3 Summary of 1988 and 1989 Water Quality Data Collected by the Delaware River Basin Commission for Water Quality Zone 5 4-14

4-4 Summary of 1988 and 1989 Water Quality Data Collected by the Delaware River Basin Commission for Water Quality Zone 6 4-15

4-5 Representative Plant Species of Wetland Habitats Within the Study Area 4-18

4-6 Life Histories of Common Finfishes of the Delaware Estuary, with Emphasis on Delaware River Species 4-31

4-7 Estimated Catch in Weight and Value of the Inshore Gill Net Fishery for the State of Delaware During 1981 4-35

5-1 New Jersey Public Water Supply Wells Within Two Miles of Delaware River Channel or Disposal Areas. 5-13

5-2 Location of Maximum Instantaneous Intrusion of 250 mg/l Isochlor with Existing Reservoir Regulation and 1986 Depletive Uses 3-22

5-3 Maximum 30-Day Average Concentration of Isochlor at River Mile 98 with Existing Reservoir Regulation and 1986 Depletive Uses 3-22

5-4 Location of Maximum Instantaneous Intrusion of Specified Isochlors with Existing Reservoir Regulation and 1986 Depletive Uses 3-32

List of Tables (Continued)

5-5 Comparison of Average Upstream Movement of Selected Isochlors with a Deepened Channel for 1962 and 1965 3-35

5-6 Basic Chemical Parameter List for Sediment Quality Analysis 5-45

5-7 Full Chemical Parameter List for Sediment Quality Analysis 5-46

5-8 Chemical Test Results of Sediment Cores Collected in the Existing Delaware River, Philadelphia to the Sea Navigation Channel, Between the Philadelphia Naval Base and Chester, PA. 5-49

5-9 Chemical Test Results of the Sediment Cores Collected in the Existing Delaware River, Philadelphia to the Sea Navigation Channel, in the Vicinity of Marcus Hook, PA. . . 5-50

5-10 Chemical Test Results of Sediment Cores Collected in the Existing Delaware River, Philadelphia to the Sea Navigation Channel, Between Oldmans Point, NJ and the Delaware Memorial Bridge 5-51

5-11 Chemical Test Results of Sediments Cores Collected in the Existing Delaware River, Philadelphia to the Sea Navigation Channel, Between Killcohook and Arnold Point, NJ. 5-52

5-12 Chemical Test Results of Sediment Cores Collected in the Existing Delaware River, Philadelphia to the Sea Navigation Channel, within Delaware Bay 5-53

5-13 Chemical Test Results of Sediment Cores Collected in Channel Bends A through F (Vicinity of Philadelphia Naval Base) of the Existing Delaware River, Philadelphia to the Sea Navigation Channel 5-54

5-14 Chemical Test Results of Sediment Cores Collected in Channel Bend G (Mouth of Sckuylkill River) of the Existing Delaware River, Philadelphia to the Sea Navigation Channel 5-55

5-15 Chemical Test Results of Sediment Cores Collected in Channel Bends H and I (Vicinity of Paulsboro, NJ) of the Existing Delaware River, Philadelphia to the Sea Navigation Channel 5-56

List of Tables (Continued)

5-16 Chemical Test Results of Sediment Cores Collected in Channel Bends J and K (Vicinity of Chester, PA) of the Existing Delaware River, Philadelphia to the Sea Navigation Channel 5-57

5-17 Chemical Test Results of a Sediment Core Collected in Channel Bend L (Vicinity of Racoon Island, NJ) of the Existing Delaware River, Philadelphia to the Sea Navigation Channel 5-58

5-18 Chemical Test Results of Sediment Cores Collected in Channel Bends M, N, and O (Located Between Oldmans Point, NJ and the Delaware Memorial Bridge) of the Existing Delaware River, Philadelphia to the Sea Navigation Channel 5-59

5-19 Chemical Test Results of Sediment Cores Collected in Channel Bends P and Q (Vicinity of Killcohook, NJ) of the Existing Delaware River, Philadelphia to the Sea Navigation Channel 5-60

5-20 Chemical Test Results of Sediment Cores Collected in Channel Bends R, S and T (Located Between the Mouth of the Salem River, NJ and Artificial Island, NJ) of the Existing Delaware River, Philadelphia to the Sea Navigation Channel 5-61

5-21 Chemical Test Results of Sediment Cores Collected in Channel Bends U, V and W (Delaware Bay) of the Existing Delaware River, Philadelphia to the Sea Navigation Channel 5-62

5-22 Grain Size Analyses of Sediment Cores Collected in the Existing Delaware River, Philadelphia to the Sea Navigation Channel 5-63

5-23 Grain Size Analyses of Sediment Cores Collected in Channel Bend Widening Locations, Along the Delaware River, Philadelphia to the Sea Navigation Channel 5-66

5-24 Interim NJDEP Soil Action Levels 5-71

5-25 EPA Sediment Classification Criteria of 1977 5-72

5-26 Previous Work in Delaware River, Philadelphia to the Sea . .5-106

5-27 Potentially Significant Remote Sensing Targets Identified at Proposed Bend Widening Area 5-108

5-28 Channel Areas with Depths of at Least 40 Feet MLW (1909 and 1937 Surveys) 5-110

List of Figures

Figure		Page
2-1	Delaware River Comprehensive Navigation Study Area	2-3
2-2	Delaware River Philadelphia to the Sea Federal Navigation Project	2-5
2-3	Delaware Bay Philadelphia to the Sea Federal Navigation Project	2-6
3-1	Location of Marcus Hook, Chester, and Eddystone Ranges within the Delaware River	3-3
3-2	Location of Bedrock within the Delaware River Navigation Channel	3-4
3-3	Marcus Hook Anchorage and Delaware River Channel Proposed Realignment	3-6
3-4	Existing and Candidate Dredged Material Disposal Sites in the Vicinity of Woodbury, NJ	3-16
3-5	Candidate Dredged Material Disposal Sites in the Vicinity of Marcus Hook, PA	3-17
3-6	Existing and Candidate Dredged Material Disposal Sites in the Vicinity of Marcus Hook, PA	3-18
3-7	Existing and Candidate Dredged Material Disposal Sites in the Vicinity of Killcohook, NJ	3-19
3-8	Existing and Candidate Dredged Material Disposal Sites in the Vicinity of the Chesapeake and Delaware Canal	3-20
3-9	Existing and Candidate Dredged Material Disposal Sites in the Vicinity of Artificial Island, NJ	3-21
3-10	Existing Buoy 10 Disposal Area in Delaware Bay	3-22
3-11	Delaware River Comprehensive Navigation Study, Limits of Reaches A Through E	3-23
3-12	Reach E Study Area Location Map	3-29
3-13	Reach E Study Area Disposal Options - Cycle 4	3-63
3-14	Reach E Study Area Disposal Options - Cycle 5	3-69
3-15	Reach E Study Area Disposal Options - Cycle 7	3-75

List of Figures (Continued)

3-16 Main Channel Deepening Channel Vibracore Locations 3-78

4-1 Delaware River Comprehensive Navigation Study, River Mile Location Map 4-2

4-2 Delaware River Comprehensive Navigation Study, County Map . 4-3

4-3 Location of Oyster Beds within the Delaware Estuary 4-27

5-1 Hydrogeologic Section A - A' Logan Township Region, New Jersey 5-4

5-2 Hydrogeologic Section B -B' Logan Township Region, New Jersey 5-5

5-3 Hydrogeologic Section C - C' Logan Township Region, New Jersey 5-6

5-4 Hydrogeologic Section D - D' Logan Township Region, New Jersey 5-7

5-5 Hydrogeologic Section E -E' Logan Township Region, New Jersey 5-8

5-6 Location of Hydrogeologic Section A, B, C, D, E, Logan Township Region, New Jersey 5-9

5-7 Vicinity Map of the Delaware Estuary 5-16

5-8 Zones of Salinity in the Delaware Estuary 5-17

5-9 Salinity Versus Distance (Statute Miles) in the Delaware Estuary. Data from All Months of the Year and from All Depths 5-18

5-10 Typical Difference in Salinity Variation Over Time for the Upper (Port of Wilmington), Middle (Ship John Light), and Lower (Cape Henlopen) Delaware Estuary 5-19

5-11 Maximum Monthly Intrusion of the 500 mg/l Isochlor within the Delaware Estuary for Existing and Deepened Channel Conditions. Period of Analysis was June 1961 to December 1965 5-27

5-12 Maximum Monthly Intrusion of the 2.5 ppt Isochlor within the Delaware Estuary for Existing and Deepened Channel Conditions. Period of Analysis was June 1961 to December 1965 5-28

List of Figures (Continued)

5-13 Maximum Monthly Intrusion of the 5.0 ppt Isochlor within the Delaware Estuary for Existing and Deepened Channel Conditions. Period of Analysis was June 1961 to December 1965 5-29

5-14 Maximum Monthly Intrusion of the 10.0 ppt Isochlor within the Delaware Estuary for Existing and Deepened Channel Conditions. Period of Analysis was June 1961 to December 1965 5-30

5-15 Maximum Monthly Intrusion of the 15.0 ppt Isochlor within the Delaware Estuary for Existing and Deepened Channel Conditions. Period of Analysis was June 1961 to December 1965 5-31

5-16 Delaware River Sediment Testing Program, Reaches A, B and C 5-37

5-17 Delaware Bay Sediment Testing Program, Reach D 5-38

5-18 Delaware River Sediment Testing Program Channel Sampling Locations 5-40

5-19 Delaware Bay Sediment Testing Program Channel Sampling Locations 5-41

5-20 Delaware River Sediment Testing Program Bend Sampling Locations 5-42

5-21 Delaware Bay Sediment Testing Program Bend Sampling Locations 5-43

5-22 Proposed Dredged Material Disposal Site 15D 5-82

5-23 Existing Raccoon Island Dredged Material Disposal Area . . .5-84

5-24 Proposed Dredged Material Disposal Site 170 5-85

5-25 Existing Reedy Point North and South Dredged Material Disposal Areas 5-87

5-26 Cover Types Mapped by the U. S. Fish and Wildlife Service On Site 15D 5-91

5-27 Cover Types Mapped by the U.S. Fish and Wildlife Service on Site 170 5-92

5-28 Location of Bedrock within the Delaware River Navigation Channel 5-99

1.0 Summary

1.1 Major Conclusions and Findings

The purpose of the Delaware River Comprehensive Navigation Study was to evaluate the existing conditions affecting waterborne commerce on the Delaware River, and to identify feasible modifications that would promote and encourage the efficient, economic and logical development of the Delaware River Ports. The study considered structural and non-structural measures that could be implemented to increase the efficiency of the navigation channel, and dredged material disposal capacity requirements for the 50-year study period. Alternatives were evaluated with regard to potential degradation of the natural and social environments, and adverse impacts to fish and wildlife resources within the study area.

Based on economic and environmental analyses, a two way, full-width channel with a depth of 45 feet below mean low water (mlw) was selected as the recommended plan of improvement. From the Beckett Street Terminal located in Camden, New Jersey through Philadelphia Harbor, the 400-500 foot width west side channel, now at a depth of 40 feet below mlw, would be deepened while the east side channel would remain 37 feet deep. Between the Philadelphia Navy Yard and Delaware Bay the existing channel would be deepened for its full 800-foot width. In the bay the full 1,000-foot width channel would be deepened. As part of this plan, the trapezoidal access channel to Beckett Street Terminal's bulk berths would also be deepened. This would modify the Delaware River in the Vicinity of Camden project. Use of anchorages has been limited in recent years. Only the Marcus Hook anchorage would be partially deepened for safety purposes. The selected plan of improvement also includes widening of channel bends for safety purposes. This plan would provide deeper access to the major import and export facilities along the main channel, including six oil refineries, the Conrail coal and iron ore facilities at Piers 122 and 124, and Beckett Street Terminal in Camden, New Jersey.

An estimated 50,100,000 cubic yards of material would be dredged to deepen the currently authorized 40-foot channel to 45 feet. Three upland sites, 170, 15D, and Raccoon Island, were determined to be most suitable for meeting dredged material disposal capacity requirements associated with construction and maintenance of a deeper channel. These sites are preferred from both environmental and economic perspectives. All three sites have been used for dredged material disposal in the past. Continued use of these areas would not significantly impact the quality of natural resources within the study area. In addition to these sites, two existing upland sites would also be required. These sites are Reedy Point North and Reedy Point South, located at the confluence of the Chesapeake and Delaware Canal and the Delaware River. The existing National Park, Oldmans, Pedricktown North, Pedricktown South, Killcohook, Penns Neck and Artificial Island sites would continue to be used for disposal of material attributed to maintenance of the existing 40-foot project. In Delaware Bay, a variety of beneficial use options have been developed for the disposition of sandy dredged material. These options include wetland restoration, island creation and sand stock piling for future beach nourishment efforts. Final selection of these options will await completion of detailed environmental studies to be conducted during the Preconstruction, Engineering and Design (PED) phase of the Corps' planning process.

Implementation of the recommended plan of improvement would not result in any significant long-term adverse impacts on the environment. Appropriate consideration was given to environmental concerns during plan formulation to avoid environmentally valuable and sensitive habitats. The three sites selected for dredged material disposal operations have been used in the past. These sites are considered disturbed and do not provide high quality habitat value. The construction of replacement habitats to mitigate the loss of wetlands or other aquatic habitat types would not be required. No adverse impacts to significant cultural resources would result from the use of two of the proposed disposal sites, since they are previously used disposal areas. The third site, 170, has been only partially used in the past. Potential adverse impacts to known prehistoric and historic resources in the unused portion of 170 would be avoided or minimized through additional investigations at this site.

Impacts to the aquatic environment, as a result of dredging operations, would be avoided or minimized through the application of appropriate dredging procedures. Established time-of-year dredging restrictions would be employed to avoid significant disturbances to fisheries during important spawning and migratory periods. Appropriate timing would also be applied to avoid impacts during rock removal operations in the Marcus Hook portion of the channel. The chemical testing of channel sediments and groundwater in the vicinity of disposal sites would continue throughout the life of the project to identify any water quality problems before they become significant. Effluent discharged from dredged material disposal sites would also be controlled to minimize the concentration of suspended sediment being discharged back to the river.

Dredging operations have the potential to impact submerged cultural resources, principally in the form of shipwrecks. In order to avoid or minimize any adverse impacts, remote sensing and underwater investigations would be undertaken to locate submerged resources in bend widening areas and naturally deep portions of the navigation channel. Any significant submerged cultural resource identified through these investigations would be avoided where possible, or appropriately mitigated where avoidance is not feasible, in accordance with the requirements of the National Historic Preservation Act.

1.2 Areas of Controversy

Subsequent to coordination of the Draft Environmental Impact Statement (DEIS) it was determined that a DEIS amendment would be required to provide additional information regarding the environmental impacts of the proposed project. Areas of controversy included the chemical characteristics of the sediments that would be dredged and potential water quality impacts, potential changes to salinity patterns of the Delaware Estuary as a result of channel deepening, potential impacts to groundwater resources in the project area, the feasibility of an oil pipeline system to limit the need for a navigation channel within the Delaware River, the impact of rock blasting on fishery resources in the vicinity of Marcus Hook, PA, the occurrence of wetlands in selected upland dredged material disposal sites, and an analysis of alternatives to the use of the existing open water disposal site in Delaware Bay. The DEIS amendment was

comprised of seven sections that addressed each of these issues, as well as a project introduction/alternatives review section and an economic evaluation of the selected plan of improvement. A notice of availability for the DEIS amendment was published in the Federal Register on December 6, 1991. Subsequent to a 45-day public comment period, the information contained in the amendment and the comments received on the DEIS and the amendment were integrated into this Final Environmental Impact Statement.

Additional studies will be conducted during the PED phase of the Corps' planning process to further address the above issues. These studies include a 3-D hydrodynamic model of the estuary to evaluate potential changes in circulation patterns and salinity; more detailed environmental assessments of the selected upland dredged material disposal sites, including wetland delineations; benthic surveys of beneficial use sites in Delaware Bay; sediment bioassays to further address potential sediment toxicity impacts on aquatic organisms, and additional cultural resource investigations in dredging and disposal locations.

The potential for oil spills and concern over the negative environmental impacts involved is very much a public concern. Any oil spill event in the Delaware River must be reported to the National Response Center. Under the National Oil Spill Contingency Plan (NCP), there are National, Regional, and Local Response Teams. The Region III and Region II Emergency Response Teams have jurisdiction in the Delaware River Comprehensive Navigation Study area. The Region III Response Team consists of representatives of the following:

- Environmental Protection Agency
- U.S. Coast Guard
- Department of Agriculture
- Department of Commerce
- Department of Defense
- Department of Energy
- Department of Health and Human Services
- Department of the Interior
- Department of Labor
- Federal Emergency Management Agency
- Commonwealths of Pennsylvania, Virginia, and District of Columbia
- States of Delaware, Maryland, and West Virginia

The Region II Response Team is composed of the same Federal agencies plus the States of New Jersey and New York. Under the Regional Contingency Plan (RCP) in the Delaware River Comprehensive Navigation Study Area the U.S. Coast Guard Captain of the Port, Philadelphia (COTP) is designated as the on scene cleanup coordinator (OSC). The OSC can call upon support for spill clean up from the Atlantic Strike Team (located at Fort Dix, NJ), a specially trained and equipped contingent of NCP's National Strike Team; the Delaware Bay and River Cooperative (DB&RC), a consortium of oil, chemical, and petroleum transportation companies which operate two cleanup vessels and have other kinds of cleanup equipment at their disposal; members of the Regional Response Team; and representatives of the Local Response Team such as the New Jersey State Police and the Philadelphia Fire Department. The Regional Contingency Plan is

updated on a continual basis. It is the Corps' plan to coordinate in detail with both Region II and Region III Response Team during the Preconstruction Engineering and Design phase. This coordination should address any environmental concerns as well as assure that the Regional Contingency Plan will be updated to reflect any changes in current vessel traffic patterns due to a modified project.

Relationship to Environmental Statutes

Preparation of this Final Environmental Impact Statement has included numerous coordination/scoping meetings with appropriate Federal and State resource agencies. An interagency scoping meeting for preparation of the DEIS was held on June 22, 1989. That meeting was attended by personnel representing the U.S. Fish and Wildlife Service, the U.S. Environmental Protection Agency, the National Marine Fisheries Service, the Delaware River Basin Commission, the State environmental agencies of Pennsylvania, New Jersey and Delaware, and the State Historic Preservation Officers of these States. Scoping for the DEIS amendment included a series of meetings with Regions II and III of the U.S. Environmental Protection Agency, the New Jersey Department of Environmental Protection and Energy, the Delaware Department of Natural Resources and Environmental Control and the Delaware Estuary Program.

In accordance with the Fish and Wildlife Coordination Act, a planning aid report and a section 2(b) report were obtained from the U.S. Fish and Wildlife Service. Letters of comment were also obtained from the U.S. Environmental Protection Agency, the National Marine Fisheries Service and the State environmental agencies of Pennsylvania, New Jersey and Delaware. These reports and letters are included in the comment/response section of the main report.

Based on the information developed during preparation of this Environmental Impact Statement, and the application of appropriate measures to minimize project impacts, it was determined in accordance with Section 307(c) of the Coastal Zone Management Act of 1972 that the proposed project complies with an will be conducted in a manner that is consistent with the approved Coastal Zone Management Programs of Pennsylvania, New Jersey and Delaware. Letters of concurrence with our statement of Coastal Zone consistency have been provided by the three States, and are included in the comment/response section of the main report.

The Philadelphia District of the U.S. Army Corps of Engineers is involved with the on-going Delaware Estuary Program. District personnel serve on the Management Committee and the Science and Technical Advisory Committee (STAC). The District has made project presentations to the Management Committee, the STAC and the Citizens Advisory Committee (CAC). The Delaware Estuary Program is leading towards preparation of a Comprehensive Management Plan to efficiently manage the resources of the Delaware Estuary. While this plan has not yet been prepared, the Corps will remain involved to insure that Corps' actvities are consistent and supportive of the program.

Coordination is on-going with the Delaware Basin Fish and Wildlife Management Cooperative with regard to appropriate seasonal dredging restrictions. Previous restrictions precluded bucket dredging and/or overboard disposal in the Delaware River from 1 March through 31 May and from 1 September through 30 November. These restrictions were in place to prevent disruption of anadromous fish migrations through creation of excessive turbidity and decreased dissolved oxygen concentrations. No restrictions were required for hydraulic or hopper dredging with upland disposal. New restrictions are now being employed with regard to bucket dredging, blasting and overboard disposal. Between Delaware Bay and the Delaware Memorial Bridge, bucket dredging, blasting and overboard disposal are restricted from 1 March through 30 June. Between the Delaware Memorial Bridge and the Betsy Ross Bridge, which is above the upstream limit of the proposed project, bucket dredging, blasting and overboard disposal are restricted from 15 March through 31 May and from 1 September through 30 November. With regard to hydraulic dredging, a 3-year study will be initiated in 1992 to consider potential impacts on fishery resources in the Delaware River. The results of this study will be used to evaluate the need for hydraulic dredging restrictions. The need for such restrictions can not be determined at this time. The Corps is providing funding to the Delaware Basin Fish and Wildlife Management Cooperative in support of this work.C

In order to implement the requirements of Section 404 of the Clean Water Act, an exemption is being sought under Section 404(r) as part of the Congressional authorization process. A Section 404(b)(1) evaluation has been prepared and is included in Appendix B of the main report. This evaluation concludes 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.

Table 1-1 provides a list of Federal environmental quality statutes applicable to this statement, and their compliance status relative to the current stage of project review. Compliance will be met for all environmental quality protection statutes and environmental review requirements with distribution of this Final Environmental Impact Statement for review and comment. Aside from the approvals discussed above, no other permits or approvals are required for implementation of the proposed plan of improvement.

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

Federal Statutes	Proposed Plan
Archeological and Historical Preservation Act, as amended	Full Compliance
Clean Air Act, as amended	Full Compliance
Clean Water Act of 1977	Full Compliance
Coastal Zone Management Act of 1972, as amended	Full Compliance
Endangered Species Act of 1973, as amended	Full Compliance
Estuary Protection Act	Full Compliance
Federal Water Project Recreation Act, as amended	N/A
Land and Water Conservation Fund Act, as amended	N/A
Fish and Wildlife Coordination Act	Full Compliance
Marine Protection, Research and Sanctuaries Act	Full Compliance
National Historic Preservation Act, as amended	Full Compliance
National Environmental Policy Act, as amended	Full Compliance
Rivers and Harbors Act	Full Compliance
Watershed Protection and flood Prevention Act	N/A
Wild and Scenic Rivers Act, as amended	N/A

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

Executive Orders, Memorandum, etc.		
EO 11988	Floodplain Management	Full Compliance
EO 11990	Protection of Wetlands	Full Compliance
EO 12114	Environmental Effects of Major Federal Actions	Full Compliance
Analysis of Impacts on Prime and Unique Farmlands		N/A
State and local Policies		
Coastal Area Management Amendment 1974		Full Compliance

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

Full - All requirements of the statute, E.O., or other policy and related regulations have been met for this stage of Project review.

Partial - Some requirements of the statue, 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 not applicable.

2.0 Needs and Objectives of Action

2.1 Study Authority

The Delaware River Comprehensive Navigation Study was authorized by a resolution adopted by the United States House of Representatives, Committee on Public Works, dated December 2, 1970. That resolution requested an evaluation of existing conditions affecting waterborne commerce on the Delaware River from Trenton, New Jersey, to the sea, and the identification of feasible modifications that would promote and encourage the efficient, economic and logical development of the Delaware River port system. The resolution partially reads: "The scope of such review shall encompass investigation of current shipping problems, adequacy of facilities, delays in intermodal transfers, channel dimensions, storage locations and capacities, and other physical aspects affecting waterborne commerce, including the conduct of such model studies as may be necessary to establish an efficient layout of the port complex and the design of navigation facilities." This study also responds to two resolutions adopted by the United States Senate, Committee on Public Works. The first resolution, adopted on March 1, 1954, requested a review of the Delaware River between Philadelphia and the sea, for the purpose of identifying the need for any modification to the existing channel dimensions and anchorage areas. The second resolution, adopted on September 20, 1974, requested development of a regional dredged material disposal plan for the tidal Delaware River, its tributaries, and Delaware Bay.

2.2 Study Objectives

The Delaware River navigation system serves the Middle Atlantic region of the United States by providing a series of navigation channels maintained by the U.S. Army Corps of Engineers. The Delaware River Comprehensive Navigation Study is analyzing the ability of the various channels to respond to the needs of current and future waterborne commerce. An interim feasibility study has been conducted to document the economic, environmental, social, institutional, and engineering feasibility of improving the main Delaware River channel for commercial navigation. The objective of this study is to address and evaluate current problems, such as adequacy of facilities, delays in intermodal transfers, channel dimensions, storage locations and capacities, and other physical factors affecting waterborne commerce on the Delaware River. The goal of the study is to identify an appropriate plan for the efficient use and logical development of the Delaware River port system. In order to accomplish this goal appropriate consideration is given to numerous structural and non-structural measures, with a focus on providing safe and efficient navigation channels.

In addition to the primary objective, the study also addresses the disposal of dredged material. The provision for sufficient dredged material disposal capacity is necessary to insure the viability of the selected plan of improvement throughout the full 50-year project life. The study considers existing dredged material disposal capacity, capacity required to maintain the current project for the 50-year study period, and additional capacity required

to accommodate alterative channel alignments and/or dimensions. All alternatives were evaluated with regard to potential degradation of the natural and social environments, and adverse impacts to fish and wildlife resources within the study area during initial construction of the selected plan, as well as long-term project maintenance.

A critical element in any planning study is plan formulation. Plan formulation is the process used to identify and develop alternative measures to address the problems, needs and opportunities identified within the study area; assess these alternative measures; and ultimately select a recommended plan of improvement. In order to facilitate plan formulation in this study, the following planning objectives were established.

Provide adequate and safe navigation channels and appurtenances to accommodate vessels travelling along the Delaware River for which existing channel dimensions are a problem.

Identify and systematically examine alternatives available for increasing the efficiency of waterborne commerce.

Identify and evaluate acceptable disposal sites and techniques for disposal of material dredged within the study area, such that dredged material disposal capacity is sufficient for initial construction and maintenance requirements during the study period.

Protect fish and wildlife resources in the study area during initial construction and project maintenance.

These planning objectives serve as the basis for plan formulation in this study.

2.3 Existing Project

The project area encompasses the Delaware River estuary from Philadelphia, Pennsylvania to the mouth of Delaware Bay (Figure 2-1). The area extends over 100 river miles, and borders 10 counties in the States of Pennsylvania, 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 fresh water 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, 1988a). Below Wilmington, Delaware, the river broadens into the Delaware Bay. Although 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.

Figure 2-1

Delaware River
Comprehensive Navigation Study Area

PHILADELPHIA DISTRICT, CORPS OF ENGINEERS
DECEMBER 1982

The existing Delaware River, Philadelphia to the sea, Federal navigation project was adopted in 1910 and modified in 1930, '35, '38, '45, '54 and '58 (Figures 2-2 and 2-3). 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 Naval Base to the sea was completed in 1942. The channel from the 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:

Project	Authorized Dimensions
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 5,400,000 cubic yards. Of this amount, the majority of material is removed from the Marcus Hook (34%), Deepwater Point (26%) and New Castle (23%) ranges. The remaining 17 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. Pertinent information

NEW CASTLE COUNTY
DELAWARE COUNTY
PHILADELPHIA COUNTY
P E N N S Y L V A N I A
D E L A W A R E
N E W J E R S E Y
WILMINGTON
CHESTER
MARCUS HOOK
PHILADELPHIA
CAMDEN
NEW CASTLE
PENNSVILLE
PENNSGROVE
PAULSBORO
DELAWARE CITY
ST. GEORGES
PORT PENN
SALEM
GLOUCESTER CO.
NEW CASTLE CO.
KENT CO.
SALEM CO.
CUMBERLAND CO.
Christina River
Twin Del. Memorial Bridges
BULKHEAD BAR R.
DEEPWATER POINT R.
Pea Patch I.
Finns Pt.
Killcohook Dike
Pennsville Dike
Bulkhead Bar Dike
Oldmans Pt. Dike
Marcus Hook Anchorage
Chester Dike
Govt. Installation
See Inset
Hog Island Bar Dike
Phila. Marine
Tinicum Dike
Hog I.
Fort Mifflin
Philadelphia Naval Base
Benjamin Franklin Bridge
Port Richmond Anchorage
Gloucester Anchorage
Hoopel Cove Dike
Walt Whitman Bridge
Reedy Point Bridge
Reedy Pt. Anchorage
Reedy I. Dike
Reedy Island Range
Alloway Cr. Dike
Stony Pt. Dike
Stony Pt.
Breakwater of Sunken Ships
Hope Cr. Dike
Liston Pt.
Bombay Hook Pt.
Arnold Pt.
Liston Range
Baker & Reedy Island Range
New Castle Range
Cherry I. Range
Bellevue R.
Tinicum R.
Mifflin R.
Gravel Hill
Schuylkill River
Delaware River
Appoquinimink River
Smyrna River
Cohansey River
Salem River
Christina River
Chester R.
Ridley Cr.
Darby Cr.
Cobbs Cr.
Pennsylvania Railroad
Pennsylvania Railroad
Conrail
Conrail
Conrail

LEGEND

Channel indicated thus: ═══

NOTE:

Distance in miles below Allegheny Ave., Phila., show along side of channel.

Figure 2-3

Delaware Bay
Philadelphia to the Sea
Federal Navigation Project

REVISED 30 JUNE 1969

SCALE OF MILES
5 0 5 10

U.S. ARMY ENGINEER DISTRICT, PHILA.

pertaining to the location, current use and dredged material disposal capacity of these sites is provided in section 3.4 of this Environmental Impact Statement.

About 250 piers, wharves and docks are located in the port system. Most of these service private facilities along the Delaware River. Public port facilities are located at the cities of Philadelphia, Pennsylvania; Camden, Gloucester and Salem, New Jersey; and Wilmington, Delaware. Several large oil refineries are located along the Delaware River between Philadelphia and Delaware City including Sun, Chevron, Mobil, Texaco, BP, Coastal and Atlantic. These refineries generate the majority of commodity movements on the region's waterways either by receipt of crude oil and refined products or by shipment of petroleum products and chemicals to other facilities in the region or domestic ports. Major dry and liquid bulk facilities are also found along the Delaware River at Wilmington, Delaware; Port Richmond in Northeast Philadelphia; Paulsboro, New Jersey; Greenwhich point in South Philadelphia; and along the Schuylkill River in Philadelphia. The numerous tributaries to the Delaware River support a variety of industries and the waterways are used primarily for delivery of fuel oils and raw materials or shipment of products.

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 Pilot's Association for the Delaware River and Bay. 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 25 years by large tankers to lighter (primarily crude oil) onto barges. Maximum drafts for tankers entering the bay is 55 ft and lightering reduces the tanker's operation drafts to those acceptable for the 40 ft channel. In 1983 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' 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 steel facility at Fairless, 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 C&D 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 pleasure 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 Pilot's Association and Mariner's 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 Pilot's 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 (275,000 + DWT) operate with tug assistance during light traffic situations. Passing/meeting situations are limited at bends depending on vessel and traffic conditions. Traffic keep in touch with the Maritime Exchange.

Vessels with drafts of 37′ or less can safely operate without use of the tides. Vessels with drafts in excess of 37′ 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 outcroppings in the channel. Typical travel times are about 7 1/2 hours upriver, and 12 hours downriver.

2.4 Problems, Needs and Public Concerns

The major problem associated with the existing Delaware River, Philadelphia to the sea, Federal navigation project is an insufficient channel depth to accommodate bulk commodity vessels at design drafts. These commodities, which include crude oil, coal and iron ore, are currently shipped in partially loaded vessels due to draft restrictions.

Existing channel dimensions reduce the economic efficiency of larger ships moving through this major commercial area. Crude and refined oil products are the highest volume commodity in United States freight trade and account for the overwhelming majority of tonnage moved in the Delaware River. The refineries located along the Delaware River account for a significant portion of the refinery capacity of the United States and provide petroleum products throughout the mid-Atlantic states. A large amount of the crude oil that comes to the Delaware River facilities is lightered. Lightering is the transfer of cargo from a large, deep-draft vessel to a smaller vessel or barge to maximize the cargo tonnage carried over a long voyage. Vessels that require a depth greater than 40 feet must transfer a portion of their cargo in Delaware Bay before they can travel upriver. In addition, many of the coal vessels and iron ore vessels are also partially loaded. Provision of a deeper channel would reduce or eliminate inefficient non-structural practices such as lightering and light loading, now employed for restricted vessels. In addition, several users are likely to utilize larger vessels if a deeper channel is provided. A detailed description of the problems, needs and opportunities associated with the existing Philadelphia to the Sea, Federal navigation project is provided in the Problem Identification section of the main report.

A critical element in the development of any navigation study is the disposal of dredged material. Approximately 5.4 million cubic yards of material for the existing 40′ deep channel project are annually dredged from the Delaware River between Philadelphia and the sea. Acquisition of disposal areas for the existing channel is now solely a Federal responsibility. There are seven active upland disposal areas for the Philadelphia to the sea project. Additional dredged material disposal sites will be needed to adequately handle dredged material from the existing Federal project past the year 2020. New disposal areas will be required for new construction and maintenance of a deeper channel. A secondary goal of this study is to upgrade present disposal areas and locate additional sites with sufficient capacity to handle deepening and maintenance dredging operations over the project's full 50-year project life (2005-2055).

Public concerns with regard to the Delaware River and bay include protection of natural resources, specifically wetlands, fisheries and wildlife; air and water quality control; protection of municipal water supplies from salinity and chemical contamination; protection of cultural resources; and enhancement of economic conditions within the Delaware Valley. A current concern with regard to water quality is prevention of oil spills in the river. A rash of major spills in recent years, including spills in the Delaware River, has focused National attention on the safety of oil tankers and the potential for environmental damage.

3.0 Alternatives

This section provides discussions on plans eliminated from further study, the no action plan, navigational improvements considered in detail, and alternative dredged material disposal plans. This information provides the reader with a background on alternatives considered during this study. More detailed discussions of the plan formulation process can be found in the main report. Several comments were received on the Draft Interim Feasibility Report and Draft Environmental Impact Statement pertaining to alternatives. Issues included an analysis of alternatives to the Buoy 10 disposal site in Delaware Bay, a more detailed evaluation of alternative channel alignments in the vicinity of Marcus Hook, PA, and the feasibility of an oil pipeline system as an alternative to channel deepening. In response to these comments supplemental information has been prepared, and is provided in this Final Environmental Impact Statement.

3.1 Plans Eliminated from Further Study

The Delaware River Comprehensive Navigation Study was initiated to address navigation related problems on the Delaware River from Trenton, New Jersey to the sea, and tributaries to the Delaware River that support waterborne commerce (Figure 2-1). Since its inception, this study has been conducted to consider existing limitations of commercial navigation on the main channel of the Delaware River, and potential measures to address navigation problems. These measures have included channel deepening with appropriate bend widening, channel realignments, anchorage modifications, and improvements at tributary projects. The following briefly describes several alternatives that were considered, but eliminated from further study.

3.1.1 Main Channel Deepening - Delaware River, Philadelphia to the Sea (50-foot alternative)

Initial consideration of deepening the existing Delaware River navigation channel from Philadelphia to the sea included alternative depths of 42, 45 and 50 feet below mean low water (mlw). Analyses included calculations of initial dredging quantities, rock excavation, utility relocations, dredged material disposal and increased annual maintenance. Based on net benefits attributable to the three alternative depths, it was concluded that a 50-foot mlw project would not be economically feasible under the conditions occurring at that time. As such, that alternative was eliminated from further study. Additional study of deepening up to 45 feet mlw was found warranted in order to determine an optimum channel depth.

3.1.2 Main Channel Deepening - Delaware River, Philadelphia to Trenton

A study was conducted to determine the feasibility of deepening the Delaware River navigation channel from Philadelphia to Trenton (Figure 2-1). Alternative depths included 42 and 45 feet mlw. An analysis of the existing and potential vessel/commodity movements along this portion of the river identified the U.S.X. Steel Plant at Fairless Hills, Pennsylvania as the only

user that would benefit from deepening the channel. Since navigation improvements to a single, non-public terminal are not in the interest of the Federal government, no further studies were conducted to consider potential modifications of the Delaware River, Philadelphia to Trenton project.

3.1.3 Channel Realignment at the Benjamin Franklin Bridge

The existing Delaware River navigation channel passes underneath the Benjamin Franklin Bridge close to the west abutment (Figure 2-2). This alignment provides a minimum vertical clearance of 129 feet mean high water (mhw), which is the lowest clearance of any bridge between Trenton and the sea. Other bridges provide clearance of 135 feet mhw and greater. According to representatives of the Delaware River Pilots Association and the Mariners Advisory Committee, this clearance constraint is a safety concern and results in inefficient vessel operations. These inefficiencies were reported to include the cost of disassembling mast-mounted equipment, delays due to tidal conditions, ballasting requirements and the use of smaller vessels than desired. Realigning the channel to pass under the center of the bridge would provide a minimum clearance of 135 feet mhw. Benefit/cost analyses determined that this realignment would be economically justified for the existing channel depth of 40 feet mlw. However, only the U.S.X. Steel Plant in Fairless Hills, Pennsylvania would benefit from this modification. Again, Federal participation is not warranted when the improvement would serve a single user firm or individual, with no additional user identified for the future. Therefore, studies of this alternative were terminated.

3.1.4 Channel Realignment at Marcus Hook, Pennsylvania

The Delaware River, Comprehensive Navigation Study, Main Channel Deepening project included consideration of alternative channel alignments through the Marcus Hook, Chester and Eddystone Ranges (Figure 3-1). The difficulty in this portion of the river is that the existing channel is underlain by numerous rock outcroppings that would need to be removed to deepen the channel. Realignment of the channel from the Pennsylvania side of the river to the New Jersey side would avoid, to a large degree, the rock outcroppings, but would require a significant increase in dredging due to the shallow nature of this section of the river and proximity of present shoreline. Factors considered in the evaluation of these two alternatives included cost, the value of riverine habitats that would be impacted, and impacts to biota during construction. Deepening the existing channel from 40 feet at mean low water (mlw) to 45 feet at mlw through the Marcus Hook, Chester and Eddystone Ranges would require removal of an estimated 5,222,000 cubic yards (cy) of sediment and 45,100 cy of rock. Figure 3-2 provides the location of bedrock relative to the existing channel bottom. As can be seen in Figure 3-2, this rock currently lies beneath the channel and is not situated such that it provides ledges or shelves that would provide attractive cryptic habitat for fish. Removal of this rock would require detonation of explosive charges within the river. Blasting could occur between December and mid-March, which is in accordance with the Delaware Basin Fish and Wildlife Management Cooperative's proposed seasonal restrictions on construction activities in that portion of the river. Blasting at this time of the year would avoid impacts to spawning, nursery and migrational periods.

Figure 3-1 Location of Marcus Hook, Chester, and Eddystone Ranges Within the Delaware River.

Figure 3-2 Location of Bedrock within the Delaware River Navigation Channel in the Vicinity of Marcus Hook

(From Duran, 1986)

Blasting techniques that would be employed to minimize impact to fish would include the use of directional charges that focus the force of the blast down into the rock, the use of appropriately sized charges, and the use of scare charges to clear fish from the impact area prior to detonation.

Realignment of the channel from the Pennsylvania side of the river to the New Jersey side would require removal of approximately 8,831,000 cy of sediment and no rock. Based on the location of the rock, the necessary offset also includes realignment of the Marcus Hook Anchorage. Figure 3-3 shows that alignment of the existing channel and anchorage, the alternative channel and anchorage alignment to avoid rock removal, and the currently undisturbed area that would be dredged in conjunction with this alternative. The alternative alignment was designed to meet Corps' safety criteria relative to navigation channels and anchorages. As such, it is not possible to shift these features back towards the Pennsylvania side of the river, or reduce the size of these features and avoid the rock without compromising on safety.

The currently undisturbed area that would be dredged with channel realignment is estimated to be approximately 500 acres in size. The majority of this area is shallow water habitat ranging in depth from 1 to 15 feet deep at mlw (Figure 3-1). Tyrawski (1979) reported the results of a variety of fish sampling efforts conducted during the 1970's in shallow waters within this reach of the river. A variety of species were collected including silvery minnow, blueback herring, mummichog, banded killifish, tidewater silverside, satinfin shiner, cyprinids, alewife, white perch, bluegill, white crappie, black crappie, large-mouth bass, brown bullhead, gizzard shad, spot, Atlantic menhaden, American shad, Atlantic croaker, bluefish and striped bass. Ichthyoplankton sampling conducted in the mid-1970's identified the presence of larval herrings, minnows, killifishes, temperate basses, sunfishes and carp (Tyrawski, 1979). More recent sampling has identified the presence of striped bass eggs and larvae within this section of the river, as well as Oldmans Creek and Raccoon Creek (Versar, 1988).

Construction of the alternative channel alignment would also result in the loss of Excelsior Bar and a portion of Chester Island. These emergent areas provide valuable resting and feeding habitat for Canada geese and ducks, and overwintering habitat for Ruddy duck and scaup (National Park Service, 1988). This area is immediately upstream of Raccoon Creek, which has been targeted as a focus area for waterfowl habitat protection under the North American Waterfowl Management Plan.

The cost of rock excavation ranges from thirty to fifty times higher than sediment excavation, depending upon the dredging technique employed. Based on the quantities of rock and sediment that would be removed for each alternative, it was determined that even with the higher cost associated with rock removal, deepening the channel along the existing alignment is the least expensive alternative. Table 3-1 provides the quantities and construction costs associated with each alternative, based on October 1989 price levels. This table indicates that deepening along the existing channel alignment would result in a net savings in average annual costs of $546,000 over the channel realignment scheme.

MARCUS HOOK RANGE
LEDGE ROCK
LEDGE ROCK
LEDGE ROCK
BELLEVUE RANGE
DELAWARE RIVER CHANNEL
MARCUS HOOK ANCHORAGE
13850 x 2300 x 40
#1
#2
match line
currently undisturbed portion of river
LEDGE ROCK
LEDGE ROCK
LEDGE ROCK
CHESTER RANGE
EDDYSTONE RANGE
LEDGE ROCK
#1
#2
match line
currently undisturbed portion of river
TINICUM RANGE
DELAWARE RIVER CHANNEL
EXISTING CHANNEL AND ANCHORAGE
PROPOSED CHANNEL AND ANCHORAGE REALIGNMENT
DELAWARE RIVER COMPREHENSIVE NAVIGATION STUDY
MARCUS HOOK ANCHORAGE & DELAWARE RIVER CHANNEL PROPOSED REALIGNMENT

Figure 3-3

Table 3-1. Analysis of Realignment of Delaware River Channel, Realignment of Marcus Hook (October 1989 Price Level)

	Existing Alignment	Realigned Channel
Quantities of Material for 45' channel		
sediment (cy)	5,222,000	8,831,000
rock (cy)	45,100	0
Project costs ($ thousands)		
Project First Cost	$ 23,485	$ 28,061
Amortized First Cost	2,067	2,460
Operations and Maintenance	8,405	8,558
Total Average Annual Cost	$ 10,472	$ 11,018

In conclusion, considering the habitat types associated with the alternative channel alignments, the importance of these habitat types to fish and wildlife resources, and construction costs, channel deepening along the existing alignment is environmentally and economically preferred. In addition, use of appropriate blasting techniques and time of year restrictions can allow blasting activity to occur within the river with minimal impact on fishery resources. As such, channel deepening along the existing alignment is the selected plan of improvement.

3.1.5 Anchorage Modification - Delaware River, Philadelphia to the Sea

A series of six Federally authorized anchorages and 13 naturally deep, U. S. Coast Guard designated anchorages adjoin the Delaware River channel between Philadelphia and Delaware Bay. Included are general and special purpose anchorages, such as those for explosives, quarantine and Naval use. These anchorages are generally used to avoid accidents during foul weather and poor visibility; during lightering, bunkering or repairs; or while waiting for berth space or favorable tidal conditions. The Big Stone Beach anchorage, located in Delaware Bay, is most commonly used by tankers for lightering operations. The next most heavily used anchorages are located at Marcus Hook and Mantua Creek. These anchorages are primarily used by tankers preparing to dock at a refinery and large dry bulk vessels.

Investigations were conducted to identify anchorage modifications that would improve commercial navigation on the river. An analysis of U. S. Coast Guard records indicated that anchorages were empty a significant percentage of the time, and that there were no existing problems to address. The analysis concluded that for safety purposes, if the main channel were deepened, a portion of the Marcus Hook anchorage should be modified to provide a compatible depth. Modifications to the Marcus Hook Anchorage are needed to continue safe vessel docking practices.

3.1.6 Feasibility of an Oil Pipeline System as an Alternative to Channel Deepening

A question was raised by EPA over the need to document an evaluation of construction of a crude oil pipeline that could extend from Delaware Bay to the refineries as an alternative to channel deepening. Also to be considered was an analysis of a reduced length pipeline from Marcus Hook to the remaining refineries. In response, the following was prepared.

A pipeline terminal in Delaware Bay would require continued use of larger tankers for transatlantic travel. Earlier Deepwater Port studies for Delaware Bay all predicted more imported oil and greater use of larger tankers than now thought reasonable. Delaware River tanker traffic would be reduced with construction of a crude oil pipeline but not eliminated since outbound chemicals and refined products will still need to travel by water.

Big Stone Beach Anchorage Terminal, Delaware Bay An oil terminal and pipeline option from this location to the refineries was analyzed in detail as part of the North Atlantic Coast Deepwater Port Study done in the early 1970's. The Corps concluded at that time that net benefits were marginal and potential ecological and social costs to the coastal zone were considerable. Without a project sponsor no recommendation for future studies was made. A group of oil companies subsequently hired the University of Delaware to evaluate a multi-component artificial island port located here. While no formal recommendations were made interest was developed.

An updated analysis of an island terminal facility located in the lower Delaware Bay off Big Stone Beach Anchorage was reanalyzed for the Corps in 1984. Designed like the main channel deepening to handle coal and iron ore as well as crude oil benefits could only offset 60% of the high construction cost of $ 1.4 billion, assuming present commodity levels. Attempts to find an interested project sponsor for this alternative were unsuccessful. Reducing the size and providing only for a crude oil facility was less viable economically. The State of Delaware was opposed to this alternative due to the ecological and secondary development effects expected.

The environmental effects of constructing an oil pipeline are expected to be high. Even with maximizing use of existing rights-of-ways there would be sizable wetland and terrestrial impacts. The opposition on environmental grounds to a recent product pipeline proposal from the Delaware City Terminal to an existing pipeline at Marcus Hook was considerable. The potential for spills and long-term leakage into the groundwater were both raised.

Other Locations in Delaware Bay, Reach E One other location off the mouth of the Maurice River on the New Jersey side of the bay was evaluated in detail as part of the Deepwater Port Study. This site was dismissed due to greater dredging quantities and higher costs than would occur with the Big Stone Beach site plus the resulting ecological impacts of terminal location in a more productive area, including oyster habitats.

There are no other locations in the bay for a pipeline terminal that could be developed without at least double the amount of terminal dredging. The impacts of pipeline construction and operation would, like a pipeline with a terminal at Big Stone Beach, be considerable, although the amount of wetlands impact might be less for a terminal off the Maurice River.

Locations in Lower Delaware River, Reach D Reach D extends from Bombay Hook to the Chesapeake and Delaware Canal. There are no locations found where a pipeline terminal facility could be developed without considerable berth dredging. Massive terminal dredging (over 10 million cubic yards) would be necessary in addition to the 15 to 22 million cubic yards of river channel dredging needed to provide a 45-foot channel somewhere in this reach. This added cost would, coupled with the economic and ecological costs of a 60 mile pipeline, make this option uneconomical. The loss in commercial fishery (finfish and shellfish) would be an additional negative factor. The effect on the oyster industry would likely be devastating.

Locations in the Lower Middle Delaware River, Reach C Like a terminal in reach D, dredged quantities would be substantial. Combined channel and berth yardage could range between 35 and 40 million cubic yards for initial dredging, even with the use of the Texaco terminal channel. This is 70 to 80% of the dredging quantities of deepening the entire channel. A channel only deepened to here would exclude coal, iron ore, and other cargoes that account for 20% of the benefits of main channel deepening. Coupled with the added cost of operating the pipeline is the additional maintenance dredging associated with locating in this heavily shoaled area. This option appears less economically viable than channel deepening. Also there does not appear to be an environmental benefit from a terminal here and a 20 mile pipeline.

Marcus Hook Terminal, Reach B A terminal located here would serve the four remaining upstream terminals by providing a 15 mile pipeline. The least costly plan would likely involve modifying the Marcus Hook Anchorage. Initial dredging yardage for the channel deepening and terminal facility could be about 5 million cubic yards less than full channel deepening. The overall dredging savings might be less since some channel realignment into rock outcrops would probably be necessary. The amount of annual maintenance will be even greater than the full length channel deepening since Marcus Hook is the most heavily shoaling segment in the river. The minimal reduction in initial yardage also assumes no compensation for lost anchorage capacity and minimal resultant reduction in safety. Other commodities, which account for 20% of the project benefits, could also not benefit from this scheme.

The need to expand the anchorage by even one or two of the three berthing areas required for a terminal would require destruction of shallows and probably freshwater wetlands that border the anchorage.

Other Locations in the Middle Delaware River, Reach B and Locations in the Upper Delaware River, Reach A There are no locations within these two reaches that appear better than the Marcus Hook location. Elsewhere, dredged yardages are likely to increase to 50 million cubic yards. This approximates the amount of dredging required to deepen the entire channel length and would result since partial use of an existing anchorage at alternate locations is not possible.

An evaluation of a crude oil pipeline alternative has identified no alterative that appears to even approach the overall viability of full channel deepening.

3.2 No Action

The no action plan would entail continued maintenance of the currently authorized Delaware River, Philadelphia to the sea, Federal navigation channel (Figures 2-2 and 2-3). This project, last modified in 1958, provides a 40-foot deep mlw channel from Allegheny Avenue in Philadelphia, Pennsylvania to deep water in Delaware Bay. Channel widths vary within the river. Through Philadelphia Harbor, an asymmetric channel is 40 feet deep and between 400 and 500 feet wide on the west side of the river, and 37 feet deep and between 500 and 600 feet wide on the east side of the river. From Philadelphia Harbor to Bombay Hook in Delaware Bay, the channel is 800 feet wide. The channel increases to 1,000 feet wide in Delaware Bay. There are 19 designated anchorages of which 13 occur in naturally deep water. The project requires average annual maintenance dredging of 5,400,000 cubic yards of material. Dredged material is placed in seven Federally operated, upland dredged material disposal areas located along the New Jersey side of the river, and an open water site located in Delaware Bay.

While separate inbound and outbound lanes are provided with the existing channel, vessels generally navigate the center of the channel, except when in a passing situation. Vessels with drafts up to 37 feet can navigate the channel without consideration of tidal stage. Vessels with drafts between 37 and 40 feet navigate the channel by using the tides. Inbound vessels generally leave the pilot transfer area at the mouth of Delaware Bay 2.5 hours before high tide. This provides sufficient time for vessels to pass the rock ledge at Marcus Hook with the water level at least three feet above local mean low water. This allows a minimum of three feet of underkeel clearance and provides enough time to dock before the current changes after high tide. Overall trip time for inbound vessels is 7.5 hours. Loaded outbound vessels leave Philadelphia two hours before high tide to clear Marcus Hook with maximum clearance. By the time low tide occurs, the ship has travelled to naturally deep water in the upper bay. Ships then wait for a rising tide to finish the trip, taking a total of 10.5 hours. Vessel speeds are adjusted to limit squat to about two feet on inbound trips and one foot on outbound trips.

Without implementation of the proposed improvements to the Delaware River Philadelphia to the sea navigation channel, the maximum draft of vessels transitting the river would be limited to the draft now accommodated. Existing channel dimensions restrict the efficiency of bulk commodity vessels calling at Delaware River Ports. A significant percentage of

tankers and dry bulk carriers are currently forced to employ non-structural practices such as lightering and light loading to transport their commodities to the Delaware River Valley. These practices increase transportation costs, which reduces the economic viability of the operations. In addition, inefficient channel conditions hinder the ability of Delaware River ports to compete for waterborne commerce with other East Coast ports.

3.3 Navigational Improvements Considered in Detail

Plan formulation has focused on three alternatives for deepening the existing Delaware River navigation channel between Philadelphia Harbor, Pennsylvania, and the mouth of Delaware Bay. These alternatives include deepening the entire width of the existing channel and two asymmetric channel designs that would deepen various widths of the inbound lane, based on different sets of design criteria. Each alternative was evaluated for deepening in one-foot increments between 41 and 46 feet mean low water (mlw). Each alternative depth includes two feet of overdepth dredging, which has been a common practice in maintaining the existing Delaware River navigation channel. Overdepth dredging provides the Contractor with a reasonable tolerance level to accomplish the job, considering the inaccuracies associated with the dredging process. The existing channel alignment has 16 bends between Delaware Bay and Philadelphia Harbor. Each of the three alternative channel schemes would require widening of channel bends to safely facilitate turning of larger vessels in accordance with Corps design criteria. The width required at each bend is dependent upon the angle of the turn, and the beam, length and maneuverability of the design vessel.

The following provides a description of each alternative channel scheme.

3.3.1 OPTION 1. Full-Width, Two Way Channel Deepening.

This option would provide deeper access to the major import and export facilities along the main channel, including six oil refineries, the Conrail coal and ore facilities at Piers 122 and 124, and Beckett Street Terminal in Camden, New Jersey.

Channel Dimensions. From the Beckett Street Terminal located in Camden, New Jersey through Philadelphia Harbor, the 400-500 foot width west side channel, now at a 40 foot depth mlw, would be deepened while the east side channel would remain at a 37 foot depth. This slightly narrower channel is sufficient since only coal and ore ships and some containers, which all have a narrower beam than crude oil tankers, would continue to use this channel segment. Between the Philadelphia Navy Yard and Delaware Bay the existing channel would be deepened for its full 800-foot width. In the bay, the full 1,000-foot channel would be deepened. The Marcus Hook anchorage would be partially deepened for safety purposes to provide a depth compatible with the proposed channel. As part of this plan the trapezoidal access channel to Beckett Street Terminal's bulk berths would also be deepened. This would modify the Delaware River in the Vicinity of Camden project.

Navigation Practice. With both inbound and outbound lanes deepened, vessel operating practices would remain the same. Currently, vessels navigate in the center of the channel when possible, and use individual lanes in passing situations. For every foot of increased channel depth, a comparable increase in maximum vessel operating draft would be provided for both inbound and outbound traffic.

3.3.2 OPTION 2. Minimum Width Asymmetric Channel

This option would provide a deeper access channel for the major import facilities including six oil refineries as well as the Conrail iron ore and dry bulk facilities at Pier 122.

Channel Dimensions. Between Pier 122 and the Philadelphia Navy Yard the 400-foot wide channel would be deepened. Between the Philadelphia Navy Yard and Delaware Bay, a channel 435 feet wide would be deepened. In the bay, a channel 580 feet wide would be deepened. The increased channel width in the bay is necessary to insure design vessel controllability due to yawing forces in the bay.

Navigation Practices. With only the inbound lane deepened, vessel operating practices would change. Crude oil tankers and iron ore carriers, which would benefit from the increased depth, would not be able to navigate the center of the full-width channel. These vessels would be required to stay within an inbound lane, which would be 42 to 46 percent narrower than the existing channel. For safety purposes, these vessels would be forced to travel slower than the current practice. It is estimated that the minimum time required for the larger ships to transit the river under these conditions would increase over option 1. Increased travel time would increase vessel operating costs, however, the dredging quantities and costs for channel deepening would be minimized.

While passing of ships with drafts over 40 feet could not occur, coordination between pilots would minimize the effect on vessel operation and travel time. Present practice in the asymmetric Philadelphia Harbor is that smaller vessels use the 37-foot, east channel and larger vessels use the 40-foot, west channel, irrespective of travel direction. In addition, vessels could position themselves in the bay, so that those with northernmost destinations proceed first. This would minimize traffic congestion while vessels are maneuvering to dock.

3.3.3 OPTION 3. More Efficient Asymmetric Channel

This option would also access the six oil refineries and Pier 122, the major import facilities for the main channel.

Channel Dimensions. Channel widths for this alternative are based upon recommendations from the Delaware River and Bay Pilots. These pilots have recommended a channel that permits speeds sufficient for transitting the river within a single tidal cycle. This option would deepen a 400-foot wide channel between Pier 122 and the Philadelphia Navy Yard and a 435-foot wide channel between the Philadelphia Navy Yard and Wilmington, Delaware. Vessel speeds are limited in this portion of the river by the need to limit the effect of ship-generated waves

on the narrow river channel above Wilmington, with it's numerous docks, and the desire to limit the effect of vessel squat on channel depth requirements to two feet. In the reach between Wilmington and Delaware Bay, the deepened inbound lane would be 600 feet wide, while in the bay the channel would be 800 feet wide. River geometry and shore facilities are such that pilots currently navigate the river at speeds that allow transit within a single tidal cycle. The pilots would like to continue this practice in order to make maximum use of the increased channel depth.

Navigation Practice. Vessel operating practices would only change slightly from those that currently exist. Larger vessels would not be able to navigate the center of the full-width channel, but would be restricted to 80 percent of it in the bay and 75 percent in the river below Wilmington. For every foot of increased channel depth a comparable increase in maximum vessel draft could occur for inbound traffic. The minimum time required to transit the river would increase over option 1.

3.4 Alternative Dredged Material Disposal Plans

3.4.1 Dredged Material Disposal Area Screening Analysis

In 1984, the Corps completed the Delaware River Dredging Disposal Study (USACE, 1984), which evaluated future dredging needs and existing dredged material disposal capacity. The study projected areas that would require additional dredged material disposal capacity within a 50-year study period, and identified candidate sites that could be considered for meeting the need. The Delaware River Dredging Disposal Study was conducted with close coordination with numerous Federal, State and local agencies, and resulted in an effectual screening of potential sites for both large-scale disposal areas, to accommodate projects on the Delaware River, and smaller areas for tributary projects. The information generated by this study has been reviewed and incorporated into this current study. The following provides a brief description of the major steps employed during the dredged material disposal site selection process.

Plan formulation with regard to identification of suitable dredged material disposal sites involved several iterations of engineering, economic and environmental screening. The initial step employed a computerized technique called Spatial Analysis Methodology (SAM). SAM stores selected parameter information for specified locations, and displays the information in graphic or tabular form. Parameters included archaeological zones, historic sites, recreational areas, groundwater recharge zones, groundwater protection zones, areas important to fish and wildlife, wetlands, development, navigation features, elevation and distance from dredging sites. Parameters would be given weighting factors to emphasize engineering or environmental criteria. Through manipulation of weighting factors, a series of runs identified locations within the study area that were attractive for dredged material disposal.

SAM essentially generated maps that identified polygons where specified parameter criteria were met. These polygons were then transferred to U.S.G.S. quadrangle sheets for manual screening. Initial screening considered features such as roads, streams and isolated structures that the computer model was

unable to define. Other considerations included minimum acreage requirements, accessibility for construction and maintenance, reasonable disposal pipeline routes and effluent water courses to the river. Sites were also visited at this stage to identify concerns that may have been missed. This analysis reduced the number of candidate areas along the Delaware River from 308 to 82.

The next step in the screening process involved the evaluation of sites with respect to institutional and environmental factors that would preclude use of a site for disposal activities. Institutional screening eliminated sites that were public park land, designated wildlife areas, or adjacent to residential areas and communities. Environmental screening eliminated sites that were not consistent with Federally approved Coastal Zone Management Plans. These plans differ between the States of Pennsylvania, New Jersey and Delaware, so different criteria were used depending on the location of the site. For example, the Pennsylvania Coastal Zone Management Plan specifically prohibits destruction of wetlands, while the New Jersey and Delaware plans do not. This screening cycle reduced the number of candidate sites from 82 to 38.

The 38 remaining sites were next subjected to a detailed cost analysis. Specific data with respect to site acquisition, initial dike construction, annual maintenance, site capacity and mitigation requirements were developed and evaluated to generate a relative ranking of the costs associated with candidate sites. Environmental reviews were also conducted to rank the significance of impacts associated with developing sites for disposal purposes. The Plan Formulation section of the main report includes summary tables that provide pertinent information relative to this analysis.

Based on this analysis, ten upland and seven aquatic sites were recommended for consideration in detailed formulation analyses. These sites are listed in Table 3-2 and located on Figures 3-4 through 3-10.

3.4.2 No Action

The no action plan consists of continued maintenance of the existing 40-foot deep, Philadelphia to the sea, Federal navigation channel. The dredged material disposal analysis for the no action plan considered disposal capacity required to maintain the existing channel for the 50-year study period (2005-2055). For the purpose of evaluating capacity requirements for the entire Philadelphia to the sea project, the channel was divided into five reaches. The limits of these reaches are defined in Figure 3-11. The following provides a description of the disposal area requirements for each reach during the study period. The ultimate capacity of existing sites and the number of new sites required will depend on maximum dike heights of existing disposal sites.

<u>Reach A</u>

Reach A extends from the upper project limit at Allegheny Avenue, Philadelphia, Pennsylvania to Billingsport Range, located near the Philadelphia International Airport. Approximately 260,000 cubic yards of material are dredged from these channel ranges on an annual basis. This material is dredged for both the

Table 3-2 Candidate Dredged Material Disposal Sites Considered in Detail.

Candidate Dredged Material Disposal Site	Reach Location	Figure	Site Type	Acreage
17G	A	3-4	Upland	295
17O	A	3-4	Upland	180
Raccoon Island	B	3-5	Upland	480
15D	B	3-5	Upland	575
15E	B	3-6	Upland	120
15F	B	3-6	Upland	145
15G	B	3-6	Upland	320
15I	B	3-6	Aquatic	775
15J	B	3-6	Aquatic	875
16O	B	3-5	Aquatic	1400
20A	C	3-7	Aquatic	1170
23C	C	3-7	Upland	200
23D	C	3-7	Upland	200
24E	C	3-7	Aquatic	3535
24G	C	3-8	Aquatic	3500
24O	C	3-8	Upland	295
27I	D	3-9	Aquatic	700

EXISTING AND CANDIDATE DREDGED MATERIAL DISPOSAL SITES IN THE VICINITY OF WOODBURY, NJ

DISPOSAL AREA LOCATIONS

PHILADELPHIA DISTRICT
CORPS OF ENGINEERS

CANDIDATE DREDGE MATERIAL DISPOSAL SITES IN THE VICINITY OF MARCUS HOOK, PA

PHILADELPHIA DISTRICT
CORPS OF ENGINEERS

EXISTING AND CANDIDATE DREDGED MATERIAL DISPOSAL SITES IN THE VICINITY OF MARCUS HOOK, PA

DISPOSAL AREA LOCATIONS

PHILADELPHIA DISTRICT
CORPS OF ENGINEERS

Figure 3-6

EXISTING AND CANDIDATE DREDGE MATERIAL DISPOSAL SITES IN THE VICINITY OF KILLCOHOOK, NJ

PHILADELPHIA DISTRICT CORPS OF ENGINEERS

Figure 3-7

EXISTING AND CANDIDATE DREDGED MATERIAL DISPOSAL SITES IN THE VICINITY OF THE CHESAPEAKE AND DELAWARE CANAL

PHILADELPHIA DISTRICT
CORPS OF ENGINEERS

Figure 3-8

EXISTING AND CANDIDATE DREDGED MATERL DISPOSAL SITES IN THE VICINITY OF ARTIFICIAL ISLAND, NJ

DISPOSAL AREA LOCATION

PHILADELPHIA DISTRICT
CORPS OF ENGINEERS

Figure 3-9

LEGEND

Channel indicated thus: ═══

NOTE:
Distance in miles below Allegheny Ave., Phila., show along side of channel.

DELAWARE RIVER

PHILADELPHIA TO THE SEA

Figure 3-10

Existing Buoy 10 Disposal Area in Delaware Bay

SCALE OF MILES 5 0 5 10

U.S. ARMY ENGINEER DISTRICT, PHILA.

Figure 3-11

Delaware River
Comprehensive Navigation Study,
Limits of Reaches A through E

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, New Jersey (Figure 3-4). This site has a capacity of about 3.2 million cubic yards to a dike height of 50 feet. With the current rate of usage, this elevation would be reached in the year 2007. Raising the dike further could add an additional 3.3 million cubic yards of capacity, and extend the life of the site to 2027.

In order to continue maintenance dredging activities for the full 50-year term of the study period, an additional disposal area will be required in the vicinity of Reach A. The existing Fort Mifflin dredged material disposal site was considered, however, this site is required for the disposal of material dredged from the Schuylkill River project. As such, a new site would be required for disposal activities by the year 2027, assuming continued dike raising will occur.

Reach B

Reach B extends from Tinicum Range, located opposite of the Philadelphia International Airport to Cherry Island Range, located opposite of Wilmington, Delaware. This reach includes the Marcus Hook Range and the Marcus Hook Anchorage, which are the heaviest shoaling areas in the river. Approximately 2,160,000 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 and Pedricktown South sites, and the adjacent Oldmans site, which is leased (Figure 3-6). These sites currently have a combined capacity of 21.3 million cubic yards to a dike height of 50 feet. Replacement sites would be needed by the base year if dikes at the Federal sites are not raised and if the Oldmans lease cannot be extended beyond the current expiration date of 1996. Raising the dikes further could add an additional 36.5 million cubic yards of capacity, and extend the life of this complex to 2030. A new site would be required by the year 2030 assuming that dike raising continues.

Reach C

Reach C extends from Deepwater Point Range, located below Wilmington, Delaware to New Castle Range, located at the mouth of the Chesapeake and Delaware Canal. Approximately 2,100,000 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 and Killcohook (Figure 3-7). These sites have a disposal capacity of 42.3 million cubic yards to a dike height of 50 feet. Based on current usage, fill would reach that evaluation in year 2014. Raising the dikes further would add an additional 48.7 million cubic yards of capacity and extend the lives of these sites throughout the planning period. As such, there is sufficient dredged material disposal capacity in Reach C to conduct maintenance dredging activities for the full term of the study period, assuming dike raising continues.

Reach D

Reach D extends from Reedy Island Range, located south of the Chesapeake and Delaware Canal to Liston Range, located just north of Delaware Bay. Approximately 340,000 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 (Figure 3-9). The Artificial Island site has a capacity of 15.8 million cubic yards to a dike height of 50 feet. By raising the dikes further, an additional 4.9 million cubic yards of capacity would be gained. There is sufficient dredged material disposal capacity to maintain the navigation channel in Reach D for the entire 50-year study period and beyond.

Reach E

Reach E covers the remaining portion of the study 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. Approximately 240,000 cubic yards of material are dredged from Reach E every five years. This material is currently placed in an overboard disposal site designated as Buoy 10 (Figure 3-10). Buoy 10 is a deep trench in the lower portion of Delaware Bay, located approximately six miles northwest of Cape May Point. Sufficient capacity exists at the Buoy 10 site to continue maintenance dredging activities within Reach E for more than the 50-year study period.

3.4.3 Candidate Dredged Material Disposal Areas Considered in Detail for the Proposed Deepening Project (Reaches A through D)

As a result of the previous levels of screening, ten upland and eight aquatic sites were identified as alternatives for meeting the projected dredged material disposal capacity needs for the proposed deepening project for the 50-year study period, for Reaches A through D (Table 3-1). These needs include projected deficits for continued maintenance of the existing 40-foot channel, and disposal requirements for alternative channel modification schemes. In order to evaluate the latter, the 45-foot, full-width channel alternative was used as it would entail the greatest amount of dredging and dredged material disposal. If a smaller channel alternative was selected, excess capacity would be available at the end of the study period. Candidate aquatic sites were considered for dredged material disposal under three scenarios. Sites were designed with final fill elevations that would allow the areas to function as shallow water, wetland or upland habitats subsequent to disposal activities. Leaving a site as shallows or wetlands would sharply limit the available disposal capacity at the site, however, it would create a more environmentally productive habitat type than uplands. U.S. Army Corps of Engineers regulation ER 1165-2-27 promotes the use of dredged material for creation of shallow water and wetland habitats, and requires that it be considered as a dredged material disposal alternative during the planning phase of a project that involves dredging. Filling an aquatic site to an elevation that would result in the creation of uplands would maximize disposal capacity at the site, and reduce the need for additional land.

In addition to the aquatic sites considered for dredged material disposal, a technique referred to as thin layering was also evaluated. This alternative involves placement of a thin layer of dredged material over the bottom of an aquatic area, such that there is no long-term change in the bottom habitat. Thin layering has been used by the Mobile District of the U.S. Army Corps of Engineers. They employ a pipeline dredge with a diffuser mounted at the end of a barge supported pipeline to evenly place material over the bottom. The economic benefit of thin layering is that it does not require construction and maintenance of containment dikes. Past experience with thin layering suggests that it should not be used in areas closer than 2,000 feet from a navigation channel, to prevent material from migrating back into the channel. Based on the configuration of the Delaware River study area, thin layering was only considered for Reaches C and D, where sufficient surface area was available to accommodate this criterion.

Both upland and aquatic sites were carried through the final analysis to evaluate the full range of disposal alternatives. Of the ten upland sites, two are located in Reach A (17G and 17O), five are located in Reach B (Raccoon Island, 15D, 15E, 15F and 15G), and three are located in Reach C (23C, 23D and 24O). Sites located in Reaches A and B have all been previously used for dredged material disposal activities. Portions of all of these sites, except Raccoon Island, are currently used for agricultural purposes. Sites located in Reach C are also used for agricultural purposes, but have not been used for dredged material disposal in the past.

Of the aquatic sites, three were located in Reach B (15I, 15J and 16O), three were located in Reach C (20A, 24E, and 24G) and one was located in Reach D (27I). All of these sites are located within the Delaware River proper. Evaluation factors employed for this final cost analysis included initial and total capacity required for a 45-foot deep, full-width channel for 50 years; site acquisition costs; mobilization and demobilization costs; dredging and disposal costs, based on location of sites; site construction and maintenance costs; and costs associated with appropriate environmental mitigation. In addition to the 17 candidate sites, the existing Federally-owned sites at Reedy Point North and Reedy Point South (Figure 3-8) were used in the analysis. A total of 19 separate disposal scenarios were developed based on capacity needs by reach, and candidate sites available for consideration within reasonable range of the need. In addition, thin layering was also evaluated for Reaches C and D where sufficient river bottom exists to accommodate this alternative. The Plan Formulation section of the main report provides summary tables and a description of this final analysis.

The final analysis indicated that upland sites were less expensive than aquatic sites, irrespective of the aquatic scenario (i.e. aquatic site filled to create uplands, wetlands or shallows). The major expense associated with aquatic sites is dike construction in the riverine environment. The engineering measures required to insure the stability of dikes constructed in the water are much more costly than dike construction in an upland situation. As such, aquatic sites were eliminated from consideration during formulation of the selected plan. This included sites 15I, 15I, 16O, 20A, 24E, 24G and 27I. Of the upland sites evaluated, it was generally found that the smaller sites were more expensive to

use than the larger sites. This is because it would be more expensive to construct and operate several smaller sites to accommodate the required amount of material than it would be to construct and operate a single site. In Reach A, sites 17G and 17O would cost approximately the same to construct and operate. In Reach B, Raccoon Island, 15D and 15G are the larger sites (320 to 575 acres), and are less expensive than 15E and 15F (120 to 145 acres). In Reach C, the three upland sites (23C, 23D and 24O) are similar in size. However, the analysis concluded that it would be less expensive to transfer material from Reach C to a larger site used for construction of the Reach B segment of the project, than to construct and operate these new sites.

From an environmental perspective, the use of aquatic sites for dredged material disposal is generally considered to be more environmentally damaging than the use of upland sites. Due to the location of disposal capacity needs within the Delaware estuary, candidate aquatic sites were located along the shorelines of the river. This is a function of available surface area within the riverine portion of the estuary. Much of the area adjacent to these shorelines is relatively shallow water, which is considered to be a habitat of high ecological value. Shallows tend to maintain higher dissolved oxygen levels than deep water areas, and provide more suitable living conditions for many aquatic organisms. The production of phytoplankton and vegetation in shallows provide food sources that attract primary, secondary and tertiary consumers. Largely due to the availability of favorable food and oxygen conditions, the eggs, larvae, juveniles and adults of hundreds of species of zooplankton, invertebrates, fish, birds and mammals have been found within the shallow water zones of the Delaware River. As such, the loss of this type of habitat is considered to be environmentally significant.

With regard to the environmental impacts of using upland areas for dredged material disposal, a distinction can be made between sites that provide low quality and high quality habitat for wildlife. Disturbed areas that support monocultures of Phragmites or large agricultural fields are less valuable than areas that are forested or contain wetlands. Of the 10 upland sites considered for this analysis, seven have been used for dredged material disposal in the past and are disturbed. The remaining three sites are less disturbed, but are used for agricultural purposes. The habitat quality of all of these sites can be considered low to moderate. This is due to a conscious effort to eliminate high quality habitats during the screening process.

3.4.4 An Analysis of Alternatives to the Buoy 10 Disposal Area in Delaware Bay (Reach E)

The development of this disposal plan was performed in accordance with guidance regarding the management of material dredged from navigation channels as stated in a policy letter dated 18 May 1989 from the Office of the Chief of Engineers, Directorate of Civil Works. The procedure requires that alternative plans be formulated in a systematic manner to ensure all reasonable alternatives have been considered. Integral to this process is an incremental cost analysis to identify the plan that reasonably maximizes national economic development consistent with protecting the Nation's environment.

This disposal analysis required 5 cycles to proceed from the identification of all reasonable disposal alternatives to the establishment of the most cost effective yet environmentally acceptable disposal plan.

CYCLE 1 Disposal Method/Disposal Area Identification
Part I. Disposal Methods Evaluated:
The first step in the screening of disposal areas was to identify all viable disposal options available within the Delaware Bay study area (see figure 3-12).

The anticipated dredge plant for a project of this scale was assumed to be a large hydraulic or hopper dredge. A dredge of this size has an effective pumping distance of approximatly 5 miles. However, by the use of a booster pump(s) sites beyond the 5 mile radius can be reached if necessary. This limited the identification of potential sites to a zone of approximately 10 miles from the channel centerline on either side of the Delaware Bay. Pumping distances will be directly affected by the digging bank, material factor, and dredging conditions in the area. A bucket dredge might be utilized with the dredged material placed on barges and transported to sites at further distances. This method, however, was only considered for the deep water and deep hole disposal since the costs for this type of dredging for exceeded those for hydraulic plants for dredging projects of this nature. Disposal of dredged material in aquatic barges can be accomplished by bottom dumping from hopper dredges or barges as well as other techniques. However, hopper dredges would be unable maneuver or operate efficiently in the shallow waters along the bay coasts. The disposal methods evaluated for this project included the following:

- Subaqueous
  - a. Thinlayering
  - b. Hole Filling to Create Shallows
  - c. Diked Containment for Wetland Creation
  - d. Diked Containment for Upland/Island Creation
  - e. Deep Water Overboard Disposal
  - f. Beachfill
  - g. Sand Stock Pile
  - h. Oyster Seed Bed Creation
  - i. Off Shore Berms/Shore Protection

SCALE

1 Inch = 6 Miles

LEGEND

Channel indicated thus:

DELAWARE RIVER
COMPREHENSIVE NAVIGATION
REACH E STUDY AREA
MAIN CHANNEL
DEEPENING

PHILADELPHIA DISTRICT
CORPS OF ENGINEERS

Figure 3-12

- Placement of Material in Wetlands (Diked Containment) to create uplands

- Placement of Material on Uplands (Diked Containment)

PART II. Disposal Area Identification

Within this zone of consideration, potential disposal areas were identified through interviews with the local officials, review of previous correspondence and reports, and public notices. Aerial photographs, maps, and surveys were also obtained to identify other possible locations for dredged material disposal operations. Table 3-3 shows 184 possible sites for the Delaware Bay.

This analysis investigated three bodies of water within the Delaware Bay where thinlayering was a possibility; off of Goose Point Delaware, and off of Dennis Creek New Jersey on the northern and southern side. Thinlayering of disposal material is a relatively new technique. By placeing a one foot layer or less of disposal material in the aquatic environments, thin layering is designed to have limited impacts on the benthic organisms and minimize habitat destruction via burial. Primary considerations for this technique are type of material, proximity to dredge site, and availability of equipment.

Beach disposal and sand stock piles are desirable disposal methods because of the potential benefits that can be obtained when the material is placed on beachfronts susceptible to erosion or storm damage. Suitable material is required to produce the desired benefits. The bay beaches of Delaware and New Jersey are within feasible pumping distances for beachfill placement and sand stockpiles. Underwater berms were also examined off of both the Delaware Bay Coast and the New Jersey Bay Coast as a means of shore protection.

The study area is adjacent to an extensive marsh system which could provide one or more locations for wetland placement of material. Both wetland and upland disposal methods utilize dikes to contain the dredge material which is typically pumped directly to the site from the dredging area. Depending on the physical characteristics of the area, the capacity of these sites depends both on its area and on the ultimate height of the containment dikes. Placement of the material in wetlands would destroy the native vegetation and intertidal habitat and would require in-kind mitigation.

Deep hole and deep water overboard options where examined in the lower Delaware Bay. This section of the bay has naturally deep depths ranging from 40 to 100 feet. Deep holes and deep water overboard sites can be filled to create shallows or to create a more uniform water bathymetry. These sites must be far enough away from the channel to ensure that the dredged material will not be reintroduced into the channel or create any navigational hazard. Theses locations where considered for filling to depths typical of the surrounding channel (40 to 45 feet).

Dredged material disposal in aquatic environments can also be used to create oyster seed beds, islands, and wetland marsh areas. U.S. Army Corp of Engineers regulation ER 1165-2-27 promotes the use of dredge material for creation of shallow water wetland habitats. Typically, these areas are built adjacent to existing marsh ecosystems, however, island creation is also employed in certain instances. These techniques generally involve filling areas with depths of 30 ft. or less thereby sacrificing medium to shallow water habitat. The areal requirements depend upon the volume of dredge material and the existing water depths.

Consistent with past practice on the Delaware River and its tributaries, acquisition of new upland site could potentially accommodate the dredge material and maintenance. The study area from the shore line on either side of the Delaware Bay heading inland, encompassed a 5 mile band. Thirty eight potential upland disposal areas were considered in the state of New Jersey and sixty nine in Delaware. Table 3-3 list the areas of consideration in New Jersey and Delaware. The site names are applicable to the U.S.G.S. quadrangle in which the site is located. In the case of overboard (OB) disposal, deep hole filling (DH), and some island creation (I) the site names are an abbreviation of the type of alternative.

TABLE 3-3
DISPOSAL OPTIONS FOR DELAWARE BAY

Site	Size App	Type
Canton NJ C 1	165 Acres	Upland
C 2	100 Acres	Upland
C 3	165 Acres	Upland
C 4	150 Acres	Upland
C 5	250 Acres	Upland
C 6	140 Acres	Upland
C 7	100 Acres	Upland
C 8	140 Acres	Upland
C 9	100+Acres	Upland
C 10	240 Acres	Upland
C 11	100 Acres	Upland
C 12	120 Acres	Oyster seed bed creation
C 13	160 Acres	Island Creation

TABLE 3-3

DISPOSAL OPTIONS FOR DELAWARE BAY

Site	Size App.	Type
Bem David Point BD 1	190 Acres	Upland
BD 2	160 Acres	Upland
BD 3	140 Acres	Upland
BD 4	85 Acres	Upland
BD 5	200 Acres	Upland
BD 6	200 Acres	Wet land creation
BD 7	160 Acres	Oyster seed bed creation
BD 8	200 Acres	Wetland Creation
BD 9	200 Acres	Oyster seed bed creation
Cedarville CV 1	100 Acres	Beachfill
CV 2	175 Acres	Upland
CV 3	145 Acres	Upland
CV 4	105 Acres	Upland
CV 5	105 Acres	Upland
CV 6	200 Acres	Upland

TABLE 3-3

DISPOSAL SITE OPTIONS FOR DELAWARE BAY

Site	Size App	Type
CV 7	165 Acres	Upland
CV 8	185 Acres	Upland
CV 9	200 Acres	Upland
Fortescue F 1	200 Acres	Wetland Creation
F 2	215 Acres	Island Creation
F 3	100 Acres	Beachfill
Port Morris PN 1	200 Acres	Wetlands Resterations
PN 2	450 Acres	Oyster seed bed creation
PN 3	200 Acres	Wetland Creation/ Restoration
Heislerville H 1	100 Acres	Upland
H 2	200 Acres	Upland
H 3	680 Acres	Upland
H 4	440 Acres	Upland

TABLE 3-3

DISPOSAL SITE OPTIONS FOR DELAWARE BAY

Site	Size App	Type
H 5	150 Acres	Uplands
H 6	100 Acres	Sand stockpile
H 7	100 Acres	Beachfill
H 8	160 Acres	Island Creation
H 9	160 Acres	Island Creation
H 10	500 Acres	Thinlayering
H 11	500 Acres	Thinlayering
Rio Grande RD 1	120 Acres	Upland
RD 2	160 Acres	Upland
RD 3	130 Acres	Upland
RD 4	100 Acres	Beachfill
RD 5	100 Acres	Beachfill
RD 6	320 Acres	Oyster Seed Bed

TABLE 3-3

DISPOSAL OPTIONS FOR DELAWARE BAY

Site	Size App	Type
Cape May CM 1	170 Acres	Upland
CM 2	140 Acres	Upland
CM 3	130 Acres	Upland
CM 4	100 Acres	Beachfill
CM 5/6	200 Acres	Beachfill/ Shore Protection
Woodbine WB 1	160 Acres	Upland
WB 2	150 Acres	Upland
WB 3	175 Acres	Upland

TABLE 3-3

DISPOSAL OPTIONS FOR DELAWARE BAY

Site Name	Size App	Type
Taylors Bridge TB 1	110 Acres	Upland
TB 2	300 Acres	Upland
TB 3	120 Acres	Upland
TB 4	120 Acres	Upland

TABLE 3-3

DISPOSAL OPTIONS FOR DELAWARE BAY

Site Name	Size App	Type
Bombay Hook BB 1	120 Acres	Upland
BB 2	500 Acres	Thinlayering
Little Creek LC 1	380 Acres	Upland
LC 2	210 Acres	Upland
LC 3	225 Acres	Upland
LC 4	170 Acres	Upland
LC 5	160 Acres	Upland
LC 6	98 Acres	Upland
LC 7	314 Acres	Upland
LC 8	100 Acres	Island Creation
LC 9	200 Acres	Wetland Creation/Resteration
LC 10	100 Acres	Sand Stockpile
LC 11	200 Acres	Under water berms shore protection
LC 12	200 Acres	Under water berms shore protection
Frederica FR 1	115 Acres	Upland
FR 2	105 Acres	Upland
FR 3	135 Acres	Upland

TABLE 3-3

DISPOSAL OPTIONS FOR DELAWARE BAY

FR 4	160 Acres	Upland
FR 5	220 Acres	Upland
FR 6	240 Acres	Upland
FR 7	330 Acres	Upland
FR 8	150 Acres	Upland
FR 9	140 Acres	Upland
FR 10	160 Acres	Upland
FR 11	160 Acres	Upland
FR 12	200 Acres	Upland
FR 13	200 Acres	Upland
FR 14	285 Acres	Upland
FR 15	115 Acres	Upland
FR 16	250 Acres	Upland

TABLE 3-3

DISPOSAL OPTIONS FOR DELAWARE BAY

Site Name	Size App	Type
Frederica FR 17	130 Acres	Upland
FR 18	130 Acres	Upland
FR 19	170 Acres	Upland
FR 20	80 Acres	Upland
FR 21	160 Acres	Upland
FR 22	100 Acres	Upland
FR 23	130 Acres	Upland
FR 24	175 Acres	Upland
FR 25	120 Acres	Upland
FR 26	100 Acres	Beachfill
FR 27	200 Acres	Underwater berms/Shore protection
FR 28	100 Acres	Sand stockpile
FR 29	200 Acres	Underwater berms/Shore protection

TABLE 3-3

DISPOSAL OPTIONS FOR DELAWARE BAY

Bennetts Pier BP 1	160 Acres	Upland
BP 2	170 Acres	Upland
BP 3	150 Acres	Upland
BP 4	100 Acres	Beachfill
Mispillian River MS 1	400 Acres	Upland
MS 2	160 Acres	Upland
MS 3	250 Acres	Upland
MS 4	150 Acres	Upland
MS 5	125 Acres	Upland
MS 6	120 Acres	Upland
MS 7	200 Acres	Upland
MS 8	100 Acres	Upland
MS 9	120 Acres	Upland
MS 10	100 Acres	Upland
MS 11	150 Acres	Upland

TABLE 3-3

DISPOSAL OPTIONS FOR DELAWARE BAY

Site Name	Size App	Type
MS 12	230 Acres	Upland
MS 13	370 Acres	Upland
MS 14	350 Acres	Upland
MS 15	110 Acres	Upland
MS 16	160 Acres	Upland
MS 17	100 Acres	Beachfill
MS 18	200 Acres	Wetland Creation
MS 19	100 Acres	Beachfill
MS 20	110 Acres	Upland
MS 21	200 Acres	Shore protection off shore berms
MS 22	120 Acres	Upland

TABLE 3-3

DISPOSAL OPTIONS FOR DELAWARE BAY

Milton ML 1	190 Acres	Upland
ML 2	210 Acres	Upland
ML 3	105 Acres	Upland
ML 4	190 Acres	Upland
ML 5	470 Acres	Upland
ML 6	140 Acres	Upland
ML 7	190 Acres	Upland
ML 8	175 Acres	Upland
ML 9	160 Acres	Upland
ML 10	130 Acres	Upland
ML 11	290 Acres	Upland
ML 12	325 Acres	Upland
ML 13	310 Acres	Upland
ML 14	320 Acres	Upland
ML 15	450 Acres	Upland

TABLE 3-3

DISPOSAL OPTIONS FOR DELAWARE BAY

Site Name	Size App.	Type
Lewis L 1	160 Acres	Upland
L 2	135 Acres	Upland
L 3	100 Acres	Upland
L 4	100 Acres	Beachfill
L 5	200 Acres	Sand stockpile
L 6	100 Acres	Beachfill
L 7	100 Acres	Beachfill
CH 1	100 Acres	Beachfill
CH 2	100 Acres	Beachfill

TABLE 3-3

DISPOSAL OPTIONS FOR DELAWARE BAY

OB 1	100	Overboard
OB 2	120	Overboard
OB 3	80	Overboard
OB 4	170	Overboard
OB 5	120	Overboard
OB 6	160	Overboard
OB 7	100	Overboard
OB 8	95	Overboard
DH 1	100	Deep Hole
DH 2	100	Deep Hole
DH 3	100	Deep Hole
I1	200	Island Creation
I2	90	Island Creation
I3	110	Island Creation

CYCLE 2 ENGINEERING ACCEPTABILITY

Following the identification phase, the potential disposal areas were then evaluated and manually screened for linear features (i.e. roads, rail road tracks, streams...) that would preclude site development and engineering acceptability. Only those options and sites which were feasible from an engineering perspective were allowed to advance onto further examination. The following criteria was used:

- Size/Capacity - Initial dredging would require a minimum of approximately 100 acres for initial placement within upland sites or for the creation of uplands at aquatic sites. Wetland creation within the surrounding shallow bays would require approximately twice the acreage of the upland site (about 200 acres) because of the lower fill height required for the creation of the necessary intertidal environment. Thinlayering would require approximately 500 acres, assuming a one foot depth of fill.

- Reasonable pipeline routes must exist to pump the dredged material to the disposal site, and require no railroad or major highway crossings.

- Acceptable water courses for draining effluent from the disposal site would be necessary.

- There must be reasonable access for construction and maintenance equipment.

- Disposal in aquatic areas should not adversely affect navigational access to channels, berths, piers, etc.

- The sites should be free from existing development or major utilities.

Table 3-4 shows the Engineering screening and those sites that were eliminated from any further evaluation.

Table 3-4

CYCLE 2 - ENGINEERING SCREENING OF DISPOSAL AREAS

SITE NAME	ENGINEERING CONSTRAINTS	REASON	OVERALL ACCEPTABILITY
Canton, N.J. C1	No	---	Yes
C2	No	---	Yes
C3	Yes	Unreasonable pipeline routes	No
C4	Yes	Unreasonable pipeline routes, roads and highways surround area.	No
C5	Yes	Roads and highways surround area, unreasonable pipeline routes	No
C6	Yes	Roads and highways surround areas	No
C7	Yes	Stream Runs along site, no water course to channel	No
C8	Yes	No Water course to channel	No
C9	Yes	Roads and highway surround areas, distance pumping constraints	No
C10	Yes	No water course to channel	No
C11	No	---	Yes
C12	No	---	Yes
C13	No	---	Yes
Ben Davis Point, N.J. BD 1	No	---	Yes
BD 2	Yes	Roads and highways surround area, distance pumping constraints	No
BD 3	Yes	Distance pumping constraints, roads and highways surround area	No

TABLE 3-4

CYCLE 2 - ENGINEERING SCREENING OF DISPOSAL AREAS

SITE NAME	ENGINEERING CONSTRAINTS	REASON	OVERALL ACCEPTABILITY
BD 4	Yes	Distance pumping constraints, roads and highway within area	No
BD 5	No	---	Yes
BD 6	No	---	Yes
BD 7	Yes	Restricts navigation channel access	No
BD 8	No	---	Yes
BD 9	No	---	Yes
Cedarville, N.J. CV 1	No	---	Yes
CV 2	Yes	Distance pumping constraints, roads and highways in area	No
CV 3	Yes	No water course to channel, R.R. tracks boarder site	No
CV 4	Yes	Distance pumping constraint, stream in area	No
CV 5	Yes	Roads and highways surround site, distance pumping constraints	No
CV 6	No	---	Yes
CV 7	Yes	Distance pumping constraints	No
CV 8	Yes	No water course to channel, distance pumping constraints	No
CV 9	Yes	R.R. tracks border, no water course to channel, distance pumping constraints	No

TABLE 3-4

CYCLE 2- ENGINEERING SCREENING OF DISPOSAL AREAS

SITE NAME	ENGINEERING CONSTRAINTS	REASON	OVERALL ACCEPTABILITY
Fortescue, N.J. F1	No	---	Yes
F2	No	---	Yes
F3	No	---	Yes
Port Morris, N.J. PN 1	No	---	Yes
PN 2	No	---	Yes
PN 3	Yes	Distance pumping constraints	No
Heislerville H1	Yes	Stream border sites, unreasonable pipeline routes	No
H2	Yes	Distance pumping constraints	No
H3	Yes	No water course to channel, unreasonable pipeline routes	No
H4	Yes	No water course to channel, unreasonable pipeline routes	No
H5	Yes	Unreasonable pipeline route	No
H6	Yes	Unreasonable pipeline route	No
H7	Yes	Unreasonable pipeline routes	No

TABLE 3-4

CYCLE 2 - ENGINEERING SCREENING OF DISPOSAL AREAS

SITE NAME	ENGINEERING CONSTRAINTS	REASON	OVERALL ACCEPTAILITY
H8	Yes	Unreasonable pipeline routes	No
H9	Yes	Unreasonable pipeline routes	No
H10	Yes	Unreasonable pipeline routes	No
H11	Yes	Unreasonable pipeline routes	No
Rio Grande, N.J. RD 1	No	---	Yes
RD 2	Yes	No water course to channel, roads surround site	No
RD 3	Yes	Man made improvements, area has been developed	No
RD 4	No	---	Yes
RD 5	No	---	Yes
RD 6	No	---	Yes
Cape May, N.J. CM 1	Yes	No water course to channel unreasonable pipeline routes	No
CM 2	No	---	Yes
CM 3	Yes	Road and highway surround site, no water course to channel	No
CM 4	No	---	Yes

TABLE 3-4

CYCLE 2 - ENGINEERING SCREENING OF DISPOSAL AREAS

SITE NAME	ENGINEERING CONSTRAINTS	REASON	OVERALL ACCEPTABILITY
CM 5/6	No	---	Yes
Woodbine, N.J. WB 1	Yes	Unreasonable pipeline routes, no water course to channel	No
WB 2	Yes	Unreasonable pipeline routes, no water course to channel	No
WB 3	Yes	Unreasonable pipeline routes, no water course to channel	No
Taylors Bridge, Del TB 1	No	---	Yes
TB 2	Yes	Distance pumping constraints	No
TB 3	No	---	Yes
TB 4	Yes	Roads and highway surround area, distance pumping constraints	No
Bombay Hook, Del BB 1	Yes	Unreasonable pipeline routes	No
BB 2	No	---	Yes
Little Creek LC 1	Yes	Unreasonable pipeline routes	No
LC 2	Yes	Stream in area, distance pumping constraints	No

TABLE 3-4

CYCLE 2 - ENGINEERING SCREENING OF DISPOSAL AREAS

SITE NAME	ENGINEERING CONSTRAINTS	REASON	OVERALL ACCEPTABILITY
LC 3	Yes	Roads and highways border site, stream in area, distance pumping constraints	No
LC 4	Yes	Unreasonable pipeline routes	No
LC 5	Yes	No water course to channel, unreasonable pipeline routes	No
LC 6	Yes	No water course to channel, roads and highways border site	No
LC 7	Yes	Stream in area, unreasonable pipeline routes	No
LC 8	No	---	Yes
LC 9	No	---	Yes
LC 10	No	---	Yes
LC 11	No	---	Yes
LC 12	No	---	Yes
Frederica, Del FR 1	Yes	No water course to channel, roads and highways border area	No
FR 2	Yes	No water course to channel, roads and highways border area	No
FR 3	Yes	Unreasonable pipeline routes	No
FR 4	Yes	Unreasonable pipeline routes, roads and highways border site	No

TABLE 3-4

CYCLE 2 - ENGINEERING SCREENING OF DISPOSAL AREAS

SITE NAME	ENGINEERING CONSTRAINTS	REASON	OVERALL ACCEPTABILITY
FR 5	Yes	Unreasonable pipeline routes	No
FR 6	Yes	Distance pumping constraints, roads and highways border area	No
FR 7	Yes	Distance pumping constraints, no water course to channel	No
FR 8	Yes	Unreasonable pipeline routes, pipeline distance pumping constraints	No
FR 9	Yes	No water course to channel	No
FR 10	Yes	Road and highways border area, distance pumping constraints	No
FR 11	Yes	No water course to channel, roads and highways boarder site	No
FR 12	Yes	No water course to channel	No
FR 13	Yes	No water course to channel	No
FR 14	Yes	Unreasonable pipeline routes no water course to channel	No
FR 15	Yes	Stream within area, distance pumping constraints	No
FR 16	Yes	Unreasonable pipeline routes	No
FR 17	Yes	Unreasonable pipeline routes	No
FR 18	No	---	Yes
FR 19	No	---	Yes
FR 20	Yes	No water course to channel	No
FR 21	Yes	Unreasonable pipeline routes	No

TABLE 3-4

CYCLE 2 - ENGINEERING SCREENING OF DISPOSAL AREAS

SITE NAME	ENGINEERING CONSTRAINTS	REASON	OVERALL ACCEPTABILITY
FR 22	Yes	No water course to channel, unreasonable pipeline routes	No
FR 23	Yes	No water course to channel	No
FR 24	Yes	No water course to channel, roads and highways border area	No
FR 25	Yes	Area has been developed	No
FR 26	No	---	Yes
FR 27	No	---	Yes
FR 28	No	---	Yes
FR 29	No	---	Yes
Bennett's Pier BP 1	No	---	Yes
BP 2	No	---	Yes
BP 3	Yes	No water course to channel	No
BP 4	No	---	Yes
Mispillion, Del MS 1	Yes	No water course to channel	No
MS 2	No	---	Yes
MS 3	No	---	Yes
MS 4	Yes	No water course to channel	No

TABLE 3-4

CYCLE 2 - ENGINEERING SCREENING OF DISPOSAL AREAS

SITE NAME	ENGINEERING CONSTRAINTS	REASON	OVERALL ACCEPTABILITY
MS 5	Yes	Unreasonable pipeline routes	No
MS 6	Yes	Distance pumping constraints, highway borders site	No
MS 7	Yes	Distance pumping constraints	No
MS 8	Yes	Unreasonable pipeline routes	No
MS 9	Yes	No water course to channel	
MS 10	Yes	Unreasonable pipeline routes, distance pumping constraints	No
MS 11	Yes	Unreasonable pipeline routes	No
MS 12	No	---	Yes
MS 13	Yes	No water course to channel, roads and highway border site	No
MS 14	No	---	Yes
MS 15	No	---	Yes
MS 16	No	---	Yes
MS 17	No	---	Yes
MS 18	No	---	Yes
MS 19	No	---	Yes
MS 20	No	---	Yes

TABLE 3-4

CYCLE 2 - ENGINEERING SCREENING OF DISPOSAL AREAS

SITE NAME	ENGINEERING CONSTRAINTS	REASON	OVERALL ACCEPTABILITY
MS 21	No	---	Yes
MS 22	Yes	No access to area	Yes
Milton, Del ML 1	No	---	Yes
ML 2	No	---	Yes
ML 3	Yes	No water course to channel	No
ML 4	No	---	Yes
ML 5	Yes	No water course to channel	No
ML 6	Yes	No water course to channel, unreasonable pipeline routes	No
ML 7	Yes	No water course to channel	No
ML 8	Yes	No water course to channel	No
ML 9	No	---	Yes
ML 10	Yes	Distance pumping constraints, unreasonable pipeline routes	No
ML 11	Yes	Road and highway border site, unreasonable pipeline routes	No
ML 12	Yes	Unreasonable pipeline routes	No
ML 13	Yes	No water course to channel, distant pumping constraints	No

TABLE 3-4

CYCLE 2- ENGINEERING SCREENING OF DISPOSAL AREAS

SITE NAME	ENGINEERING CONSTRAINTS	REASON	OVERALL ACCEPTABILITY
ML 14	Yes	No water course to channel	No
ML 15	Yes	No water course to channel unreasonable pipeline route	No
Lewis L1	No	---	Yes
L2	NO	---	Yes
L3	No	---	Yes
L4	No	---	Yes
L5	No	---	Yes
L6	No	---	Yes
L7	No	---	Yes
Cape Henlopen CH 1	No	---	Yes
CH 2	No	---	Yes

TABLE 3-4

CYCLE 2 - ENGINEERING SCREENING OF DISPOSAL AREAS

SITE NAME	ENGINEERING CONSTRAINTS	REASON	OVERALL ACCEPTABILITY
OB 1	Yes	Navigational Restraints, impact on anchorage area	No
OB 2	No	Navigational Restraints, impact on anchorage area	Yes
OB 3	No	Does not meet minimum size requirements	No
OB 4	No	---	Yes
OB 5	Yes	Navigation Restraints, adjacent to inbound traffic lane	Yes
OB 6	Yes	Site presently being use for Cape May Canal disposal	Yes
OB 7	Yes	Navigational Restraints, Cape May Canel enterance	No
OB 8	No	Navigational Restraints Cape May/Lewes Ferry route	No
DH 1	Yes	Navigational Restraints anchoage area	
DH 2	Yes	Navigational Restraints Cape May/Lewis Ferry route	
DH 3	Yes	Navigational Restraints pilot area	
I1	No	---	Yes
I2	Yes	Does not meet minimum size requirements	No
I3	No	---	Yes

CYCLE 3 INSTITUTIONAL AND ENVIRONMENTAL FACTORS

The next screening phase analyzed the remaining disposal options from an institutional and environmental viewpoint. The purpose of this screening was to eliminate sites which would violate the Federally approved regulations (in particular New Jersey and Delaware Coastal Zone Management Plans). Environmental concerns included adverse impacts to quality ecological habitats and disturbance of cultural resources. The following criteria were applied at this stage:

- The site cannot be public parkland or a designated wildlife area.
- The site cannot adversely effect the future capacity requirements for maintenance of an existing Federal navigation project.
- The disposal site cannot adversely impact ground water aquifers.
- Delaware CZM discourages and NJ CZM prohibits the destruction of undisturbed wetlands for the disposal of dredged material.
- NJ CZM prohibits relocation of streams, filling of ponds, and actions which reduce the flood flow capacity of streams.
- NJ CZM prohibits disposal in tidal guts, man-made harbors, medium rivers, creeks and streams.

Field inspections of the potential sites were then conducted to verify and update information used in the initial screening and to gather additional information to be used in later screening stages. Table 3-5 shows the results of the Environmental/ Institutional screening which further reduced the number of candidate sites.

TABLE 3-5

CYCLE 3 - INSTITUTIONAL/ENVIRONMENTAL SCREENING

SITE NAME	TYPE	INSTITUTIONAL ACCEPTABILITY	ENVIRONMENTAL ACCEPTABILITY	OVERALL ACCEPTABILITY
Canton N.J. C1	Upland	No Schools Across Highway	No Stream within Area	N
C2	Upland	Y	Y	Y
C11	Upland	Y	Y	Y
C12	Oyster Bed Creation	Y	N Unsuitable Silty Material	N
C13	Island Creation	Y	Y*	Y
Ben Davis BD1	Upland	N Wildlife Management Area	Y	N
BD5	Upland	N Wildlife Management Area	Y	N
BD6	Wetland Creation	Y	N Oyster Bed within Area	N
BD8	Wetland Creation	Y	N Oyster Beds within Area	N
BD9	Oyster Seed Bed Creation	Y	N Unsuitable Silty Material	N
Cedarvill CV1	Beachfill	Unsuitable Silty Material	Unsuitable Silty Material	N

*Pending Benthic Testing

TABLE 3-5

CYCLE 3 - INSTITUTIONAL/ENVIRONMENTAL SCREENING

SITE NAME	TYPE	INSTITUTIONAL ACCEPTABILITY	ENVIRONMENTAL ACCEPTABILITY	OVERALL ACCEPTABILITY
CV6	Upland	N Fish and Wildlife Management Area	Y	N
Fortescue F1	Wetland Creation	Y	Y *	Y
F2	Island Creation	Y	Y *	Y
F3	Beachfill	Y	Y	Y
PN1	Wetland Creation	Y	Y *	Y
PN2	Oyster Seed Bed Creation	Y	N Unsuitable Silty Material	N
Rio Grande RD1	Upland	Y	Y	Y
RD4	Beachfill	Y	Y	Y
RD5	Beachfill	Y	N Unsuitable Silty Material	N
RD6	Oyster Seed Bed Creation	Y	N Unsuitable Silty Material	N

*Pending Benthic Testing

TABLE 3-5
CYCLE 3 - INSTITUTIONAL/ENVIRONMENTAL SCREENING

SITE NAME	TYPE	INSTITUTIONAL ACCEPTABILITY	ENVIRONMENTAL ACCEPTABILITY	OVERALL ACCEPTABILITY
Cape May CM2	Upland	Y	Y	Y
CM4	Beachfill	Y	Y	Y
CM5/6	Beachfill/Shore Protection	Y	Y	Y
Delaware Taylors Bridge TB1	Upland	State Designated Wildlife Area	No Wetlands in Area/No Streams	N
Bombay BB2	Thin layering	Y	N Oyster Lease Bed	N
Little Creek LC8	Island Creation	N Bombay Hook, Natural Wildlife Area	N Oyster Lease Bed	N
LC9	Wetland Creation / Restoration	Y	Y *	Y

TABLE 3-5

SITE NAME	TYPE	INSTITUTIONAL ACCEPTABILITY	ENVIRONMENTAL ACCEPTABILITY	OVERALL ACCEPTABILITY
LC10	Sand stock pile	Y	Y *	Y
LC11	Under water berms/ shore protection	Y	N Oyster Beds	N
LC12	Under water berms / shore protection	Y	N Oyster Beds	N
Frederica FR18	Upland	Y	N Pond in Area	N
FR19	Upland	Y	Y	Y
FR26	Beachfill	Unsuitable Silty Material	Unsuitable Silty Material	N
FR27	Underwater berms/ shore protection	Y	N Oyster Bed	N
FR28	Sand stock pile	Y	Y *	Y
FR29	Under water berms/ Shore Protection	Y	N Oyster Bed	N

* Pending Benthic Testing

TABLE 3-5

CYCLE 3 - INSTITUTIONAL/ENVIRONMENTAL SCREENING

SITE NAME	TYPE	INSTITUTIONAL ACCEPTABILITY	ENVIRONMENTAL ACCEPTABILITY	OVERALL ACCEPTABILITY
Bennetts Pier BP1	Upland	Y	Y	Y
BP2	Upland	Y	Y	Y
BP4	Beach Fill	Y	N Unsuitable Silty Material	N
MS2	Upland	N Milford Neck Wildlife Area	Y	N
MS3	Upland	Y	Y	Y
MS12	Upland	Y	Y	Y
MS14	Upland	N State Park	N Stream/Wetlands	N
MS15	Upland	N State Park	Y Stream/Wetlands	N
MS16	Upland	N State Park	Y	N
MS17	Beachfill	Y	N Unsuitable Silty Material	Y
MS18	Wetland Creation	Y	Y *	Y
MS19	Sand Stock Pile	Y	Y *	Y

* Pending Benthic Testing

TABLE 3-5

CYCLE 3 - INSTITUTIONAL/ENVIRONMENTAL SCREENING

SITE NAME	TYPE	INSTITUTIONAL ACCEPTABILITY	ENVIRONMENTAL ACCEPTABILITY	OVERALL ACCEPTABILITY
MS20	Upland	N Historic Area	N Wetlands Border site	N
MS21	Underwater Berms/Shore Protection	Y	N Oyster Seed Beds in Area	N
Milton ML1	Upland	Y	N Wetlands	N
ML2	Upland	Y	Y	Y
ML4	Upland	Y	Y	Y
ML9	Upland	Y School grounds Residential Area	Y	Y
Lewis L1	Upland	Y	Y	Y
L2	Upland	Y	Y	Y
L3	Upland	N Historic Site University Del	Y	N
L4	Beachfill	Y	Y	Y
L5	Sand stock pile	Y	Y *	Y
L6	Beachfill	Y	Y	Y
L7	Beachfill	N	N	N
CH1	Beachfill	N National Park	N Shore Bird Nesting Area	N
CH2	Beachfill	N National Park	Y	N

SITE NAME	TYPE	INSTITUTIONAL ACCEPTABILITY	ENVIRONMENTAL ACCEPTABILITY	OVERALL ACCEPTABILITY
OB4	Overboard	Y	Y *	Y
I 1	Island Creation	Y	Y *	Y
I 3	Island Creation	Y	Y *	Y

* Pending Benthic Testing

RESULTS OF ENGINEERING, INSTITUTIONAL & ENVIRONMENTAL SCREENING:

The following identifies the areas which were eliminated from further consideration based on the aforementioned screening for engineering acceptability and institutional and environmental acceptability.

Thinlayering within any of the three shallow bays areas was screened out. These shallow bay areas are less than 5 ft. deep at low water and would be virtually inaccessible to the barges, boats and other assorted equipment required to introduce and spread the dredge material. Off of Dennis Creek New Jersey on the northern and southern side is outside the ten mile radius determined to be the limiting distance for disposal area selection. In addition off of Goose Point Delaware thinlayering is discouraged as a means of open water disposal because of the potential harmful effects on the existing oyster seed beds and other aquatic habitat.

The deep holes within the study area were screened out due to the uncertainty that exists about the currents which initially formed the holes. Re-suspending of dredged sediments placed in the deep hole could contribute to future shoaling problems. In addition the deep hole sites within the study area are all located in and around the Big Stone Anchorage, with in the Cape May/Lewes Ferry route or in the pilots area. By filling these holes the risk of adversely affecting navigational access to these areas could increase. Therefore, no deepholes identified within the project area could be used for dredged material disposal.

Beach nourishment and sand stock piling for future beach nourishment are feasible options. The criteria for beach nourishment assumes use of sandy material with grain size distributions similar to the native material. Sediment dredged from the project area varies depending on which part of the bay the material is being dredged. For the purposes of this study, the bay was broken up into four sections. Lower Liston/Upper Cross Ledge Range and Lower Miah Maull/Upper Brandywine Range consist primarily of fine grained silty material with a small percentage of sand found in a few remote areas. Placement of this type of material within the surfzone would result in rapid winnowing and erosion of the newly placed material. Cross Ledge/Upper Miah Maull Range and the Lower Brandywine Range were made up of clean sandy material with grain size distribution similar to the bay beaches of both New Jersey and Delaware will be dredged. Initially 38 possible sites where examined. Due to the distributions of silty material, 14 sites remained. However, two of the remaining sites did not pass the institutional screening as they where part of Cape Henlopen National Park.

Under water berms/off shore protection is similar to beach nourishment. The criteria being the material should be sandy with

grain size distributions similar to the native material. For this reason one out of five site was eliminated. The other four site are all located in or near oyster seed bed areas. Creation of these

sites would result in the loss of high quality shallow bay habitat the oyster and other estuarine shellfish and finfish depend on. Therefore this option did not pass the Environmental screening.

Wetland disposal of the dredged material, even with suitable mitigation was eliminated under the respective CZM regulations prohibiting and discouraging the destruction of undisturbed tidal wetlands for disposal purposes.

Wetland creation and Island creation was considered a suitable option. Initially 15 sites where analyzed on the Delaware and New Jersey coast with 8 sites surviving the engineering, environmental, and institutional screening. Two of the remaining sites are located in the Lower Liston/Upper Cross Ledge Range. Both site are located in areas of high wetland erosion; Alder Cove in New Jersey and Port Mahon in Delaware. The Lower Miah Maull/Upper Brandywine Range consist of three of the remaining sites. One of the three is a wetland erosion area (Maurice River Cove N.J.), the second is an island creation along the Lower Middle Shoal in the Delaware Bay, and the third is south of the Egg Island Flats in Delaware Bay . Egg Island Point N.J. was costed out as a wetland creation. Off of Raybins Beach N.J. was costed out for Island Creation. Both sites are located in the Lower Cross Ledge/Upper Miah Maull Range. The final wetland creation site, Mispillion Light, is locted within the Delaware Lower Brandywine Range. Creation of these sites could result in the loss of high quality shallow bay habitat for a variety of marine and estuarine shellfish and finfish. Due to the limited extent and high value placed on shallow, bays, in-kind habitat replacement at an appropriate site would be required for mitigation.

Oyster Seed Bed Creation was examined as a beneficial use of dredge material option. The main criteria for oyster seed bed creation assumes use of sandy material with variations in grain size distributions. However due to the silty nature of the material being dredged in those particular areas of the bay this option did not survive the Environmental screening.

Ocean disposal was eliminated as an option in six out of eight sites due to navigational restraints. A seventh site was dismissed for not meeting the minimum size requirement. The remaining overboard site is the buoy 10 site that is located in the lower bay.

Upland disposal was eliminated in 90 out of 127 possible sites due Engineering acceptability (refer to table 3-4). Environmental and Institutional acceptability screen out an additional 12 sites. The remaining 25 upland sites went on to cycle 4.

The remaining disposal sites that attained engineering, institutional and environmental acceptability were moved forward to cycle 4

CYCLE 4: Assessment of Cost and Disposal Impact

For remaining sites to be considered (see Figure 3-13) an evaluation must be made of the critical cost factors and in each range the environmental and cultural resource concerns in order to rank the remaining 40 sites. The sites were ranked LOW, MODERATE, and HIGH (depending on the general cost per cubic yard.)

The habitat and land cover as well as other critical environmental and cultural values at each site were described and quantified in order to assess the significance of impacts and the probable need for mitigation at each site. Impacts were summarized as HIGH, MODERATE, and LOW, and mitigation requirements assessed citing acreage and habitat type.

Using these comparisons of cost and impact the sites were classified and screened. Tables 3-6 to 3-9 demonstrate the ranking of the disposal options. All LOW cost site regardless of environmental impact (where mitigation is possible) and MODERATE cost sites with LOW impact were carried forward to Cycle 5.

LEGEND

UPLAND *

AQUATIC ♦

BEACHFILL o

DELAWARE RIVER
COMPREHENSIVE NAVIGATION
REACH E STUDY AREA
MAIN CHANNEL
DEEPENING
DISPOSAL OPTIONS
PHILADELPHIA DISTRICT
CORPS OF ENGINEERS

Figure 3-13

TABLE 3-6
DISPOSAL OPTIONS FOR LOWER LISTON/UPPER CROSS LEDGE RANGE

Site Name	Size App	Type	Env/ Cult Rank	Cost Rank Hopp	Cost Rank Hyd	$ per CY Hopper	$ per CY HYD	Overall Acceptability
C2	100 Acres	Upland	L	H	H	17.90	15.70	No
C11	100 Acres	Upland	L	H	M	22.50	10.30	Yes
C13	160 Acres	Island Creati on	M	H	L	16.25	7.50	Yes
LC 9	200 Acres	Wetlan d Creati on/ Restor ation	M	H	M	15.95	7.35	Yes

TABLE 3-7
DISPOSAL OPTIONS FOR LOWER CROSS LEDGE/UPPER MIAH MAULL RANGE

Site Name	Size App	Type	Env./ Cult Rank	Cost Rank Hopp	Cost Rank Hyp	$ per CY Hopper	$ per CY HYD	Overall Acceptability
F 1	200 Acres	Wetland Creation	H	H	L	32.85	10.00	Yes
F 2	215 Acres	Island Creation	M	H	M	22.45	9.75	Yes
F 3	100 Acres	Beachfill	L	H	M	43.30	12.10	Yes
RD 1	120 Acres	Upland	L	H	H	47.10	31.75	No
LC10/FR28	200 Acres	Sand Stockpile	M	H	M	25.85	8.25	Yes
BP 1	160 Acres	Upland	L	H	H	45.10	20.25	No
BP 2	170 Acres	Upland	L	H	H	45.10	19.75	No
CV 1	100 Acres	Beachfill	L	H	H	47.30	30.80	No

TABLE 3-8
DISPOSAL OPTIONS FOR LOWER MIAH MAULL/ UPPER BRANDY WINE RANGE

Site Name	Size App	Type	Env./ Cult Rank	Cost Rank Hopp	Cost Rank Hyd	$ per CY Hopper	$ per CY HYD	Overall Acceptability
PN 1	200 Acres	Wetland Restoration	M	H	M	32.10	9.45	Yes
FR 19	170 Acres	Upland	L	H	H	46.90	20.25	No
MS 3	250 Acres	Upland	L	H	H	33.10	20.25	No
MS 12	230 Acres	Upland	L	H	H	32.60	20.65	No
ML 1	190 Acres	Upland	L	H	H	25.90	20.00	No
ML 2	210 Acres	Upland	L	H	H	22.80	20.00	No
ML 4	190 Acres	Upland	L	H	H	30.50	20.00	No
I 3	110 Acres	Island Creation	M	L	L	7.10	20.00	NO
I 1	200 Acres	Island Creation	M	M	L	7.85	6.70	Yes
LC 2	210 Acres	Upland	L	H	H	21.35	21.35	NO

TABLE 3-9
DISPOSAL OPTIONS FOR LOWER BRANDY WINE RANGE

Site Name	Size App	Type	ENV./ CULT Rank	Cost Rank Hopp	Cost Rank Hyd	$ per CY Hopper	$ per CY HYD	Overall Acceptability
RD 4	100 Acres	Beachfill	L	H	M	48.20	12.10	Yes
OB 4	170 Acres	Over board	H	L	L	5.10	4.05	Yes
CM 2	140 Acres	Upland	L	M	M	13.50	14.30	Yes
CM 4	100 Acres	Beachfill	L	M	M	13.05	14.80	Yes
CM 5/6	200 Acres	Beachfill/ Shore protection	L	M	M	10.35	13.80	Yes
MS 18	200 Acres	Wetland Creation	M	H	H	15.10	20.60	No
MS 19	200 Acres	Sand Stock Pile	M	M	M	14.55	11.15	Yes
L1	160 Acres	Upland	L	H	H	21.00	19.95	No
L 2	135 Acres	Upland	L	H	H	21.15	19.95	No
L 3	100 Acres	Upland	L	H	H	20.00	19.80	No
L 4	100 Acres	Beachfill	L	H	M	16.85	14,75	Yes
L 5	200 Acres	Sand Stock pile	M	M	M	14.55	11.10	Yes
L 6	100 Acres	Beachfill	L	H	H	16.85	19.75	No
L 7	100 Acres	Beachfill	L	H	H	15.25	15.75	No

Tables 3-10 to 3-13 displays the remaining candidates prior to Cycle 5

TABLE 3-10
REMAINING DISPOSAL OPTIONS FOR LOWER LISTON/ UPPER CROSS LEDGE RANGE

Site Name	Size App	Type	Env/ Cult Rank	Eng. Rank	$ per CY HYD/Hopper
C11	100 Acres	Upland	L	M	HYD/10.30
C13	160 Acres	Island Creation	M	L	HYD/7.50
LC 9	200 Acres	Wetland Creation/ Restoration	M	M	HYD/7.35

TABLE 3-11
REMAINING DISPOSAL OPTIONS FOR LOWER CROSS LEDGE/ UPPER MIAH MAUL RANGE

Site Name	Size App	Type	Env./ Cult Rank	Eng. Rank	$ per CY HYD/HOPPER
LC 10	100 Acres	Sand Stockpile	M	M	8.25 HYD
FR 28	100 Acres	Sand Stockpile	M	M	8.30 HYD
F 1	200 Acres	Wetland creation	H	L	10.00 HYD
F 2	215 Acres	Island Creation	M	L	9.75 HYD
F 3	100 Acres	Beachfill	L	M	12.10 HYD

Tables 3-10 to 3-13 displays the remaining candidates prior to Cycle 5

TABLE 3-12

REMAINING DISPOSAL OPTIONS FOR LOWER MIAH MAUL/ UPPER BRANDY WINE RANGE

Site Name	Size App	Type	Env./ Cult Rank	Eng. Rank	$ per CY HYD/HOPPER
I 1	200 Acres	Island Creation	M	M	7.85/HYD 6.70/HOPP
I 3	110 Acres	Island Creation	M	M	7.10/HYD 6.00/HOPP
PN 1	200 Acres	Wetland Restoration	M	M	9.45/HYD

TABLE 3-13
REMAINING DISPOSAL OPTIONS FOR LOWER BRANDY WINE RANGE

Site Name	Size App	Type	ENV./ CULT Rank	ENG. Rank	$ per CY HYD/ HOPPER
RD 4	100 Acres	Beachfill	L	M	12.10 HYD
OB 4	170 Acres	Over board	H	L	4.05 HYD 5.10 HOPP
CM 2	140 Acres	Upland	L	M	14.30 HYD 13.50 HOPP
CM 4	100 Acres	Beachfill	L	M	14.80 HYD 13.05 HOPP
CM 5/6	200 Acres	Beachfill/ Shore protection	L	M	13.80 HYD 10.35 HOPP
MS 19	200	Sand Stockpile		M	11.15 HOPP 14.55 HYD
L 4	100 Acres	Beachfill	L	M	14.75 HYD
L 5	200 Acres	Sand Stockpile		M	11.10 HYD. 14.55 HOPP

CYCLE 5: Disposal Area Scheme Selection

The 19 remaining sites which passed the previous disposal cycle utilized a more detailed incremental cost analysis including incremental mitigation to prepare a final ranking of disposal based on the disposal requirements of the Delaware River Main Channel in the Delaware Bay (see Figure 3-14). Initial cost were evaluated using acquisition cost, mobilization and demobilization cost, and dredging and disposal cost for a given disposal area(s). To these construction cost were added, and the costs associated with mitigation of environmentally and culturally sensitive habitat. The total cost of the initial construction was converted to an annualized cost and added to the average annual maintenance cost to determine total average annual cost. These scenarios are evaluated in Tables 3-14 to 3-17.

LEGEND

UPLAND *

AQUATIC ♦

BEACHFILL o

DELAWARE RIVER
COMPREHENSIVE NAVIGATION
REACH E STUDY AREA
MAIN CHANNEL
DEEPENING
DISPOSAL OPTIONS
PHILADELPHIA DISTRICT
CORPS OF ENGINEERS

Figure 3-14

TABLE 3-14
CYCLE 7 DISPOSAL AREA SCHEME SELECTION
(COSTS IN THOUSAND DOLLARS)
FOR
LOWER LISTON/UPPER CROSS LEDGE RANGE

SITE NAME/ TYPE	C11 UPLAND	C13 ISLAND CREATION	LC9 WETLAND RESTORATION
ACREAGE (AC) INITIAL COST	100 $10,500	160 $8,900	200 $8,900
FEDERAL SITE REPLACEMENT	0	0	0
ENVIRONMENTAL CONCERNS/CRITERIA	None	Nursery, spawning and foraging habitat	Nursery, spawning and foraging habitat
FOR:	------	Shallow water habitat	Shallow water habitat
DISPOSAL AREA MITIGATION	None	None, site selection to avoid critical areas*	None, site selection to avoid critical areas*
DISPOSAL AREA MITIGATION COST	0	0	0
TOTAL INITIAL COSTS	$10,500	$8,900	$8,900
AMORTIZED FIRST COSTS	$932.8	$790.7	$790.7
ANNUAL O&M REQUIREMENTS	58,200cy	58,200cy	58,200cy
AVG. ANNUAL MAINT. COST	$145.5	$145.5	$145.5
TOTAL AVG. ANNUAL COST	$1,078	$936.2	$936.2

* Final site boundary will be based on detailed benthic testing in Preconstruction, Engineering and Design (PED) phase

TABLE 3-15
CYCLE 7 DISPOSAL AREA SCHEME SELECTION
(COSTS IN THOUSAND DOLLARS)
FOR
CROSS LEDGE/UPPER MIAM MAULL RANGE

SITE NAME/ TYPE	LC10/FR28 SAND STOCK PILE	F1 WETLAND CREATION	F2 ISLAND CREATION	F3 BEACHFILL
ACREAGE (AC) INITIAL COST	100 $13,120	280 $27,230	215 $28,030	100 $17,070
FEDERAL SITE REPLACEMENT	0	0	0	0
ENVIRONMENTAL CONCERNS/CRITERIA	Nursery, spawning and foraging habitat	Nursery, spawning and foraging habitat	Nursery, spawning and foraging habitat	NONE
FOR:	Shallow water habitat	Shallow water habitat	Shallow water habitat	-----
DISPOSAL AREA MITIGATION	None, site selection to avoid critical areas*	None, site selection to avoid critical areas*	None, site selection to avoid critical areas*	NONE
DISPOSAL AREA MITIGATION COST	---	---	---	---
TOTAL INITIAL COSTS	$13,120	$27,230	$28,030	$17,070
AMORTIZED FIRST COSTS	$1,165.6	$2,419.1	$2,490.2	$1,516.5
ANNUAL O&M REQUIREMENTS/	2,500cy	2,500cy	2,500cy	2,500cy
AVG. ANNUAL MAINT. COST	$6.3	$6.3	$6.3	$6.3
TOTAL AVG. ANNUAL COST	$1,171.9	$2,496.5	$2,496.5	$1,522.8

* Final site boundary will be based on detailed benthic testing in Preconstruction, Engineering and Design (PED) phase

TABLE 3-16
CYCLE 7 DISPOSAL AREA SCHEME SELECTION
(COSTS IN THOUSAND DOLLARS)
FOR
LOWER MIAH MAULL/UPPER BRANDY WINE RANGE

SITE NAME/ TYPE	I 1 ISLAND CREATION	PN1 WETLAND RESTORATION	I3 ISLAND CREATION
ACREAGE (AC) INITIAL COST	200 $14,800	200 $14,400	110 $14,400
FEDERAL SITE REPLACEMENT	0	0	0
ENVIRONMENTAL CONCERNS/CRITERIA	Nursery, spawning and foraging habitat	Nursery, spawning and foraging habitat	Nursery, spawning and foraging habitat
FOR:	Shallow water habitat	Shallow water habitat	Shallow water habitat
DISPOSAL AREA MITIGATION	None, site selection to avoid critical areas*	None, site selection to avoid critical areas*	None, site selection to avoid critical areas*
DISPOSAL AREA MITIGATION COSTS	0	0	0
TOTAL INITIAL COSTS	$14,800	$14,400	$14,400
AMORTIZED FIRST COSTS	$1,314.8	$1279.3	$1279.3
ANNUAL O&M REQUIREMENTS	900cy	900cy	900cy
AVG. ANNUAL MAINT. COST	$2.3	$2.3	$2.3
TOTAL AVG. ANNUAL COST	$1,317.2	$1,281.6	$1.281.6

* Final site boundary will be based on detailed benthic testing in Preconstruction, Engineering and Design (PED) phase

TABLE 3-17
CYCLE 7 DISPOSAL AREA SCHEME SELECTION
(COSTS IN THOUSAND DOLLARS)
FOR
LOWER BRANDYWINE RANGE

SITE NAME/ TYPE	RD4 BEACHFILL	OB4 OVERBOARD	CM2 UPLAND	MS19 SANDSTOCK PILE	CM4 BEACHFIL L	CM5/6 BEACHFIL L	L4 BEACHFIL L	L5 SANDSTOCK PILE
ACREAGE (AC) INITIAL COST	100 $32,680	170 $33,855	140 $27,570	200 $25,080	100 $32,680	200 $32,680	100 $32,680	200 $25,080
FEDERAL SITE REPLACEMENT	0	0	0	0	0	0	0	0
ENVIRONMENTAL CONCERNS/CRITERIA	NONE	Blue crab wintering, critical fish wintering area	NONE	Nursery, spawning and foraging habitat	NONE	NONE	NONE	Nursery, spawning and foraging habitat
FOR:	-----	Deep water habitat	-----	Shallow water habitat	-----	-----	-----	Shallow water habitat
DISPOSAL AREA MITIGATION	NONE	Due to large quantities, mitigation by alternative deep water site improvement	NONE	None, site selection to avoid critical areas*	NONE	NONE	NONE	None, site selection to avoid critical areas*
DISPOSAL AREA MITIGATION COST	0	11,285	0	0	0	0	0	0
TOTAL INITIAL COSTS	$32,680	$33.855	$27,570	$25.080	$32,680	32,680 29022	32,680 29033	25,080 2,228.1
AMORTIZED FIRST COSTS	$2903.3	$3,007.7	$2449.3	$2,228.1	$2903.3	0 15.0	0 15.0	0 15.0
ANNUAL O&M REQUIREMENTS	6000cy	6000cy	6000cy	6000cy	6000cy	2918.3	2,918.3	2,243.1
AVG. ANNUAL MAINT. COST	$15.0	$15.0	$15.0	$15.0	$15.0			
TOTAL AVG. ANNUAL COST	$2,918.3	$3,022.7	$2,464.3	$2,243.1	$2918.3			

* Final site boundary will be based on detailed benthic testing in Preconstruction, Engineering and Design (PED) phase

Based on the costs shown in Table 3-14, LC 9 (Port Mahon) or C 13 (Alder Cove) were determined to be the NED disposal plans for the disposal of dredged material associated with Lower Liston/ Upper Cross Ledge Range. Due to the closeness of the cost comparisions, final selection will await the findings of the PED studies. FR 28/ LC 10 (sand stockpiles off of Kitts Hummock and Pickering Beach, shown in table 3-15) was determined to be the NED disposal plan for the disposal of dredged material associated with the Lower Cross Ledge/Upper Miah Maull Range. If benthic studies, conducted during PED phase, reveal that significant mitigation is required for sand stockpile areas then beachfill options could become the NED plan. Table 3-16 shows island creation at I 3 (lower Middle Shoal), and wetland restoration at PN 1 (Maurice River Cove area) were determined to be the NED disposal plan for the disposal of dredged material associated with the Lower Miah Maull/Upper Brandywine Range. Again the closeness of the cost comparision will force final selection to wait for the results of the PED studies. Sand stockpiles off of Lewis, Broadkill, and Slaughter Beach (Table 3-17) were determined to be the NED disposal plan for the disposal of dredged material associated with the Lower Brandywine Range. Final selection of these options will await completion of the detailed benthic studies to be conducted durning the PED phase. If the studies reveal that significant mitigation is reuired for sand stockpile areas then the beachfill options could become the NED plan.

The range areas and sites listed below, jointly make up the disposal alternatives to use of Buoy #10 for Reach E of the Main Channel deepening of Delaware Bay (see Figure 3-15).

RANGE	SITE NAME/LOCATION	TYPE
LOWER LISTON /UPPER CROSS LEDGE	LC 9 / PORT MAHON C 13 / ALDER COVE	WETLAND RESTORATION ISLAND CREATION
LOWER CROSS LEDGE /UPPER MIAH MAULL	FR 28 / OFF OF KITTS HUMMOCK BEACH LC 10 / OFF OF PICKERING BEACH	SAND STOCK PILE
LOWER BRANDYWINE RANGE	L5 / OFF OF LEWIS, BROADKILL, MS 9 / SLAUGHTER BEACH	SAND STOCK PILE
LOWER MIAH MAULL /UPPER BRANDYWINE	PN 1 / MAURICE RIVER COVE AREA I 3 / LOWER MIDDLE SHOAL	WETLAND RESTORATION ISLAND CREATION

LEGEND

UPLAND *

AQUATIC ♦

BEACHFILL o

DELAWARE RIVER
COMPREHENSIVE NAVIGATION
REACH E STUDY AREA
MAIN CHANNEL
DEEPENING
DISPOSAL OPTIONS
PHILADELPHIA DISTRICT
CORPS OF ENGINEERS

Figure 3-15

3.5 Tentatively Selected Plan

In order to select the optimum channel alternative, economic analyses were run on each of the three options discussed in section 3.3. Each option was evaluated at one-foot increments ranging between 41 and 46 feet mlw. The purpose of these analyses was to identify and measure the economic impacts of each plan, to determine the plan that maximizes net economic benefits, considering the costs associated with construction and maintenance of the plan for the 50-year study period. Refer to the Plan Formulation Section of the main report for a detailed discussion of the analyses and their results.

Based on a comparison of the economic costs and benefits associated with the various channel depths, the 45-foot depth was identified as optimum, regardless of channel option. This depth maximized net benefits through the increased navigational efficiencies of vessels using six of the seven oil refineries located on the river, as well as Conrail's Pier 122 facility, which imports iron ore.

Of the three channel options, the minimum width asymmetric channel is least expensive, and least efficient. This option is economically justified, as the increased depth would benefit vessels transporting cargo to the six oil refineries and Conrail's iron ore facility. However, out bound traffic (exporting coal, scrap, and container movement) requires its own separate channel below Philadelphia Harbor to safely handle the large amount of traffic (over 38,000 ship movements per year in each direction), and would not benefit from this option.

The wider asymmetric channel would benefit the same vessels as the narrower asymmetric channel. Benefits to these vessels would increase, however, as they would be able to travel faster than they could with the narrower channel. The benefits associated with reduced travel times were found to out weigh the higher costs associated with construction and maintenance of a wider channel. However, as with the minimum width asymmetric channel, this option would be of no benefit to the exporting vessels as they require a separate outbound channel to safely handle the large amount of outbound traffic.

The two way, full-width channel is the most expensive and most efficient. This option offers further operating savings to inbound vessels using the six refineries and iron ore facility as they will be able to travel faster and safer than a narrow asymmetric channel. The full width channel has estimated import benefits that are seven percent higher than the more efficient asymmetric channel.

In addition, the outbound vessels using Conrail Pier 124, which exports coal, would also benefit, as would Packer Avenue Terminal in the upriver to the Beckett Street Terminal in Camden, New Jersey. The additional coal and scrap exports, plus new container traffic that would only use the Delaware River with a full width channel, provide approximately 20 percent of the project benefits. Additional benefits would be gained by vessels using these facilities to import and export dry commodities. Together these benefits more than offset the additional cost of dredging and disposal associated with the incremental width between the asymmetric channel and full width channel.

The selected plan consists of a navigation project extending from deep water in Delaware Bay to the Beckett Street Terminal in Philadelphia Harbor, a distance of about 102.5 miles. The selected plan provides for a full-width channel with a 45-foot depth at mean low water and an allowable dredging overdepth of two feet. The channel sideslopes are 3 horizontal to 1 vertical. The selected channel dimensions allow for navigation practices similar to existing conditions, which allow full use of the tide range by inbound vessels. Through Philadelphia Harbor up to the Beckett Street Terminal, the 400-500-foot west side channel would be deepened from its current 40-foot depth. A trapezoidal access channel would be provided to the bulk berths at the Beckett Street Terminal. The channel width would be 800 feet from the Philadelphia Naval Yard to Bombay Hook, DE, and then 1,000 feet in Delaware Bay.

The tentatively selected plan also includes widening of channel bends for safety purposes. A two space anchorage would be provided at Marcus Hook within its existing limits, and an additional portion of the Marcus Hook anchorage would be deepened to allow vessel turns into refinery docks at Marcus Hook. Preliminary indications are that the proposed project would likely require relocation of several pipelines crossing the river. Pipeline relocations will be addressed as part of the Preconstruction, Engineering and Design (PED) studies. Navigation aids would require only minor modification.

An estimated 50,100,000 cubic yards of material would be dredged to deepen the currently authorized 40-foot channel to 45 feet. The selected disposal plan includes use of site 17O for initial construction in the upper Delaware River (Reach A), site 15D for construction in Reach B, the Raccoon Island site for construction in Reach C, and the Federally owned Reedy Point North and South disposal sites and the Raccoon Island site in Reach D. Hydraulic pipeline dredging techniques would be employed to remove material in Reaches A and B, except for the removal of rock in Reach B. This technique provides direct movement of material, via pipeline, from the dredging location to the upland disposal site. The rock would require blasting and a bucket dredge to remove the material from the channel. The approximately 45,100 cubic yards of rock is considered clean material that would be suitable for beneficial use. A plan for such use will be developed as part of the PED phase of project development. In Reaches C and D, hopper dredging techniques would be employed. This technique initially places material in the hopper of the dredge. The dredge is then moved to the disposal site, where the material would be directly pumped from the dredge to the upland disposal site.

Based on the findings of 1991 vibracore explorations, Reach E (ie. the Delaware Bay portion of the project area) was divided into four subreaches, E-1 through E-4. These subreaches are identified on Figure 3-16. An estimated 14.8 million cubic yards of material would be dredged from this area for initial construction of the project. This material is slated for beneficial use. Subreaches E-1 and E-3 consist of fine-grained sediments; subreaches E-2 and E-4 are predominantly coarse-grained. A summary of the gradation analysis is contained in Table 3-18. The results of the vibracore analyses can be found on Tables 5-22 and 5-23. The coarse-grained sediments are suitable for beachfills, oyster bed

SCALE

1 Inch = 6 Miles

LEGEND

Channel indicated thus:

DELAWARE RIVER COMPREHENSIVE NAVIGATION STUDY

MAIN CHANNEL DEEPENING CHANNEL VIBRACORE LOCATIONS

PHILADELPHIA DISTRICT CORPS OF ENGINEERS

Figure 3-16

Table 3-18

Delaware River
Comprehensive Navigation Study
Sediment analysis for reach E Disposal

REACH	RANGE	STATION	QUANTITY(CY)	MATERIAL	VIBRACORES
E 1	Lower Liston	334+600 to 384+222	1,260,000	SILT	DRV 14-16
E 2	Cross Ledge	384+222 to 404+815	712,800	SAND	DRV 17
E 2	Cross Ledge-Miah Maull	Bend	191,800	SAND	V-1
E 2	Miah Maull	404+815 to 439+000	3,065,900	SAND	DRV 18-20
E 3	Miah Maull	439+000 to 447+507	1,070,800	CLAY-SILT	DRV 22
E 3	Miah Maull-Brandywine	Bend	265,350	CLAY-SILT	W-1
E 3	Brandywine	447+507 to 453+000	657,900	CLAY-SILT	DRV 22
E 4	Brandywine	453+000 to 537+000	7,646,900	SAND	DRV 23-27
			14,870,650		

*TOTALS

11,616,600 CY SAND - Suitable for beach for disposal, oyster bedcreation, open water disposal or upland disposal

3,254,050 CY Clay-Silt - upland disposal

NOTES:

1. Material information based on July 91 vibracores DRV 14 thru 29 and U-1 thru W-1.

2. Quantities based on 1982-1983 channel survey, depth of excavation = elevation - 47 C.O.E. MLW datum.

creation, wetland creation and offshore stockpiling, while the fine-grained sediments may be used for wetland creation or disposed of in an upland site. Approximately 11.6 million cubic yards of granular material from subreaches E-2 and E-4 will be utilized to create sand stockpiles for future beach restoration projects. The remaining 3.2 million cubic yards will be used for wetland creation.

Additional studies will be conducted during the PED phase of project development to finalize beneficial use plans. These studies will include a benthic invertebrate sampling program to assess habitat quality at selected sites. Bioassays and bioaccumulation studies will also be necessary to determine the impact of open water disposal on aquatic life. Along with biological studies, detailed engineering studies will be conducted to develop feasible designs for all options. Due to the varying nature of the bay sediments and the distance between vibracore holes (1 to 2 miles), an acoustic subbottom profile will be performed in the channel in subreaches E-2 through E-4 to accurately delineate the changes in material. This work will be performed prior to preparation of plans an specifications, thus preventing the unnecessary and environmentally unacceptable discharge of fine grained materials. An acoustic subbottom profile will not be conducted in in subreach E-1 due to the slated use of the fine-grained sediments for wetland creation.

The use of sand stockpiles for beach nourishment will be the responsibility of the State of Delaware. A State-owned hydraulic pipeline dredge would be used to move sand from stockpiles to appropriate beaches. Kitts Hummock Beach, Pickering Beach, Lewis Beach, Broadkill Beach and Slaughter Beach have been identified as beaches that would benefit from periodic nourishment. The rate of nourishment can not be determined at this time, as it is dependent on a number of factors including rates of erosion, storm events, desired beach profiles and State funding.

The existing National Park, Oldmans, Pedricktown North, Pedricktown South, Killcohook, Penns Neck and Artificial Island sites would continue to be used for disposal of material attributed to maintenance of the existing 40-foot project, with the new sites accommodating material from the added five-foot increment. Maintenance dredging quantities would increase an estimate 756,000 cubic yards per year with a five-foot deepening. The selected dredged material disposal plan is sufficient to handle both initial construction and maintenance requirements for the 50-year project life.

Full realization of project benefits would require additional dredging at several private facilities located along the Delaware River, to provide access channels and berthing areas with depths compatible with a deeper main channel. These access channels and berthing areas are currently maintained for compatibility with the existing 40-foot project, but would require deepening to 45 feet and subsequent maintenance. Associated dredging projects would be required at the Mobil, Sun, British Petroleum, Atlantic, Gulf and Eagle Point oil refineries, as well as the Conrail, Packer Avenue and South Jersey Port Corporation shipping terminals. The initial project construction at these nine facilities would total approximately 2.4 million cubic yards of dredging. This dredging would be accomplished with a hopper dredge, with upland disposal of

dredged material at the American Dredging Company's White's Basin dredged material disposal area. In addition to dredging, the bulkhead at the British Petroleum oil refinery would need to be replaced. The pilings that provide the foundation for this bulkhead are insufficient to support the bulkhead with a five-foot deepening.

These associated project features are all within existing industrial facilities that are currently maintained for the 40-foot navigation channel. Dredging for access channels and berthing areas would be modifications to existing features as opposed to new construction. This work would require Federal and State approvals, including Department of the Army permits pursuant to Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act, State Water Quality Certification, and approvals with regard to the various State Coastal Zone Management Programs. These approvals have been obtained for past maintenance activities. Environmentally acceptable plans that include appropriate dredging windows and upland disposal of dredged material can be developed for this work that would lead to securing the necessary permits. As such, no significant problems are anticipated with respect to associated project features.

3.6 Mitigation Measures

The appropriate application of mitigation is to formulate a project that avoids or minimizes adverse impacts first, and compensates for impacts only as a final alternative. This concept has been incorporated into formulation of the recommended plan of improvement.

The most important step in the mitigation process is avoidance of impacts. The dredged material disposal area screening analysis was effectively used to select disposal sites that do not contain valuable or sensitive ecological habitats. The analysis resulted in the selection of three additional disturbed areas that have previously been used for dredged material disposal. These areas are predominantly vegetated with common reed and cultivated agricultural species. Site 170 is the only site with habitat diversity. This site contains areas dominated by oldfield herbaceous vegetation, shrubs and mature trees. Wetland habitats in the vicinity of disposal sites will be preserved by aligning dikes to exclude these areas. As such, the proposed upland disposal sites do not contain wetland or other aquatic habitat types. The continued use of these sites for dredged material disposal operations would have no long-term adverse impacts on the quality of the natural or social environment within the study area.

Avoidance would also be employed to lessen the impact of dredging on the aquatic environment. Coordination is on-going with the Delaware Basin Fish and Wildlife Management Cooperative with regard to appropriate seasonal dredging restrictions. Previous restrictions precluded bucket dredging and/or overboard disposal in the Delaware River from 1 March through 31 May and from 1 September through 30 November. These restrictions were in place to prevent disruption of anadromous fish migrations through creation of excessive turbidity and decreased dissolved oxygen concentrations. No restrictions were required for hydraulic or hopper dredging with upland disposal. New restrictions are now

being employed with regard to bucket dredging, blasting and overboard disposal. Between Delaware Bay and the Delaware Memorial Bridge, bucket dredging, blasting and overboard disposal are restricted from 1 March through 30 June. Between the Delaware Memorial Bridge and the Betsy Ross Bridge, which is above the upstream limit of the proposed project, bucket dredging, blasting and overboard disposal are restricted from 15 March through 31 May and from 1 September through 30 November. With regard to hydraulic dredging, a 3-year study will be initiated in 1992 to consider potential impacts on fishery resources in the Delaware River. The results of this study will be used to evaluate the need for hydraulic dredging restrictions. The need for such restrictions can not be determined at this time. The Corps is providing funding to the Delaware Basin Fish and Wildlife Management Cooperative in support of this work. Chemical testing of channel sediments and groundwater in the vicinity of disposal sites would assist in avoiding water quality impacts by facilitating the identification of problems before they become significant. The monitoring and control of effluent leaving an upland disposal site would also minimize potential water quality impacts by limiting the concentration of suspended sediments in the effluent.

Through appropriate consideration of the environment during plan formulation, and the use of established procedures during construction and maintenance of the proposed project, significant adverse environmental impacts would be avoided and/or minimized. Construction of replacement habitats is not required to mitigate with-project losses.

Throughout the course of this study the Corps has endeavored to avoid or minimize adverse impacts to cultural resources. With regard to the proposed disposal sites, only Site 170 has the potential to contain significant cultural resources. In the next phase of study a cultural resources investigation of the identified prehistoric and historic sites at 170 will be undertaken, and the results coordinated with the New Jersey State Historic Preservation Officer (SHPO). With regard to the proposed channel deepening and bend widening, all bend widening areas, and all areas within the channel with natural depths of 40 feet or greater, will be subjected to a remote sensing survey in the next phase of study. In consultation with the appropriate state historic preservation officer, the Corps will conduct an underwater examination of each remote sensing target that has the potential to be a significant historic resource.

If significant cultural resources are identified at proposed disposal site 170 or found within proposed project areas in the Delaware River, the Corps will follow the procedures outlined in the Advisory Council's regulations, 36 CFR Part 800, to avoid or minimize adverse impacts to significant cultural resources.

3.7 Comparative Impacts of Alternatives

Impacts on significant environmental resources are displayed on two tables. Table 3-19 provides a summary comparison of impacts with regard to alternative channel plans. The magnitude of stated impacts would increase for each option as channel depth increases from 41 to 46 feet below mean low water. Table 3-20 provides an impact comparison with regard to dredged material disposal alternatives. The numbers used in this table do imply the relative magnitude of the impact for each resource, but are not intended to be additive between resources. As such, a final numerical rating for each candidate disposal site can not be obtained from Table 3-20. The no action alternative is defined as continued maintenance of the existing navigation channel, which is 40 feet deep mlw.

Table 3-19 Comparative Impacts of Alternate Channel Plans of Significant Resources.

Resource	No Action	Option 1 Full Width, Two Way Channel Deepening	Option 2 Minimum Width Asymmetric Channel	Option 3 More Efficient Asymmetric Channel
Surface Water Quality	Short-term increase in suspended sediment levels during maintenance dredging cycles. Sediment testing indicates little contamination potential.	Of the three channel options, maximum duration of increased suspended sediment levels during construction; maintenance impacts similar to no action.	Of the three channel options, shortest duration of increased suspended sediment levels during construction; maintenance impacts similar to no action.	Of the three channel options, medium duration of increased suspended sediment levels during construction; maintenance impacts similar to no action.
Groundwater Quality	No Impact	No Impact	No Impact	No Impact
Wetlands	No Impact	No Impact	No Impact	No Impact
Shallows	No Impact	No Impact	No Impact	No Impact
Fin and Shellfish	No impact with appropriate seasonal dredging restrictions.	No impact with appropriate seasonal dredging restrictions.	No impact with appropriate seasonal dredging restrictions.	No impact with appropriate seasonal dredging restrictions.
Benthos	Periodic disruption to benthic community within limits of channel during maintenance dredging cycles.	Maximum disruption of three channel options during construction; disruption during maintenance similar to no action.	Least disruption of three channel options during construction; disruption during maintenance similar to no action.	Medium disruption of three channel options during construction; disruption during maintenance similar to no action.
Endangered Species	No Impact	No Impact	No Impact	No Impact
Cultural Resources	No Impact	Medium to high potential for impacts to shipwrecks at bend widenings; medium potential for impacts in the channel.	Medium to high potential for impacts to shipwrecks at bend widening; low potential for impacts in the channel.	Medium to high potential for impacts to shipwrecks at bend widenings; low to medium potential for impacts in the channel.
Navigation/Shipping	No change; continued inefficiencies in commerical navigation.	Maximum improvement to both inbound and outbound commercial navigation.	Minimal improvement to inbound commercial navigation only.	Maximum improvement to inbound commercial navigation only.

Table 3-20 Comparative Impacts of Alternative Dredged Material Disposal Sites on Significant Resources

Site	Terrestrial Habitats	Aquatic Habitats	Wetland Habitats	Ground Water Quality	Surface Water Quality	Threatened & Endangered Species	Cultural Resources
Reach A							
17G	-2	0	-1	0*	-1	0	-1*
170	-2	0	0	0*	-1	0	-2
Reach B							
15D	-2	0	0	0*	-1	0	0
15E	-2	0	-1	0*	-1	0	0
15F	-2	0	0	0*	-1	0	-1*
15G	-2	0	0	0*	-1	0	0
15I	+1	-3	+1	0	-2	0	-1*
15J	+1	-3	+1	0	-2	0	-1*
160	+1	-3	+1	0	-2	0	-1*
Raccoon Island	-1	0	0	0*	-1	0	0
Reach C							
20A	+1	-2	+1	0	-2	0	-1*
23C	-3	0	0	-1	-1	0	-1
23D	-3	0	0	-1	-1	0	-1*
24E	+1	-2	+1	0	-2	0	-1*
24G	+1	-2	+1	0	-2	0	-1*
240	-3	0	0	-1	-1	0	-1*
Reach D							
27I	+1	-3	+1	0	-2	0	-1*
Thin Layering	0	-1	0	0	-3	0	0

Table 3-20 Comparative Impacts of Alternative Dredged Material Disposal Sites on Significant Resources (Cont'd)

Terrestrial Habitats:	-3	=	Loss of agricultural land and various upland habitats from undeveloped site
	-2	=	Loss of agricultural land and successional habitat from previously used dredged material disposal site
	-1	=	Loss of successional habitat from previously used dredged material disposal site
	0	=	No effect
	+1	=	Potential creation of upland habitat
*Aquatic Habitats:	-3	=	Significant loss of tidal flat and shallow water habitats
	-2	=	Significant loss of deep water habitat and some shallow water habitat
	-1	=	Temporary disturbance of bottom habitat during disposal operation
	0	=	No effect
Wetland Habitats:	-1	=	Loss of five to ten acres of non-tidal wetland habitat
	0	=	No effect
	+1	=	Potential creation of wetland habitat with fill height restriction
Groundwater Quality:	-1	=	Potential for disposal area leachate reaching underlying aquifers until fine grained dredged sediments accumulate and seal site
	0	=	No effect, aquatic disposal
	0*	=	No effect, upland site was previously used for dredged material disposal and is effectively sealed from underlying aquifers by past deposition of fine grained dredged sediments
Surface Water Quality:	-3	=	Excessive turbidity and associated water quality impacts as a result of unconfined dredged material disposal operations
	-2	=	Excessive turbidity and associated water quality impacts as a result of aquatic dike construction; minor turbidity and associated water quality impacts during disposal operations due to site dewatering practices

Table 3-20 Comparative Impacts of Alternative Dredged Material Disposal Sites on Significant Resources (Cont'd)

Surface Water Quality: (Cont'd)	-1	=	Minor turbidity and associated water quality impacts during disposal operations due to site dewatering practices
	0	=	No effect
Threatened & Endangered Species:	0	=	No effect
Cultural Resources:	-2	=	Potential impacts to known significant prehistoric or historic site
	-1	=	Potential impacts to possible prehistoric or historic sites
	-1*	=	No data, but assumed potential impacts
	0	=	No effect

* The impacts associated with the -3 and -2 categories could be partially mitigated by filling the aquatic sites such that they provide shallow water or wetland habitats subsequent to disposal.

4.0 Affected Environment

4.1 Study Area

4.1.1 Location

The study area encompasses the Delaware River estuary from Philadelphia, Pennsylvania to the mouth of Delaware Bay (Figure 4-1). The area extends over 100 river miles, and borders 10 counties in the states of Pennsylvania, New Jersey and Delaware (Figure 4-2). The upstream portion of the study 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, 1988a). Below Wilmington, Delaware, the river broadens into the Delaware Bay. Although 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.

In the following sections, the Delaware River is defined as the portion of the study area from Philadelphia, PA to Liston Point, DE (RM 48.2); Delaware Bay is defined as that portion of the estuary falling between Liston Point and the mouth of the bay. The entire study area is referred to as the Delaware estuary.

The western shoreline of the Delaware River between Philadelphia and Wilmington is characterized by piers, bulkheads, industrial complexes, protected and unprotected high ground and dredged material disposal areas (Tyrawski, 1979). The Philadelphia Naval Base, the mouth of the Schuylkill River and Tinicum Island are also located along this portion of the river. The Christina River is located along the western portion of the shoreline, south of Wilmington. South of the Christina River to Liston Point the shoreline is characterized by dredged material disposal areas and wetlands (Tyrawski, 1979). Pea Patch Island, the Chesapeake and Delaware Canal and Reedy Island are also located along this portion of the Delaware River shoreline.

The eastern shoreline of the Delaware River from Philadelphia to Wilmington is predominantly filled ground, bulkheads, piers, industrial complexes and dredged material disposal areas (Tyrawski, 1979). Gloucester City, the mouths of Big Timber, Woodbury and Mantua Creeks, the City of Paulsboro, Chester and Monds Islands and the mouths of Raccoon and Oldmans creeks are also located along the eastern shoreline through this stretch of the river. From just above the Delaware Memorial Bridge downstream, the shoreline is heavily industrialized. Below RM 62 the shoreline returns to natural conditions including tidal wetlands (Tyrawski, 1979). Mill and Alloway Creeks, the Salem River and Artificial Island are all located south of Pennsville, New Jersey.

Figure 4-1
Delaware River
Comprehensive Navigation Study,
River Mile Location Map

Figure 4-2
Delaware River
Comprehensive Navigation Study,
County Map

PHILADELPHIA DISTRICT, CORPS OF ENGINEERS
DECEMBER 1982

The Delaware Bay region is an area of small towns, farmlands and salt marshes. Dover, Delaware is the largest city in the region, although it is not located directly on the bay. Miles of saltmarshes and numerous wildlife management areas are found along the bay shorelines (DRBC, 1988a).

4.1.2 Socio-economics

There are three states and 10 counties within the limits of the study area (Figure 4-2). Total population of this area in 1985 was projected to be 2,194,600, 985,900 and 607,100 in Pennsylvania, New Jersey and Delaware, respectively. County totals range from the heavily urbanized Philadelphia County with a population of 1,637,400 to the predominantly rural Salem County with a population of 65,200. Philadelphia, the major metropolitan center, is the most densely populated with 12,693 people per square mile, while Sussex County, Delaware had the lowest density with 110 people per square mile. The most heavily populated portion of the study area lies between Philadelphia, Pennsylvania and Wilmington, Delaware. The principal municipalities include Philadelphia, Pennsylvania, Camden, New Jersey, Chester, Pennsylvania and Wilmington, Delaware.

An extensive complex of industrial plants are located on both sides of the Delaware River. Major industries produce goods such as chemicals and allied products, petroleum, primary metals, paper and allied products, processed foods and electric power. The area is considered to be one of the world's greatest concentrations of heavy industry, and is the nation's second largest complex of oil refining and petrochemical plants (DRBC, 1988a).

In 1980, the economic sector employing the most people in the area was the service industry, followed by manufacturing. This is the reverse of the situation in 1970. Wholesale and retail trade remained a strong third during both 1970 and 1980.

The Ports of Philadelphia are a significant part of the regional economy. In 1986, there were approximately 100,000 port related jobs in the Delaware Valley, which generated one billion dollars of income. State and local taxes, including income, profit and sales taxes, amounted to over 92 million dollars.

The Delaware River port complex, located between Trenton, New Jersey and Wilmington, Delaware is considered to be the world's busiest freshwater port (Brezina, 1988). About 25 piers, wharves and docks are located in the 133 miles port system. Most of these service private facilities along the Delaware River. Public port facilities are located at the cities of Philadelphia, Pennsylvania; Camden, Gloucester and Salem, New Jersey; and Wilmington, Delaware. Several large oil refineries are located along the Delaware River between Philadelphia and Delaware City including Sun, Chevron, Mobil, Texaco, BP, Coastal and Atlantic. These refineries generate the majority of commodity movements on the region's waterways either by receipt of crude oil and refined products or by shipment of petroleum products and chemicals to other facilities in the region or domestic ports. Major dry and liquid bulk facilities are also found along the Delaware River at Wilmington, Delaware; Port Richmond in

Northeast Philadelphia; Paulsboro, New Jersey; Greenwich Point in South Philadelphia; and along the Schuylkill River in Philadelphia. The numerous tributaries to the Delaware River support a variety of industries and the waterways are used primarily for delivery of fuel oils and raw materials or shipment of products. The tributary projects off of Delaware Bay also support a variety of smaller industries including fishing and vessel repair.

In addition to commercial and industrial activities, the Delaware River Study area is also used for recreation. Recreation within the upstream portion of the study area, between Philadelphia and Wilmington, has increased in the last several years, primarily due to improvements in water quality. Recreational parks in Philadelphia and Camden, waterfront restaurants, marinas and residential development are all signs of new interest in this old, urban waterfront. Water-related recreation in the Delaware River between Wilmington and Delaware Bay includes boating, sailing, fishing, limited swimming and waterfowl related activities such as hunting. Many access areas for boating and fishing are found in both New Jersey and Delaware. Delaware Bay is heavily used for recreation. Swimming beaches are scattered all along the shorelines. Boating and fishing are also very popular.

4.2 Physical Resources

4.2.1 Climate

The entire 10 county study area lies within one broad climatic zone, which is considered subtropical. In general, the climate is mild with a few brief hot, humid periods in summer and cold, windy periods in winter. Summer weather patterns are influenced by maritime tropical air masses, in which high pressure systems dominate and remain stable for several days at a time. Weather systems in the winter are generally more intense because of rapidly moving fronts and continental, polar air masses. Air masses change frequently during the spring and fall. Mean annual temperatures in the estuary are 55 to 58 degrees F.

Precipitation, about 45 inches annually, is well distributed throughout the year, with generally more than three inches reported every month. The driest month is October, with rainfall varying between 2.5 and 3.0 inches. Temporary droughts or periods of subnormal rainfall are not uncommon for the area.

4.2.2 Geology

Geologically, the Delaware estuary is situated near the border of two subdivisions, the Appalacian Piedmont province and the Atlantic Coastal Plain province. The Piedmont Plateau lies along the eastern edge of the Appalacian Mountains and runs from New Jersey to Alabama. The rocks of the Piedmont are old, hard and crystalline. They extend downward and toward the Atlantic, forming a platform that supports the Coastal Plain. The Piedmont Plateau borders the western side of the Delaware estuary study area between Philadelphia and Wilmington. At Wilmington, the Piedmont shifts to the west of the estuary, eventually running through Baltimore, Maryland and Washington, D.C. The Coastal Plain physiographic province borders the entire eastern side

of the Delaware estuary study area, as well as the western side of the estuary below Wilmington. The rocks of the Coastal Plain are much younger than those of the Piedmont, and are largely unconsolidated sediments. The Coastal Plain sediment layers are mainly comprised of sands and clays that dip to the southeast, and generally thicken oceanward. The older formations are at or near the surface in the vicinity of the Delaware estuary, and are progressively deeper towards the Atlantic Ocean. The unconsolidated sediments consist of pervious and impervious layers that form a series of aquifers and aquicludes.

Lands bordering the estuary from Philadelphia to the sea are generally flat. Elevations range from five to 10 feet in the lower portion of the estuary, to 20 feet in the vicinity of Wilmington, and 20 to 30 feet at Philadelphia. Slopes near the lower portion of the estuary are generally less than 10 percent, while in the upper portion of the study area slopes vary considerably with many steeper grades. The tributaries to the estuary generally have a flat gradient with few rapids.

4.2.3 Groundwater

Groundwater within the Delaware River basin supplies more than 2.5 million people with drinking water (Brezina, 1988). This water is contained within aquifers, which are porous geologic formations that store or transmit groundwater in appreciable quantities. Significant aquifers underlying the study area include the Raritan, Cape May and Pennsauken in Pennsylvania; the Raritan-Magothy, Englishtown, Mount Laurel-Wenonah and Kirkwood-Cohansey formations in New Jersey; and the Potomac, Magothy, Monmouth, Rancocas, Frederica, Cheswold and Columbia in Delaware.

The primary aquifer units within the Philadelphia to Wilmington reach of the Delaware River belong to the Potomac-Raritan-Magothy formations of Cretaceous age, and the Cape May and Columbia formations of the younger Pleistocene age. The Potomac-Raritan-Magothy 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 overlie areas of the Cretaceous aquifers, and 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 Potomac-Raritan-Magothy formation is composed of sand and gravel interbedded by silt and clay confining units. These Cretaceous deposits are fluvial in character, and therefore are highly variable. Because of this variability, it is assumed that pervious "windows" can occur in the clay units, and the sandy units of the Potomac-Raritan-Magothy formation may be hydraulically interconnected to overlying aquifers.

The Pleistocene Cape May and Columbia formations are predominantly composed of sands and gravels. In areas where windows of sandy materials outcrop in the clays of the Potomac-Raritan-Magothy formation, a hydraulic connection will exist between the shallow water table aquifers in the Cape May and Columbia formations and the underlying Cretaceous aquifers.

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

Groundwater use in the Pennsylvania portion of the study area is limited to a large extent by contamination. Extensive heavy metal contamination of aquifers in urban and industrial areas is common. For example, leachate from landfilling at the Naval Base in Philadelphia has contaminated the Magothy-Raritan aquifer with sulfates, iron and dissolved solids. Industrial and domestic waste disposal practices are causing groundwater contamination in the League Island area and Five Mile Point area in Philadelphia.

In the New Jersey portion of the study area, the Magothy-Raritan aquifer is considered most important. For example, it provides 75 percent of the total water use in Gloucester County. Well yields of up to 1500 gallons per minute (GPM) are common. The contiguous beds of the Kirkwood and Cohansey formations combine to form an aquifer potentially more valuable than the Magothy-Raritan. The Kirkwood Formation is generally an unreliable water source, but it is an important source of recharge for underlying aquifers. Wells in eastern Cumberland County tap the lower Kirkwood aquifer. Yields of up to 800 GPM have been recorded for the Kirkwood-Cohansey aquifer, but it is at present relatively undeveloped and used only for domestic and agricultural supply. The Englishtown, Mount Laurel-Wenonah and Vincentown formations are minor aquifers outcropping in parallel bands between the Magothy-Raritan and Kirkwood-Cohansey aquifers. They are moderately productive, with reported yields between 100 and 500 GPM. They are used primarily for domestic and agricultural supply.

The interface between saltwater and freshwater in the Magothy-Raritan aquifer has moved westward as groundwater withdrawal along the urbanized Delaware River waterfront has increased. Overpumping induces saline intrusion not only from the Atlantic Ocean, but also from the Delaware estuary, and is a potential source of chloride contamination in wells in Salem County. Increased mineralization of the aquifer in Camden County has been traced to an industrial waste dump located over a recharge area near Philadelphia. The aquifer is basically of good quality, however, with isolated hardness, iron, and manganese problems. Quality improves with distance from the outcrop area. The quality of the Magothy-Raritan is closely linked to the quality of the Delaware River, which flows over the outcrop and is hydrologically connected to the aquifer. The quality of the Englishtown, Mount Laurel-Wenonah and Vincentown aquifers is satisfactory. Isolated iron and hardness problems are common, and may require treatment at the well site. The high water table of the Kirkwood-Cohansey aquifer makes it extremely vulnerable to degradation. Its quality is determined by local surface conditions, which have limited the use of the aquifer in some areas. Water quality is generally good, though some pH and iron adjustment may be necessary for industrial use. If land uses with the potential to contaminate groundwater are carefully monitored, the

Kirkwood-Cohansey will be an extremely valuable water source for southern New Jersey in the future.

Due to the geologic similarity between New Jersey and Delaware, groundwater resources can be expected to be abundant in Delaware. In fact, groundwater resources represent 58 percent of Delaware's total available water supply, although presently only 43 percent of the water used in the state comes from groundwater sources. Surface water withdrawals are negligible compared to groundwater use in Kent and Sussex counties. However, surface water use in New Castle County far outweighs groundwater pumpage. The population centers of Wilmington and Newark are located in or near the Piedmont Province, groundwater is far less abundant in the crystalline rocks of the Piedmont than in Coastal Plain sediments. Therefore, these cities take most of their water from surface water sources.

Although several of the prominent New Jersey aquifers are found in Delaware as well, they have different names and may be more or less valuable as aquifers in Delaware than they are in New Jersey. For ease of comparison, the Potomac and Magothy formations in Delaware are of the same origin as New Jersey's Magothy-Raritan aquifer. The Monmouth and Rancocas aquifers in Delaware correlate with the Vincentown and Mount Laurel-Wenonah formations in New Jersey. Delaware's Frederica and Cheswold aquifers are extensions of the Kirkwood Formation in New Jersey, and the Cohansey sands are similar to the Manokin aquifer of Delaware. The Pleistocene deposits are the most important present and future aquifer in the State of Delaware. They are and will continue to be most valuable for water supply in Sussex and southern Kent counties. Other productive aquifers are the Manokin, Potomac, Piney Point, Cheswold, and Frederica formations, all of which have extensive supplies untapped at present.

The quality of all of Delaware's groundwater resources is generally good, although local problems exist. The Potomac, Magothy and Rancocas formations are usually high in iron. Nitrate contamination is a problem near St. Georges in the Monmouth and Pleistocene deposits. The most widespread groundwater quality problem in Delaware is saline encroachment. A high chloride concentration is natural within two miles of Delaware Bay and within one mile of tidal streams. There is some evidence of increased saline intrusion caused by overpumping in the New Castle area.

4.2.4 Hydrology

Hydrologic circulation patterns within the Delaware estuary are a complex phenomenon dependent on a number of environmental factors. As is typical of Atlantic Coastal Plain estuaries, astronomical tides within the Delaware estuary are semidiurnal. Flood and ebb tides each last approximately six hours. The mean tidal range is from 4.1 feet at the bay mouth to 6.8 feet at Trenton, New Jersey, although tidal amplitudes to 13 feet have been reported during periods of extreme flood and ebb conditions. Variation in tidal amplitude occurs over the course of the estuary due to the opposing forces of convergence of the sides of the estuary, which tends to increase the amplitude,

and friction, which tends to decrease it. Current velocity and direction within the estuary are dependent upon tidal stage, freshwater discharge, rainfall, local winds acting directly on Delaware Bay waters, regional winds acting over adjacent continental shelf waters, Coriolis effects caused by the earth's rotation, and the interaction of currents with bottom topography and shoreline geometry. All of these factors contribute to the considerable variability in water level, direction and velocity that occurs in the Delaware estuary and it's tidal tributaries.

A major concern with regard to hydrology of the Delaware estuary is salinity intrusion. Salinity is a critical factor affecting the distribution of organisms within the estuary. Organisms subjected to salinities outside of their acceptable tolerance limits will undergo stress that can adversely impact their growth, reproduction and mortality. Salinity may also impact society through contamination of municipal and industrial freshwater supplies. A 1978 water use inventory conducted by DRBC estimated that municipal intakes for Philadelphia, Bristol and Lower Bucks withdrew 264 million gallons per day (mgd) from the Delaware estuary. These intakes are located on the Delaware River at river miles 110, 119 and 122, respectively. In addition, the 1978 survey identified 56 industrial plants that withdrew directly from the estuary for a variety of purposes including generation of electricity, electric and gas utilities, petroleum refining, inorganic chemical processes and steel manufacturing.

Salinity distribution within the Delaware estuary is the result of saltwater inflow from the Atlantic Ocean and freshwater inflow from the upstream tributary drainage area. Salinity at the mouth of the bay is typically 30 to 31 parts per thousand (ppt). Freshwater inflow to the study area is from two major sources, the Delaware and Schuylkill rivers. Average annual flow of the Delaware River at Trenton, New Jersey is 11,700 cubic feet per second (cfs). Average annual flow at the mouth of the Schuylkill River is 2,960 cfs. Under normal flow conditions, salinity in the upstream portion of the study area is typically less than 0.1 ppt.

The Delaware River basin has experienced eight extended periods of drought since 1905. The most severe drought occurred from 1961 to 1966. Awareness of the impacts of salinity in the Delaware estuary significantly increased during this period of time. Low rainfall and aquifer depletion led to record low natural surface flows in 1964 and 1965. The lowest natural average monthly flow at Trenton, New Jersey was 1,106 cfs, recorded in September of 1964. It is estimated that this drought had a recurrence interval of several hundred years in the upper river basin and about 100 years at the mouth of the Schuylkill River.

The intrusion of record high levels of salinity into the upper reaches of the Delaware estuary during the 1960's drought threatened municipal water supply systems, and adversely affected the operations of direct industrial withdrawal users. In 1967, the Delaware River Basin Commission adopted water quality standards to maintain reasonable levels of salinity throughout the Delaware estuary, and to protect both withdrawal and instream users. A salinity control

point has been established at river mile 98 near Camden, New Jersey, with associated chloride and sodium water quality standards of 0.18 ppt and 0.10 ppt, respectively as a maximum 30-day average (Albert and Kausch, 1988). In order to achieve this goal, a minimum flow objective of 3,000 cfs at Trenton has been established for normal flow periods to manage salinity intrusion. During periods of drought, the minimum flow objective at Trenton is 2,500 cfs to 2,900 cfs, which is considered sufficient to maintain appropriate salinity levels within the upper portion of the estuary. Seventeen basin reservoirs have been utilized in the past to augment river flow. If these reservoirs did not exist, drought flows would be extremely low, potentially damaging the biota of the Delaware estuary as well as water supplies.

4.2.5 Water Quality

The Delaware River Basin Commission (DRBC), a four-state Federal compact agency, is responsible for managing the water resources within the entire Delaware River basin. Pursuant to Section 305(b) of the Clean Water Act (33 U.S.C. 1251 et seq.), the DRBC prepares biennial assessments of water quality for the 339-mile long Delaware River and bay. In order to more accurately characterize the entire river, the DRBC has divided the area into six water quality zones. This study encompasses water quality zones three through six, as defined by the DRBC. The information presented in this section was obtained from the Delaware River Basin Commission's 1988 and 1990 Delaware River water quality assessment reports (DRBC, 1988a, 1990).

Water quality zones three and four extend from northeast Philadelphia to the Pennsylvania-Delaware-New Jersey state line at Marcus Hook. This 30-mile reach has historically been one of the most polluted rivers in the United States. In this area the river runs through the Philadelphia-Camden metropolitan area and adjacent urban and suburban areas. Extensive networks of combined sewers discharge untreated wastewater into the river during wet and dry periods. Industrial development is extensive, major industries include oil-refineries and paper manufacturing. Many industries discharge wastewater directly into the river after treatment. Since 1968, cleanup efforts have resulted in a 76 percent reduction in the amount of oxygen-demanding wastes being discharged to the river. As a result of this effort, major improvements in water quality and fisheries have been observed in recent years.

Tables 4-1 and 4-2 provide 1988-1989 water quality data collected by the DRBC in zones three and four. The DRBC characterizes water quality in this portion of the estuary as fair to poor. Minimum dissolved oxygen (DO) levels for the summer seasons were as low as 2.0 mg/l. However, the average DO concentration was above the DRBC standard of 3.5 mg/l. In the lower portion of zone four, the average DO was above 4.5 mg/l. pH valves were generally within the range of DRBC standards. Nutrient levels appear high enough to support algal blooms, however, chlorophyl A concentrations were low. During the summer months of 1988 the DRBC secondary contact recreation standard was exceeded in the vicinity of the Benjamin Franklin Bridge. During the summer months of 1988 and 1989, the USEPA recommended primary contact recreation criteria was exceeded from river mile 107 to river mile 88.

Table 4-1

Summary of 1988 and 1989 Water Quality Data Collected by the Delaware River Basin Commission for Water Quality Zone 3

		Palmyra RM 107	Bray Ross Br RM 105	Allegheny Avenue RM 103	Lehigh Avenue RM102	Benj-Franklin Br. RM 100	Wharton Street RM 99
Dissolved Oxygen (mg/l)	Ave	7.8	7.4	7.4	7.2	7.0	6.8
	Max	12.0	11.8	12.0	12.2	11.7	11.7
	Min	3.8	3.5	3.4	2.7	2.4	2.7
	#	36	36	36	36	36	36
Fecal Coliform M-TEC (#/100 ml)	Ave*	134	249	277	402	525	585
	Max	2066	5600	6300	6000	6000	5200
	Min	6	26	20	30	30	40
	#	32	38	32	32	38	32
E. Coli (#/100 ml)	Ave*	95	161	198	280	343	406
	Max	1600	4400	5800	5400	4800	4900
	Min	3	10	20	20	10	20
	#	32	38	32	32	38	32
Enterococci (#/100 ml)	Ave*	16	22	22	23	36	32
	Max	500	600	780	720	750	680
	Min	2	1	3	2	2	2
	#	32	38	32	32	38	32
Total Phosphorus (mg/l)	Ave	0.11	0.12	0.13	0.13	0.15	0.14
	Max	0.25	0.23	0.30	0.23	0.42	0.21
	Min	0.04	0.04	0.03	0.02	0.06	0.06
	#	36	36	36	36	36	36
Dissolved Ortho-phosphate (mg/l)	Ave	0.07	0.07	0.08	0.09	0.09	0.10
	Max	0.09	0.10	0.10	0.18	0.14	0.18
	Min	0.04	0.05	0.05	0.06	0.06	0.06
	#	10	10	10	10	10	10
Nitrate Nitrogen (mg/l)	Ave	1.25	1.30	1.33	1.35	1.36	1.44
	Max	2.06	2.16	2.15	2.27	2.21	2.52
	Min	0.69	0.70	0.70	0.68	0.70	0.70
	#	36	36	36	36	36	36
Ammonia Nitrogen (mg/l)	Ave	0.14	0.25	0.19	0.24	0.37	0.34
	Max	0.35	0.75	0.53	0.83	0.96	0.96
	Min	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	#	36	46	36	36	46	36
pH (units)	Ave	7.5	7.4	7.4	7.5	7.5	7.5
	Max	9.4	9.2	8.8	8.9	8.8	9.1
	Min	6.2	5.9	6.0	6.0	6.0	6.1
	#	36	36	36	36	36	36
Alkalinity mg/l	Ave	38.7	39.1	38.6	39.4	40.5	40.8
	Max	60	63	60	63	64	60
	Min	18	22	24	20	23	23
	#	36	36	36	36	36	36
BOD_5	Ave	<2.4	<2.4	<2.4	<2.4	<2.4	<2.4
	Max	3.0	3.0	3.0	3.0	4.6	3.5
	Min	<2.4	<2.4	<2.4	<2.4	<2.4	<2.4

Table 4-2

Summary of 1988 and 1989 Water Quality Data Collected by the Delaware River Basin Commission for Water Quality Zone 4

		Navy Yard RM 93	Paulsboro RM 88	Eddystone RM 84
Dissolved Oxygen (mg/l)	Ave	6.7	6.8	6.7
	Max	11.1	11.4	11.2
	Min	3.0	2.4	2.1
	#	36	35	36
Fecal Coliform M-TEC (#/100 ml)	Ave*	291	108	68
	Max	1966	1066	610
	Min	20	10	8
	#	38	38	38
E. Coli (#/100 ml)	Ave*	204	66	43
	Max	1600	600	560
	Min	10	3	3
	#	38	37	38
Enterococci (#/100 ml)	Ave*	20	8	8
	Max	560	310	240
	Min	1	1	<1
	#	38	38	38
Total Phosphorus (mg/l)	Ave	0.15	0.15	0.17
	Max	0.25	0.27	0.60
	Min	0.06	0.07	0.06
	#	36	36	36
Dissolved Ortho-phosphate (mg/l)	Ave	0.09	0.08	0.08
	Max	0.12	0.11	0.13
	Min	0.04	0.04	0.04
	#	10	10	10
Nitrate Nitrogen (mg/l)	Ave	1.59	1.76	1.81
	Max	2.72	2.90	2.93
	Min	0.71	0.82	0.92
	#	36	36	36
Ammonia Nitrogen (mg/l)	Ave	0.42	0.44	0.46
	Max	1.36	1.39	1.41
	Min	<0.05	<0.05	<0.05
	#	46	46	46
pH (units)	Ave	7.5	7.5	7.5
	Max	8.6	9.1	8.8
	Min	6.3	6.3	6.3
	#	36	36	36
Alkalinity mg/l	Ave	41.0	43.5	43.4
	Max	62	64	65
	Min	23	28	31
	#	36	36	36
BOD_5	Ave	<2.4	<2.4	<2.4
	Max	3.0	3.0	3.1
	Min	<2.4	<2.4	<2.4

During 1986-1987 many water sample locations within zones three and four exceeded the freshwater acute values for priority pollutant metals including cadmium, copper, chromium, lead, mercury, silver and zinc. In addition, some water samples exceeded the carcinogenicity protection levels for organic priority pollutants including the compounds benzene, chloroform, methylene chloride, trichloroethylene and tetrachloroethylene. Fish collected in this area are reasonably healthy, however, significant concentrations of heavy metals and organic compounds including PCB's, DDT metabolites and chlordane have been observed in fish tissue.

Water quality zone five extends from the Pennsylvania-Delaware-New Jersey border at Marcus Hook to Liston Point, Delaware, which is the legally defined upstream limit of Delaware Bay. The only major urban area in zone five is the city of Wilmington, Delaware. Wilmington is the largest commercial and industrial city in the state. Industries within the Wilmington area include inorganic and petrochemical plants, oil-refineries and steel manufacturing. Several electric generating stations are also located within zone five. A small portion of the Wilmington area is served by combined sewers, which discharge untreated sewage during periods of heavy rainfall. Zone five is also characterized by rural, agricultural areas and brackish wetlands.

Table 4-3 provides 1988-1989 water quality data collected by the DRBC in zone five. The DRBC characterizes water quality in this portion of the Delaware estuary as fair to good. This portion of the estuary is a transition zone between the urbanized upstream area and rural Delaware Bay. Minimum DO levels for the summer seasons did not meet DRBC standards, but summer averages were consistently above DRBC standards. pH levels were generally within the range of DRBC standards. As with zones three and four, nutrient levels appear to be high enough to support algal blooms, but chlorophyl A concentrations are low. Bacteria levels remained well below the DRBC and USEPA recommended criteria for primary contact recreation during the summer seasons of 1988 and 1989.

Water quality zone six covers the 782 square mile Delaware Bay. The bay region is characterized by small towns, agricultural lands and extensive salt marshes. Resort areas are located on both the New Jersey and Delaware sides of the bay, near the mouth. These areas experience significant increases in population during the summer.

Table 4-4 provides 1988-1989 water quality data collected by the DRBC in zone six. The DRBC characterizes the water quality of Delaware Bay as good. Minimum DO levels were occasionally violated during the 1988 and 1989 summer seasons. Average DO concentrations were consistently above 6.0 mg per liter. pH values were generally within the limits of DRBC standards. The geometric mean of fecal coliform readings were less than 15 colonies per 100 ml, which indicates that the bay has an excellent sanitary quality.

Table 4-3

Summary of 1988 and 1989 Water Quality Data Collected by the Delaware River Basin Commission for Water Quality Zone 5

		Marcus Hook RM 78	Oldmans Point RM 75	Cherry Island RM 71	New Castle RM 66	Pea Patch RM 61	Reedy Island RM 55	Appoquin-imink Is. RM 51
Dissolved Oxygen (mg/l)	Ave	6.9	7.0	6.9	7.2	7.5	8.1	8.2
	Max	11.0	10.8	11.0	11.5	12.7	12.2	12.0
	Min	2.5	2.8	3.0	3.8	4.3	5.4	6.0
	#	36	36	36	35	35	35	36
Fecal Coliform M-TEC (#/100 ml)	Ave*	72	57	62	59	43	32	19
	Max	600	510	510	220	166	280	220
	Min	9	10	15	14	7	5	4
	#	36	38	38	38	38	38	38
E. Coli (#/100 ml)	Ave*	47	38	44	44	33	24	15
	Max	520	460	490	163	146	210	200
	Min	6	7	10	10	4	3	2
	#	36	38	38	38	38	38	38
Enterococci (#/100 ml)	Ave*	7	7	8	9	9	10	7
	Max	210	250	70	34	46	103	38
	Min	1	1	1	2	1	1	1
	#	37	38	38	38	38	38	38
Total Phosphorus (mg/l)	Ave	0.14	0.14	0.15	0.15	0.15	0.18	0.14
	Max	0.27	0.23	0.40	0.36	0.27	0.40	0.32
	Min	0.03	0.02	0.05	0.07	0.08	0.08	0.02
	#	36	36	36	36	35	36	36
Dissolved Ortho-phosphate (mg/l)	Ave	0.08	0.08	0.07	0.06	0.05	0.05	0.05
	Max	0.11	0.16	0.11	0.10	0.08	0.07	0.08
	Min	0.05	0.02	0.02	0.02	0.02	0.02	<0.02
	#	10	10	10	10	10	10	10
Nitrate Nitrogen (mg/l)	Ave	1.89	1.92	1.95	1.99	1.85	1.81	1.69
	Max	3.00	2.99	2.91	2.81	2.38	2.26	2.50
	Min	1.00	1.00	1.30	1.30	1.30	1.40	1.27
	#	36	36	36	36	35	36	36
Ammonia Nitrogen (mg/l)	Ave	0.40	0.40	0.41	0.42	0.37	0.28	0.26
	Max	1.37	1.30	1.39	1.33	1.38	0.86	0.94
	Min	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	#	45	46	46	46	45	46	46
pH (units)	Ave	7.5	7.6	7.7	7.7	7.7	7.6	7.6
	Max	9.2	8.8	8.7	9.0	8.7	8.6	8.4
	Min	6.3	6.4	6.3	6.4	6.5	6.4	6.5
	#	36	36	36	35	35	34	34
Alkalinity mg/l	Ave	43.0	42.9	44.6	43.9	44.8	46.9	49.9
	Max	65	63	63	63	67	67	70
	Min	31	31	31	30	31	32	31
	#	36	36	36	36	35	36	36
BOD_5	Ave	<2.4	<2.4	<2.4	<2.4	<2.4	<2.4	<2.4
	Max	3.0	4.0	4.0	4.0	3.0	3.1	2.7
	Min	<2.4	<2.4	<2.4	<2.4	<2.4	<2.4	<2.4

Table 4-4

Summary of 1988 and 1989 Water Quality Data Collected by the Delaware River Basin Commission for Water Quality Zone 6

		Smyrna Rm44	Ship John RM 37	Port Mahon RM 31
Dissolved Oxygen (mg/l)	Ave	8.2	8.1	7.7
	Max	11.8	12.0	11.8
	Min	5.5	5.2	4.6
	#	35	36	36
Fecal Coliform M-TEC (#/100 ml)	Ave*	10	4	2
	Max	63	32	4
	Min	1	<1	<1
	#	38	38	10
E. Coli (#/100 ml)	Ave*	8	3	1
	Max	50	20	3
	Min	1	<1	<1
	#	38	38	10
Enterococci (#/100 ml)	Ave*	4	3	2
	Max	31	23	6
	Min	<1	<1	<1
	#	38	38	32
Total Phosphorus (mg/l)	Ave	0.12	0.10	0.11
	Max	0.43	0.19	0.21
	Min	0.03	<0.02	0.04
	#	36	36	36
Dissolved Ortho-phosphate (mg/l)	Ave	0.06	0.06	0.04
	Max	0.07	0.10	0.07
	Min	0.04	<0.02	<0.02
	#	10	10	10
Nitrate Nitrogen (mg/l)	Ave	1.47	1.19	0.70
	Max	2.00	2.00	1.22
	Min	1.01	0.62	0.21
	#	36	36	36
Ammonia Nitrogen (mg/l)	Ave	0.20	0.16	0.12
	Max	0.94	0.62	0.97
	Min	<0.05	<0.05	<0.05
	#	46	46	36
pH (units)	Ave	7.7	7.8	7.8
	Max	8.5	8.5	8.6
	Min	6.5	6.6	6.7
	#	34	34	35
Alkalinity mg/l	Ave	54.4	62.8	74.2
	Max	75	84	92
	Min	21	42	56
	#	36	36	36
BOD_5	Ave	<2.4	<2.4	<2.4
	Max	<2.4	<2.4	3.1
	Min	<2.4	<2.4	<2.4
	#	26	26	26

4.2.6 Sediment Quality

The quality of bottom sediments within the Delaware estuary has become a concern as efforts to improve the estuary continue. Between Trenton, New Jersey and Wilmington, Delaware there are 39 public wastewater treatment plants and 33 industries that discharge to the river. Chemical contaminants introduced to the aquatic environment tend to bind to suspended sediment particles, and ultimately end up in bottom sediments. The concentrations of these contaminants can increase overtime as sediment accumulates on the bottom. The buildup of contaminants in bottom sediments can potentially have long-term impacts on the quality of public water supplies withdrawn from the river, and the health of aquatic biota.

The Delaware River Basin Commission's Delaware Estuary Use Attainability (DEL USA) Project has begun to address these issues through surveys of bottom sediments and fish tissue. Sediment samples collected in the estuary between Philadelphia and Wilmington were found to contain heavy metals and a variety of organic compounds (DRBC, 1988a). Heavy metals included cadmium, copper, chromium, lead, mercury, silver and zinc. The organic compounds included benezene, chloroform, methylene chloride, trichloroethylene, tetrachloroethylene, petroleum hydrocarbons, chlordane, napthalene, fluoranthene and toluene. Many of these heavy metals and organic compounds were also detected in water samples collected in the same area. While recent information is not available for portions of the estuary below Wilmington, past studies suggest that various contaminants are also present in bottom sediments, but to a lesser degree than upstream areas (DRBC, 1988a).

Bottom sediments within the limits of the Federal navigation channel are periodically sampled in conjunction with the Corps' maintenance dredging program. Sediments are analyzed via the elutriate test, which was developed by the Corps and the U. S. Environmental Protection Agency to predict the soluble release of contaminants from bottom sediments during the dredging process. Dredging resuspends bottom sediments to various degrees depending on the sediment type, hydrological conditions and dredging procedures employed. The movement of sediments from an anaerobic environment on the bottom to an aerobic environment in the water column may result in the release of chemical contaminants previously bound to sediment particles. Once released from the sediment particles, the dissolved forms of contaminants are much more available for uptake by aquatic biota. The elutriate test mimics the dredging process by oxygenating sediments through agitation, to promote release of contaminants from sediment particles. The liquid fraction of the sample is then analyzed to determine contaminant concentrations. The validity of the elutriate test as a predictor of dissolved contaminant release from sediment particles has been demonstrated through extensive laboratory and field studies conducted by the U. S. Army Engineer Waterways Experiment Station.

The analysis of bottom sediments within the Philadelphia to the sea, Federal navigation channel has not identified any contamination problems associated with the maintenance dredging program, to date. Samples are periodically collected in areas that routinely shoal to meet the requirements of the various State Water Quality Certifications necessary for disposal. The most probable reason explaining why contaminants have not been identified in channel sediments, while they have been found in other areas of the estuary, is that contaminants concentrate over time as sediment accumulates. Channel reaches that accumulate sediment are frequently dredged to maintain channel depth, thus sufficient time is not provided to allow contaminants to increase to appreciable levels. While no problems currently exist, it will be necessary to continue testing in the future to insure that this situation does not change. The most recent sediment testing program was conducted during the summer of 1991. The results of this testing are presented in Section 5.1.3 of this Environmental Impact Statement.

4.3 Ecological Resources

4.3.1 Wetland Resources

Historically, the Delaware estuary between Trenton and the Atlantic Ocean, and all tidal tributaries, were abundantly fringed with lush wetlands. The characteristic salt marsh vegetation of the bay merged with freshwater marshes in the vicinity of New Castle and Salem counties. The values of these ecosystems were largely unrecognized in the past, and most of the wetlands on both shores north of New Castle and Camden have been eliminated by dredging or filled for development. For example, the Philadelphia International Airport rests almost entirely on filled wetlands. Extensive tidal wetlands in a largely natural state are abundant south of Wilmington and Gloucester County.

Wetlands are among the most productive ecosystems in the world, and our increased understanding of their important role in the maintenance of water quality and supply makes their further destruction highly undesirable. Wetlands vegetation provides food for a variety of wildlife, and tidal marshes are essential nurseries for economically valuable species of fish and blue crab. Dense aquatic vegetation filters sediment, and absorbs nutrients from polluted waters passing through the marsh. The absorbent substrate upon which wetlands grow, called peat, steadily releases large quantities of groundwater during dry periods and absorbs floodwaters, thereby helping to maintain water supplies. All of these valuable functions are on-going in healthy wetland ecosystems, but these areas are very sensitive to environmental degradation.

Both tidal and non-tidal wetlands occur in the study area. Non-tidal marshes usually grow in freshwater along streams and in ponds. Bogs and swamps are also occasionally found in the study area. Tidal wetlands are flooded twice daily by tides, and it is this tidal fluctuation that maintains their high level of productivity. Tidal marshes thrive at all levels of salinity, which has been found to be the primary determinant of vegetational differences between fresh, brackish and saline marshes in the Delaware estuary. Disturbances such as filling, ditching, and diking induce changes in vegetation. Table 4-5 contains a list of representative plant species for each kind of marsh, and species characteristic of disturbed wetlands.

Table 4-5 Representative Plant Species of Wetland Habitats Within the Study Area.

Tidal and Non-Tidal Freshwater Marsh (natural)	
Common Threesquare	*Scirpus americanus*
Bullrush	*Scirpus olneyi*
Dotted Smartweed	*Polygonum punctatum*
Spikerush	*Eleocharis* sp.
Arrowhead	*Sagittaria* sp.
Wild Rice	*Zizania aquatica*
Arrow Arum	*Peltandra virginica*
Spatterdock	*Nuphar advena*
Pickerelweed	*Pontedera* sp.
Loosestrife	*Lythrum* sp.
Tidal and Non-Tidal Freshwater Marsh (disturbed)	
Common Reed	*Phragmites australis*
Brackish Marsh	
Wild Rice	*Zizania aquatica*
Cattail	*Typha* sp.
Saltwater Marsh	
Cordgrass	*Spartina alterniflora*
Salt Hay	*Spartina patens*
Spikegrass	*Distichlis spicata*
Saltwater Marsh (disturbed)	
Common Reed	*Phragmites australis*
Groundsel Bush	*Baccharis halimifolia*
Marsh Elder	*Iva frutescens*

Although it is very difficult to quantify the environmental values of wetlands, it is possible to rank the various types of wetlands by their general ecological importance.

Tidal wetlands, both fresh and saline, are the most valuable type of wetland ecosystem in the study area because they provide nutrients for estuarine and marine organisms. Those marine species which cannot migrate into the estuarine marshes are sustained by the regular tidal flushing of nutrients from the marshes into the estuary and the Atlantic Ocean.

Non-tidal wetlands are also valuable wildlife habitats and feeding grounds, and perform the same roles as tidal marshes in maintaining water quality and supply. Such benefits, however, are generally only of local importance, and for this reason non-tidal marshes are of slightly less overall value than tidal marshes.

The wetlands with the least environmental value are those which have been disturbed. The plant species inhabiting these areas are far less attractive to wildlife for forage than natural wetlands vegetation. Filling and diking interrupts tidal flooding, so much of the productivity of the marsh is lost. Disturbed marshes are not without value, however. They provide food and shelter for wildlife, and are still important recharge areas for groundwater supplies.

Wetlands by County

Philadelphia County: Besides a small freshwater tidal wetland growing at the mouth of Pennypack Creek, the Tinicum National Environmental Center (TNEC) is the only wetland area in Philadelphia. One hundred forty-five acres of this wildlife preserve lie in the Eastwick area of southwest Philadelphia, north of the Philadelphia International Airport. This section of Tinicum Marsh is non-tidal, and is located along the shores of a lagoon impounded for wildlife habitat. Despite the urban nature of the area, the marsh is a valuable feeding area for wildfowl. Dominant species are spatterdock, loosestrife and cattail.

Delaware County: An additional 500 acres of the TNEC are located in Delaware County near the mouth of Darby Creek. The largest freshwater tidal marsh in Pennsylvania (320 acres) is part of the Center. The rest of the TNEC presently consists of diked or filled wetlands, with radically altered vegetation. The tidal portion is characterized by plants such as spatterdock, wild rice, and narrow-leaved cattail. The dominant vegetation in the diked areas is common reed, while filled areas support upland field and forest species. A 78-acre site, including 65 acres of water surface, represents lagoons dredged for fill for Interstate Route 95. These lagoons are fringed by tidal wetlands, and will eventually be annexed to the TNEC.

Camden County: Wetlands adjacent to the Delaware River are sparse in Camden County. The only wetlands mapped during an inventory taken in 1973 are a 50-acre freshwater marsh along the back channel behind Petty Island, and a

marsh slightly greater than 100 acres located inside a bay on the Pennsauken Township shoreline, just north of Petty Island. Very small, isolated, freshwater wetlands are scattered along Big Timber Creek.

Gloucester County: The abundance of tidal wetlands begins to increase in New Jersey south of Camden. Wetlands occupy approximately 6.5 percent of Gloucester County. Extensive freshwater marshes are common along tidal reaches of Big Timber, Woodbury, Mantua, Raccoon and Oldman's creeks. Approximately 100 acres of mixed saltwater marsh vegetation grows along Mantua Creek near its confluence with the Delaware. The major saltwater species in this area is cordgrass. An extensive mixed freshwater marsh is located along the Delaware behind Monds Island. South of Raccoon Creek, a 500-acre tidal marsh site has been disturbed. Common reed is the dominant plant here.

Salem County: Due to the increasing salinity of the Delaware River in the vicinity of Salem County, the vegetation of coastal wetlands begins to be characterized by the presence of salt-tolerant species. Marshes in brackish areas support saline and freshwater species tolerant of low levels of salinity. Wetlands are sparse along the Delaware River shoreline until below Pea Patch Island, where common reed and cordgrass marshes become very extensive. Common reed is evidence of diked or otherwise altered marshland. Brackish or saline marshes merge into freshwater wetlands and extend up to ten miles inland along tidal streams in Salem County. Freshwater marshes are widespread along Alloway Creek, Salem River, Mannington Creek and the Mannington Meadow above Salem City. Large stands of valuable wild rice grow in the wetlands around Salem City.

South of Artificial Island, wetlands vegetation characteristic of brackish conditions extends over three miles inland, and even farther along streams. Just north of the Cumberland County border, salt hay and spikegrass appear. The presence of these species indicates high salinity in the Delaware estuary.

Cumberland County: The entire southern boundary of the county, in seven municipalities along Delaware Bay, is dominated by tidal wetlands from one to five miles wide. Wetlands extend even farther inland along tidal streams, reaching to Bridgeton on the Cohansey River and Millville on the Maurice River. Approximately 20 percent of the total Cumberland County acreage is tidal wetlands vegetation.

The brackish Cohansey River supports large stands of cordgrass and common reed in the tidal reach. South of the mouth of the Cohansey, the higher salinity of the Delaware Bay allows salt hay to thrive, as well as mixed saltwater-tolerant species. In general, cordgrass and salt hay each account for about 45 percent of the tidal wetlands vegetation in the county, with mixed species making up the other 10 percent. Inland along the Maurice River, freshwater conditions influence the tidal marsh composition, and large pure stands of wild rice are abundant.

Cape May County: Tidal wetlands account for 38 percent of the total county land area. Most of these wetlands are in their natural state, and grow behind the barrier islands on the Atlantic coast. Along the Delaware Bay, wetlands grow most extensively in the first six miles of shoreline below Cumberland County. Here, the cordgrass and salt hay marsh extends almost five miles inland along Dennis Creek. Along the Cape May peninsula, wetlands narrow to widths of one mile or less. Some sections have been extensively ditched for mosquito control, and these are dominated by common reed vegetation. The only wetlands south of the town of North Cape May are 250 acres of common reed along the Cape May Canal and 500 acres of common reed behind Higbee Beach.

New Castle County: New Castle County has 23,700 acres of tidal wetlands, and most are situated south of the Chesapeake and Delaware Canal. Between the Christina River and Silver Run, the only wetlands present have been disturbed and are characterized by the dominance of common reed. The only stand of common reed marsh greater than 200 acres in size is located along St. Georges Creek, immediately south of the Canal. This marsh covers approximately 600 acres. Many smaller stands of common reed are scattered along the twelve-mile tidal reach of the Christina River.

South of Silver Run, the marshes are much larger, and the dominant plant species becomes cordgrass, reflecting the increasing salinity of the tidal waters. Cordgrass marshes line Appoquinimink Creek to Odessa and Blackbird Creek to Blackbird Landing. This vegetation merges with mixed freshwater species as the water in tidal streams changes to brackish and fresh in upstream reaches. South of Blackbird Creek, salt hay and spikegrass are dominant along the Delaware Bay shoreline, with cordgrass more commonly found on the inland side of the marshes. Salt hay and spikegrass grow along the lower two miles of the Smyrna River, while cordgrass is found along this tidal stream as far west as the town of Smyrna. There are numerous shallow, groundwater-fed ponds in southern New Castle County. Freshwater marshes are common in such ponds and along freshwater streams.

Kent County: Nearly half of the State of Delaware's total wetland acreage, over 50,000 acres, is located in Kent County. Wetland vegetation extends the entire length of the county's 35-mile Delaware Bay shoreline. Marshes are widest in the vicinity of Bombay Hook, (four miles), but in the south, peninsulas of stable land dissect the wetlands. Four marshland-oriented conservation areas, the largest of which is Bombay Hook National Wildlife Refuge, are located in Kent County and include 23,000 acres of wetlands. The expansive Bombay Hook wetlands support primarily cordgrass, salt hay and spikegrass, but the vegetation changes to mixed freshwater species eight miles inland along the Leipsic River. At least 1,000 acres of freshwater marsh are located long the estuary shoreline north and south of Little River. Arrow arum and spatterdock are the dominant species in this area. Another smaller freshwater marsh is located along the estuary north of the St. Jones River.

The saline marshes at the mouths of the St. Jones and Murderkill rivers have been extensively ditched for mosquito control, so stands of common reed, marsh elder and groundsel bush are scattered throughout the wetlands. These are also

the dominant species in the three-mile stretch between Sandy Point and Big Stone Beach. The wetlands along the southern shoreline are narrower than in the north of Kent County, and are usually less than two miles deep. They reach much farther inland along the tidal rivers, and cordgrass borders the St. Jones to Dover Air Force Base and occurs four miles inland at Frederica on the Murderkill. The Milford Neck Wildlife Area north of the Mispillion River is primarily a cordgrass marsh, though other grasses are also common. Three miles inland along the Mispillion, freshwater species dominate and grow extensively up to one mile south of Milford.

Sussex County: Most of Sussex County's 30,000 acres of wetlands are found in protected lagoons behind the barrier islands along the Atlantic coast. In general, the marshes of the Delaware Bay shoreline segment have been extensively ditched and filled, and pure stands of natural wetlands vegetation are infrequent. One such natural area lies between the Mispillion River and Fowler Beach where the dominant plants are cordgrass, salt hay and spikegrass. These wetlands are narrow, ranging from one-quarter to one mile wide. Between Fowler Beach and the Broadkill River, disturbance has almost eliminated natural tidal species, and common reed, marsh elder and groundsel bush are the most common plants found. The cordgrass marsh south of the Broadkill River extends six miles inland to Milton.

4.3.2 Phytoplankton

The diversity of phytoplankton is high in the Delaware estuary due to the presence of freshwater, brackish and marine environments. Several hundred species of phytoplankton from most of the 13 major classes have been observed in the estuary (Pennock and Herman, 1988). The most predominant are diatoms (Class Bacilliariophyceae), particularly the chain forming species such as *Skeletonema costatum*, *Thalassiosira nordenskioldii*, *Rhizosolenia* sp. and *Chaetoceros* sp. (Pennock and Herman, 1988).

During spring when temperatures are low and nutrient concentrations are high, a spring diatom bloom occurs in the estuary, supporting the growth of larval and juvenile forms of oyster, weakfish and many other important fisheries. However, when nutrient concentrations are lower and temperatures are warmer during the summer months, other phytoplankton classes predominate (Pennock and Herman, 1988).

The Academy of Natural Sciences (1981) reviewed the abundance of phytoplankton from Little Tinicum Island to the Delaware Memorial Bridge. This study concluded that the phytoplankton community in this portion of the Delaware was dominated by a few taxa, demonstrating low diversity. Chlorophytes (green algae) and diatoms were the predominant groups with the following algae being abundant: *Nitzschia palea*, a diatom and *Scenedesmus*, *Pediastrum*, *Actinastrum* and *Microspora* (all green algae). Cyanophyta (blue-green algae), chiefly represented by the filamentous *Oscillatoria* and *Lyngbya*, were also common. Generally, this phytoplankton community is indicative of an enriched and turbid system; many of the species are considered pollution tolerant. According to this study, the phytoplankton community is water-quality limited in this area of the Delaware River (ANSP, 1981).

The Academy (1981) also reviewed the algal flora of the Delaware River in the vicinity of the Marcus Hook area and found it to be diverse and abundant, but dominated by the pollution-tolerant species Microcoleus vaginatus (a blue-green alga), Bacillariophyta (diatoms), Rhizoclonium (a filamentous green alga), Oscillatoria (a blue-green alga) and Cladophora glomerata (a green alga). The presence of large mats of such algae along the bulkhead of the Delaware River in the Marcus Hook area suggested stressed conditions (ANSP, 1981).

In the upper portion of the study area, phytoplankton chlorophyl concentrations exhibit a major period of accumulation during the summer months. In this region, summer chlorophyl concentrations average 30 ug/L (Pennock, 1985).

Phytoplankton chlorophyl concentrations exhibit a major period of accumulation during spring in mid-bay, and transient blooms have been observed during September and November. Both the spring (March-May) chlorophyl maximum (reaching 50-60 ug chlorophyl/L during a bloom dominated by Skeletonema costatum, Leptocylindrus sp. and Thalassiosira sp.) and transient fall blooms (15-20 ug/L) are focused in mid-bay (Pennock, 1985).

These blooms are regulated spatially by settling out of suspended sediment and both spatially and temporally by physical factors (e.g., river flow) that cause vertical stratification in mid-bay (Pennock and Herman, 1985). Despite minimum turbidity and non-nutrient limiting conditions during the summer months, chlorophyl concentrations in the lower bay remain below 10 ug/L. These chlorophyl concentrations appear to be regulated by a combination of light availability and grazing (Pennock, 1985). Small green and brown algae make up much of the summer phytoplankton population in this portion of the lower bay. These small green algae and brown algae seldom reach high biomass, although they are often very productive. This is primarily the result of small zooplankton grazing on the phytoplankton population (Pennock and Herman, 1988).

4.3.3 Zooplankton

In the Delaware River estuary, zooplankton occupy a critical position in the food web. These small current drifting animals feed on phytoplankton and provide a large source of food for larger aquatic animals (Pennock and Herman, 1988). Since changes in zooplankton abundance can have a direct effect on populations, such as fish that feed upon them, their quantity and quality is an important indicator of the productivity of the system (Shuster, 1959).

The Academy of Natural Sciences (1981) found that between the Delaware Memorial Bridge and Little Tinicum Island, the zooplankton populations consisted primarily of ciliate and heliozoan protozoa and rotifers. Sarcodina and suctoria protozoa, gastrotrichs and Cladocera were encountered, but did not make up a large portion of the zooplankton population. Of the ciliates, Codonella cratera and the tintinnids Tintinnopsis fimbriata and T. major were the most abundant. During the late fall, helizoans, mostly Actinosphaerium and Staurophyra, formed a large portion of the population. Keratella cochlearis was the dominant rotifer with a small number of other species also present. Cladocera and Copepoda were not abundant, especially in the 1973 to 1974 period

(ANSP, 1981). It was found that the zooplankton community in this reach of the River showed a high dominance of a few taxa, and the populations themselves were not particularly abundant.

In the Delaware Bay, more than 30 different species of zooplankton have been identified (Pennock and Herman, 1988). More than 85 percent of the total zooplankton population was made up of Copepoda (Pennock and Herman, 1988). Other abundant forms include crab and shrimp larvae, mollusk larvae, barnacle larvae, worm larvae and fish eggs and larvae (Pennock and Herman, 1988).

In a 1982 study by Herman and Hargreaves (1988), the bay was divided into upper bay and lower bay subsections. The upper bay is inhabited by zooplankters that can tolerate brackish water. The lower bay is characterized by organisms that are considered to be marine forms. In their 1982 study, Herman and Hargreaves (1988) determined that the mean number of zooplankton was 23,000/m^3 of water (upper bay 16,000; lower bay, 29,000), indicating that the productivity of the lower bay far surpasses that of the upper bay.

Herman and Hargreaves (1988) reported that only five species of copepod accounted for most of the recorded numbers. The only abundant species distributed throughout the bay were Acartia tonsa and Oithona species; Temore longicornis, Pseudocalanus minutus and Centropages hamatus were found only in the lower, more saline region. These latter three marine species were present only in winter and spring, while the other two were present most of the year. As in most temperate estuaries, Acartia tonsa was the dominant copepod, both geographically and seasonally (Herman and Hargreaves, 1988).

Several factors affect zooplankton distribution in the Delaware Bay. The major increases in zooplankton during the spring occur shortly after blooms of their phytoplankton food source (Pennock and Herman, 1988). The increases are due primarily to reproduction in different species of Copepoda and Cladocera (Pennock and Herman, 1988). In addition, during the warmer times of the year, high numbers resulting from the spawning of larval crabs, worms, shrimp and various mollusks are often observed (Pennock and Herman, 1988).

4.3.4 Benthic and Planktonic Macroinvertebrates

The distribution of macroinvertebrate species within the Delaware River estuary is determined by sediment type, salinity and current velocity (Price et al., 1988). In the Philadelphia portion of the river, Walton and Patrick (1973) found that Oligochaeta and Hirundinea were the most abundant species. The leech, Helobdella stagnalis, and an asellote isopod were found in fewer numbers. Blue crabs were also found in this stretch of the river. Sixteen were captured in impingement studies at the Southwark Generating Station (RM 97.5), located just above the Walt Whitman Bridge in Pennsylvania between 1975 and 1976 (PECO, 1977c). The Academy of Natural Sciences (1981) concluded that in this portion of the Delaware River, the macroinvertebrate fauna, with the exception of blue crabs, fingernail clams, leeches, tubificid worms and some scuds, was very sparse. Walton and Patrick (1973) contribute this low species diversity to the high degree of organic and industrial pollution in this

portion of the river. In the Marcus Hook-Chester region of the Delaware, Tyrawski (1979) states that Potter and Harmon (1973), Potter et al. (1974), and Harmon and Smith (1975) reported a low benthic macroinvertebrate diversity. The Academy (1981) reported this reach of the Delaware River to be poor in benthic macroinvertebrate diversity, especially with regard to insects, because of water quality and the state of the shorelines existing at the time of the study.

In a short-term study of benthic macroinvertebrates in the Delaware River and bay, RMC (1988) found that biota in the freshwater portion of the study area (Philadelphia to Wilmington) tended to be dominated by amphipods of the genus Gammarus; other major taxa were the isopods Cyathura polita and Chiridotea almyra, and tubificid worms of the genus Limnodrilus (mostly L. hoffmeisteri). At the downstream portion of this reach, the euryhaline polychaete worm Scolecolepides viridis was recovered. The low taxonomic diversity and low numbers in this portion of the river are typical of estuarine environments where fluctuating salinities, temperatures, and other environmental parameters result in a fairly inhospitable environment.

Between Wilmington and Liston Point, low species diversity and the frequent occurrence of chironomid larvae and the common occurrence of oligochaete worms in the benthos indicate organic enrichment (Walton and Patrick, 1973). Other benthic macroinvertebrates recorded in this area are Hydroids, Nereis succinea, Sphaeromatid isopods, Gammarus spp., Palaemonetes pugio and Rhithropanopeus harrisii (Walton and Patrick, 1973).

RMC (1988) found biota in the oligohaline portion of the estuary (Delaware Memorial Bridge to Artificial Island) to be transitional between that observed in freshwater and higher salinities. Tubificid worms were not collected and only an occasional chironomid larva was found. In contrast, the polychaete worms became more important at the downstream portion of this reach.

Crustaceans were represented by the isopods Chiridotea almyra and Cyathura polita, the mysid shrimp Neomysis americana, and Gammarus. Gammarus was not as abundant in this portion of the estuary as at freshwater sites. The relative abundance of Chiridotea and Cyathura were reversed (Cyathura more abundant at freshwater sites; Chiridotea more abundant here). Molluscs were conspicuous in their near absence; only low numbers of the euryhaline clam Macoma balthica and two Nucula proxima were collected.

In the upper portion of Delaware Bay, RMC (1988) found very low numbers of the amphipod Gammarus and the two isopods that were abundant at upstream sites. The sediments at these sites ranged from silty sand and gravel (good benthic habitat) to fine sand (poor habitat). In contrast with upper estuary sites, species diversity was greater, with more taxa contributing significantly to the biota. Some 15 taxa of polychaetes, six of molluscs, and 11 of crustacea were found. Dominant species included bloodworms (Glycera spp.), the limpet Crepidula, the anemone Haliplanella, the mysid shrimp Neomysis americana and the pelecypod Tellina agilis.

In the lower portion of Delaware Bay, RMC (1988) found biota typical of marine environments, including a diverse assemblage of polychaetes, molluscs and crustaceans. Important organisms included the polychaete Sabellaria vulgaris, the mysid shrimp Neomysis americana, the amphipods Unciola and Acanthohaustorius, the hermit crab Pagurus longicarpus, and the snail Nassarius trivittatus. Decapod crustaceans collected in the lower bay included several species of crab (Ovalipes, Panopeus, Cancer and Libinia) and the sand shrimp Crangon septemspinosa.

The most downstream sampling site, located at the mouth of Delaware bay, stood apart from other bay sites in the composition of benthic fauna. The small clam Nucula proxima accounted for 97 percent of the total numbers of organisms present, with an average density of almost 24,000 per square meter. Other organisms collected at this site included the pelecypod molluscs Tellina agilis and Yoldia limatula, the gastropods Retusa canaliculata and Nassarius trivittatus, amphipods of the genus Ampelisca, and the polychaete worm Nephtys incisa.

Free-swimming macroinvertebrates include some of the larger zooplankton and jellyfish. Four species of jellyfish are common in Delaware Bay waters: the sea nettle (Chrysaora quinquecirrha), the moon disc jellyfish (Aurelia aurita), the lion's mane jellyfish (Rhopilema verrilli) and the red winter jellyfish (Cyanea capillata) (Daiber et al., 1976). The first three species appear in the estuary in late spring and become prominent in the summer. The red winter jellyfish, begin to appear in mid-summer and remain in these waters throughout most of the fall (Daiber et al., 1976). Jellyfish feed on several marine organisms: gastropods, oysters, copepods, epicardeans, barnacles and eggs of some polychaete worms and rotifers have all been found in their digestive systems (Daiber, et al., 1976).

In the lower Delaware River and Delaware Bay, oysters, blue crabs, lobsters, mussels and clams are shellfish of commercial importance (DRBC, 1988). However, lobsters, mussels and clams are limited.

Traditionally, the Delaware Bay oyster industry has been dependent on two locations within the bay (Figure 4-3). Oyster seed beds are located in the upper portion of Delaware Bay, primarily between the Maurice River and the Cohansey River. These low salinity areas provide a refuge for young oysters to grow, free from the predation and competition that limits survival success in higher salinity, downbay water. It has been common practice to remove seed oysters from these beds and transplant them to privately leased grounds in the lower bay. The higher salinity in these areas promotes faster growth of the oysters, bringing them to market size in less time.

Based on harvest statistics and early studies, it has been estimated that between 1880 and 1950 Delaware Bay seed beds produced an average of one to two million bushels of oysters annually. Average annual harvests of market size oysters from the leased grounds were 13.9 million pounds between 1880 and 1931; 6.5 million pounds between 1932 and 1956; 1.0 million pounds between 1957 and 1977; and 0.86 million pounds between 1978 and 1985.

Figure 4-3 Oyster seed beds in New Jersey (cross hatched) and Delaware (solid) are shown as well as areas of planted beds for the two states (delineated by dashed lines).

The decline in annual yield between the 1930's and the mid-1950's is attributed to over-harvesting. This was compounded in 1945 when the oyster fleet was permitted to dredge for seed oysters using engine rather than sail power, which increased maneuverability and dredging efficiency. Setting of young oysters did not keep pace with the increased removal of seed. Setting refers to a process by which the mobile larval stage of the oyster finds suitable bottom substrate, cements itself to the substrate, and becomes a sedentary animal. At this stage the oyster is no larger than a grain of sand. A series of set failures around 1950 further diminished the oyster population on the seed beds. To compensate for this lack of seed oysters in the Delaware Bay, oystermen began to import seed from Virginia. It has been estimated that in the early and mid-1950's over half of the seed planted in Delaware Bay was imported.

To further complicate problems that the oyster industry was experiencing in the 1950's, a series of oyster mortalities caused by a sporozoan parasite devastated nearly all of the oyster producing areas in the Delaware Bay. This parasite was classified as Haplosporidium nelsoni in 1978, but is commonly referred to as MSX. The initial kill occurred in 1957, and was confined to the lower bay. A second kill in 1958 spread over all of the lower bay and onto the seed beds as far upbay as the Cohansey River. While mortalities on the seed beds were high, the severity of the disease appeared to decrease on the upbay beds. This led to an early conclusion that MSX is a salinity limited organism. Following the initial outbreaks of MSX, New Jersey and Delaware prohibited the importation and planting of out-of-state seed oysters in Delaware Bay. It was decided that this practice should not continue because of the possibility that MSX was introduced to the bay with out-of-state oysters.

While numerous problems still plague the Delaware bay oyster industry, substantial improvement has been seen since the low point reached in the late 1950's. Between 1974 and 1979 the average annual harvest for the New Jersey side of the Delaware Bay was 1.3 million pounds. Currently, this yield has dropped off significantly. This is attributed to drought conditions in 1984 and 1985, which increased salinities on the oyster beds, which in turn stimulated an outbreak of MSX. The impact of this episode is still being felt through the lack of market size oysters.

As a result of these recurrent problems, the Delaware Bay oyster industry may be described as cyclical. It is expected that this trend of "good years" and "bad years" will continue at least for the near future. On-going research by Rutgers University is geared towards understanding the environmental variables that influence oyster productivity in Delaware Bay. These variables include habitat suitability, salinity, MSX, and other predators such as the oyster drill. Studies are aimed at understanding the biology of MSX, development of a strain of oysters with resistance to the MSX pathogen, and locating oyster beds in portions of the bay that are both suitable for growth and minimize predation. Management practices are also being implemented to insure that harvesting pressures do not deplete the existing population. State advocated management practices currently under consideration include restrictions on the types of equipment that can be used to harvest oysters and limits on the number

of days that harvesting may occur. It is hoped that through a combination of active management and research, the Delaware Bay oyster industry will stabilize in the future.

The blue crab (Callinectes sapidus) has been reported to occur from the mouth of Delaware Bay up to RM 97 (PECO, 1977c). They are, however, more common in the lower portion of the study area. The blue crab is found in Delaware Bay according to salinity and water temperature (Tyrawski, 1979). Generally, the crabs reside in shallow, lower salinity water in the spring and summer, and deeper, higher salinity water during the winter. Following mating in the spring and summer, which normally occurs in shallow, lower salinity water, the female returns again to deeper, higher salinity water to spawn. After hatching, the larvae move toward shallow, lower salinity water to mature (Tyrawski, 1979). During the winter, they bury in the mud until water temperatures rise in the spring.

The blue crab population in the Delaware estuary is considered to be healthy. While year-to-year variations in catch can be large, there is no indication of overfishing. Over the last two decades harvests have exceeded two million pounds a year, which are the highest ever. Commercial crabbing in the upper portion of the estuary occurs in near-shore regions north of Port Mahon on the Delaware side and north of Maurice River cove on the New Jersey side, upstream to Salem River cove. Commercial crabbing in this area occurs during the spring and summer months, with buoyed crab pots. In the lower portions of Delaware Bay, commercial crabbers dredge bottom sediments for hibernating crabs. Recreational crabbing is popular in the Delaware estuary. It is estimated that the recreational catch approximates 10 percent of the commercial catch.

4.3.5 Finfish

The finfish population of the Delaware estuary is extensive and diverse. Over 100 species of finfish have been found in the Delaware estuary (Price et al., 1988). They are represented by: freshwater species; freshwater species that occasionally enter brackish water; estuarine species which spend their entire life cycle in the estuary; anadromous and catadromous species passing through the area; marine species which regularly spend time in the estuary; marine species utilizing the estuary as a nursery and/or spawning zone; and adventitious visitors of marine origin (ANSP, 1981).

DeSylva et al. (1962) identified 60 species of finfish that spawn in the Delaware estuary. These species may be divided into five major groups relative to spawning characteristics. Anadromous species, such as the American shad (Alosa sapidissima), spend most of their lives in offshore coastal waters, but migrate to freshwater areas to spawn. Other anadromous species, such as striped bass (Morone saxatilis) and blueback herring (Alosa aestivalis), also spend most of their adult lives in offshore waters, but enter the estuary to spawn in fresh to brackish water. Catadromous species, represented by the American eel (Anguilla rostrata), spend their lives within the estuary, but migrate to the ocean to spawn. Species such as the spottail shiner (Notropis hudsonius) and the channel catfish (Ictalurus punctatus) are year-round

residents of fresh and brackish waters, and do not migrate to any significant degree to spawn. Species such as the Atlantic silverside (Menidia menidia) and bluefish (Pomatomus saltatrix) spend their lives in higher salinity waters and use the bay as spawning habitat. A final group, represented by the Atlantic menhaden (Brevoortia tyrannus) and the Atlantic croaker (Micropogon undulatus), spawn offshore and use the bay as a nursery area.

Table 4-6 provides information pertaining to habitats, spawning locations, nursery locations, migratory routes, reproductive timing and food items for 25 species of interest within the Delaware River and bay. When using Table 4-6, it must be noted that the resident species white catfish (Ictalurus catus), brown bullhead (Ictalurus nebulosus), channel catfish (Ictalurus punctatus) and banded killifish (Fundulus diaphanus) actually spawning in the Delaware River is not well documented, rather, these species presently spawn in tributaries outside the study areas. With improved water quality conditions, however, these spawning areas may become more widespread and include areas within the river. Also, the shortnose sturgeon (Acipenser brevirostrum) is presently confined to areas above Philadelphia due to low dissolved oxygen in the Philadelphia region and below. Again, with improved water quality conditions in these areas, more species may be found further down the river during winter months. For additional information on the life histories of finfish of the Delaware see Wang and Kernehan (1979), Scotton et al., (1973) and de Sylva et al. (1962).

Fisheries of the Delaware estuary and the Mid-Atlantic Bight have declined since the late 19th century (Grimes, 1983). Factors contributing to this decline include loss of habitat, water quality degradation, toxic substances and fishing pressures. Significant stress has been placed on the Delaware estuary through the prolonged discharge of industrial and municipal wastes into the system, while significant progress has been made to clean up the estuary, pollution levels are still considered high. A recent fisheries survey conducted in the vicinity of Philadelphia concluded that fish in the Delaware estuary appear healthy, but do show signs of stress including tumors, gill lesions and accumulation of toxic compounds (DRBC, 1988b). Another survey conducted between 1984 and 1986, identified 36 species of fish occurring within the most polluted portion of the estuary (the Philadelphia-Camden metropolitan area) (DRBC, 1987). This was considered significant as only 16 species were found during surveys conducted between 1959 and 1982.

Species of current recreational and commercial importance include weakfish (Cynoscion regalis), blue fish (Pomatomus saltatrix), American shad (Alosa sapidissima), white perch (Morone americana), striped bass (Morone saxatilis), windowpane flounder (Scophthalmus aquosos), summer flounder (Paralichthys dentatus), spot (Leiostomus xanthurus), black drum (Pogonias cromis), Atlantic Sturgeon (Acipenser oxyrhynchus) and butterfish (Peprilus triacanthus) (Seagraves, 1982). Historically, the alewife (Alosa pseudoharengus), Atlantic croaker (Micropogon undulatus), and Atlantic menhaden (Brevoortia tyrannus) were also important (McHugh, 1981). Table 4-7 provides the estimated catch in tons and value of the inshore gill net fishery for the State of Delaware for 1981 (Seagraves, 1982). Weakfish, bluefish, American shad and white perch were

Table 4-6. Life Histories of Common Finfishes of the Delaware Estuary, with Emphasis on Delaware River Species.

Keys

Locations:
- A = Areas outside of study area
- P = Walt Whitman Bridge to Mantua Creek, NJ (Phila.)
- W = Mantua Creek to Wilmington
- U = Wilmington to Liston Point (upper Bay)
- B = Bay (shallow)
- O = Oceanic (possibly also deeper parts of Bay)

Habitats:
- D = Deep
- O = Open Water
- S = Shallows
- V = Vegetated
- W = Widespread

Food Items:
- A = Epiphytic algae
- B = Benthic invertebrates (including aquatic insects in low salinity areas)
- D = Detritus
- F = Fish
- M = Macrophytes
- O = Omnivorous
- S = Shrimp
- Z = Zooplankton; also some macroplankton

References:
- 1 = ANSP (1981)
- 2 = Wang and Kernehan (1979)
- 3 = Scotton et al. (1973)
- 4 = Lippson and Moran (1974)
- 5 = Grosslein and Azarovitz (1982)
- 6 = Hastings (1983)
- 7 = Horwitz (1986)

Species	Migration Times of Anadromous and Catadromous Species Throughout the Lower Estuary	Common Residency		Food Items
		Location	Habitat	
Atlantic sturgeon *Acipenser oxyrhynchus*	adults upstream to spawn (spring)			B
Shortnose sturgeon *Acipenser brevirostrum*		P, A; (upstream to spawn)	D	B
American eel *Anguilla rostrata*	adults to ocean to spawn (fall); young elvers migrate to fresh-water (Mar)	——	——	O
Blueback herring *Alosa aestivalis*	adults upsteam to spawn (Mar - May); young & adults downstream (Aug - Nov)	——	——	Z
Alewife *Alosa pseudoharengus*	adults upstream to spawn (Mar - May); young & adults downstream (Aug - Nov)	——	——	Z
American shad *Alosa sapidissima*	adults upstream to spawn (Apr - May); juveniles & adults down-stream (fall)	——	——	Z
Atlantic menhaden *Brevoortia tyrannus*	——	——	——	P
Bay anchovy *Anchoa mitchilli*	——	B, U	W	Z, B, D
Carp *Cyprinus carpio*	——	U, W, P, A	S	O
Silvery minnow *Hybognathus nuchalis*	——	U, W, P, A	V	A
Spottail shiner *Notropis hudsonius*	——	U, W, P, A	S	Z, B
White sucker *Catostomus commersoni*	——	W, P, A	D	B
White catfish *Ictalurus catus*	——	U, W, P, A	S	F
Brown bullhead *Ictalurus nebulosus*	——	U, W, P, A	V	O
Channel catfish *Ictalurus punctatus*	——	U, W, P, A	D	O
Branded killifish *Fundulus diaphanus*	——	U, W, P, A	S	B
Mummichog *Fundulus heteroclitus*	——	B, U, W, P, A	V, S	B, D, M
Atlantic silverside *Menidia menidia*	——	O, U, B	S	Z, B
White perch *Morone americana*	——	B, U, W, P, A	D (winter)	F, S, B, Z
Striped bass *Morone saxatilis*	——	B, U, W, P, A	V (summer) D (winter)	F, S
Weakfish *Cynoscion regalis*	——	O, B	S	F, S
Spot *Leiostomus xanthurus*	——	B, U, W, P, A	S	Z, B, D
Summer flounder *Paralichthys dentatus*	——	O, B	D	F, B
Windowpane flounder *Scophthalmus aquosus*	——	O, U, B	S, D	B
Hogchoker *Trinectes maculatus*	——	O, U, B	D (winter)	B

Species	Spawning within Study Area			Nursery within Study Area		
	Locations	Habitat	Times	Locations	Habitat	Times
Atlantic sturgeon *Acipenser oxyrhynchus*	U, W	S	Mar - May	B?, U, W	S	?
Shortnose sturgeon *Acipenser brevirostrum*	A	—	early May - Jun	P, A	W	May - Oct
American eel *Anguilla rostrata*	O	—	mid-winter	U, W, P, A	S	Feb - Apr
Blueback herring *Alosa aestivalis*	A	—	late Apr - early Jun	B, U, W, P, A	S	late Apr - Nov
Alewife *Alosa pseudoharengus*	A	—	Apr - May	B, U, W, A	W	Apr - Nov
American shad *Alosa sapidissima*	A	—	late Apr - Jul	A	—	late Apr - fall
Atlantic menhaden *Brevoortia tyrannus*	O, B	O	fall - spring	B, U	V, S	summer - early fall
Bay anchovy *Anchoa mitchilli*	B, U	—	May - Sept	B, U	S	May - Nov
Carp *Cyprinus carpio*	A		May - early Jul	U, W, A	V, S	May - fall
Silvery minnow *Hybognathus nuchalis*	A	S	Apr - May	W, P, A	S	Jun - Aug
Spottail shiner *Notropis hudsonius*	A	V, S	Apr - Jul	B, U, W, P, A	S	Apr - fall
White sucker *Catostomus commersoni*	A		late Mar - May	A		Apr - fall
White catfish *Ictalurus catus*	A	S	Apr - Jul	B, U, W, P, A	S	May - fall
Brown bullhead *Ictalurus nebulosus*	A	V, S	May - Jul	P, A	V	
Channel catfish *Ictalurus punctatus*	A		May - Jul	A	S	
Banded killifish *Fundulus diaphanus*	A	V, S	late Apr - Aug	A	V, S	
Mummichog *Fundulus heteroclitus*	B, U, W, P?, A	V, S	Apr - Sep	B, U, W, P?, A	V, S	May - Dec
Atlantic silverside *Menidia menidia*	B, U	V, S	Apr - Aug	B	S	Apr - fall
White perch *Morone americana*	W, P, A	S	Apr - early Jun	B, U, W, P, A	S	Apr - Oct
Striped bass *Morone saxatilis*	U, W, P?, A	Variable	early Apr - early Jul	U, W, P, A	S	early Apr - fall
Weakfish *Cynoscion regalis*	B	S	mid-May - early Aug	B, U, W	D	mid-May - fall
Spot *Leiostomus xanthurus*	O, B	O	Dec - Mar	B, U, W	S	Jun - Dec
Summer flounder *Paralichthys dentatus*	O	—	Aug - Feb	B, U	S	fall - spring
Windowpane flounder *Scophthalmus aquosus*	B, U	D	late Apr - Dec	O, B, U	D	late summer - fall
Hogchoker *Trinectes maculatus*	O, B, U	O	May - Aug	B, U, W		May - fall

Species	References used for each Species in Tables 1A and 1B
Atlantic sturgeon *Acipenser oxyrhynchus*	1, 2, 7
Shortnose sturgeon *Acipenser brevirostrum*	6, 7
American eel *Anguilla rostrata*	1, 2
Blueback herring *Alosa aestivalis*	1, 2
Alewife *Alosa pseudoharengus*	1, 2
American shad *Alosa sapidissima*	1, 2, 7
Atlantic menhaden *Brevoortia tyrannus*	1, 2
Bay anchovy *Anchoa mitchilli*	1, 2
Carp *Cyprinus carpio*	1, 2
Silvery minnow *Hybognathus nuchalis*	1, 2
Spottail shiner *Notropis hudsonius*	1, 2
White sucker *Catostomus commersoni*	1, 2
White catfish *Ictalurus catus*	1, 2
Brown bullhead *Ictalurus nebulosus*	1, 2
Channel catfish *Ictalurus punctatus*	1, 2
Banded killifish *Fundulus diaphanus*	1, 2
Mummichog *Fundulus heteroclitus*	1, 2
Atlantic silverside *Menidia menidia*	2, 3, 4
White perch *Morone americana*	1, 2
Striped bass *Morone saxatilis*	1, 2
Weakfish *Cynoscion regalis*	2, 3, 4, 5
Spot *Leiostomus xanthurus*	1, 2, 5
Summer flounder *Paralichthys dentatus*	2, 3, 5
Windowpane flounder *Scophthalmus aquosus*	2, 3, 4, 5
Hogchoker *Trinectes maculatus*	2, 3, 4

Table 4-7 Estimated Catch in Weight and Value of the Inshore Gill Net Fishery for the State of Delaware During 1981. (Seagraves, 1982).

Species	Estimated Landing (Metric tons)	Estimated Value (Dollars)
Weakfish	477	462,748
Bluefish	89	39,200
American shad	88	87,030
White perch	22	28,740
Striped bass	10	19,125
Windowpane flounder	5.4	2,400
Spot	5.0	2,750
Shark	3.4	1,875
Summer flounder	3.0	4,355
Black drum	1.1	250
Atlantic sturgeon	1.1	1,250
Butterfish	0.9	400
Tautog	0.05	10
Totals	769	650,058

the most commercially important, with 477, 89, 88 and 22 tons landed in 1981, respectively. In 1982, summer flounder, bluefish and weakfish ranked first through third as recreational species in Delaware (Grimes, 1983). Weakfish, windowpane flounder, spot and the hogchocker (Trinectes maculatus) are the most abundant species found in Delaware Bay (Grimes, 1983). Of these, the weakfish is the most important edible fish, and is the most significant commercial and recreational species.

Weakfish (Cynoscion regalis) inhabit coastal waters from Nova Scotia to eastern Florida, but are most prevalent in the vicinity of Delaware and Chesapeake bays. Adults move into Delaware Bay during late spring and early summer to spawn, and leave in the fall. Most spawning occurs between Woodland Beach and the Atlantic Ocean. Larvae and young move up the estuary, as far as Wilmington, Delaware and use the tidal creeks as nursery habitat. Young begin to move down the estuary in August, and are mostly gone from Delaware Bay by mid-November. Weakfish mature at two to three years of age, when they are 10 to 13 inches long. Weakfish have been reported to reach 35 inches in length. Weakfish feed on a wide variety of food items including small fish, crabs, amphipods, shrimp, squid, shelled mollusks and annelid worms.

The American shad (Alosa sapidissima) is one of the most important species of finfish in the Delaware basin. The shad harvest was highest in 1880, when it was reported to be over 10 million pounds. By 1920, however, it had dropped to several hundred thousand pounds and has remained low. The decline in the shad population has been attributed to overfishing, dam construction and water pollution. Efforts to restore the shad population in the Delaware River have begun to prove successful. Improvements in water quality, specifically dissolved oxygen levels, have led to larger shad runs. Low dissolved oxygen levels in the Philadelphia-Camden metropolitan area previously prevented adults from migrating to spawning areas in the spring, and juveniles from migrating downstream in the fall.

American shad spend most of their lives in coastal waters. They only enter the Delaware estuary and the freshwater portion of the river to spawn. Spawning migrations are triggered by water temperature, peak runs occur at temperatures between 55 and 61 degrees F. Spawning occurs in the Delaware River between late-April and July. Larvae and juveniles remain on the spawning grounds until fall, when they migrate downstream and leave the estuary. Adults return to the Delaware in four to six years, when they are ready to spawn. American shad live five to seven years, and typically weigh two to six pounds. Shad are opportunistic feeders, food items include insects, insect larvae, crustaceans, rotifers, copepods, diatoms, shrimp, worms, barnacles and small fish.

Another species of concern within the Delaware estuary is the striped bass (Morone saxatilis). Historically, the striped bass was an important commercial and recreational species within the estuary. Like the American shad, striped bass were abundant in the 1800's, but experienced a significant decline in the 1900's. Again, the Philadelphia-Camden pollution block precluded migrating adults from reaching up-river spawning sites. The preferred spawning sites of the striped bass are freshwater portions of rivers and streams immediately

above brackish zones. Spawning within he Delaware estuary has been reported to occur from Oakwood Beach to Bridgeport, New Jersey and from Rivertown to Newbold Island, New Jersey (Murawski, 1969). It is hoped that recent water quality improvements in the Delaware estuary will improve striped bass spawning. Reports from fishermen suggest that the number of spawning-age striped bass has increased in the vicinity of Trenton, New Jersey (Versar, 1987).

Adult striped bass spend much of the year in schools along the coast. They migrate north and into estuaries during the spring, and south and into higher salinity waters in the fall and winter. Spawning takes place from April to June, when water temperatures are between 54 and 72 degrees F. Eggs are semi-buoyant, and require turbulence to keep from settling to the bottom, where they may be smothered by sediments. Juveniles remain in the estuary for two to three years before migrating to sea. They do migrate to the lower bay, to spend the winter in deeper water. Striped bass mature in three to five years. The mean size of striped bass in the Delaware is 12 to 30 inches in length, and one to 10 pounds in weight. Occasionally a specimen four feet in length and 50 or more pounds is taken. Larval and juvenile striped bass feed primarily on microcrustaceans. Larger individuals consume worms, squid, shrimp, and fish.

Another species of concern within the Delaware estuary is the Federally endangered shortnose sturgeon (Acipenser brevirostrum). While believed to be common in the 1800's and early 1900's, very few captures were reported between 1910 and 1970. Pursuant to the Endangered Species Act of 1977 (16 U.S.C. 1531 et seq.), the U. S. Army Corps of Engineers contracted Rutgers, The State University of New Jersey in 1981 to conduct an in-depth study of shortnose sturgeon in the Delaware estuary. Between July of 1981 and December 1984, Rutgers personnel documented a total of 1,376 individual shortnose sturgeon captures and 76 recaptures (Hastings, 1983a; 1983b; 1985). Based on early data from these studies, Dadswell (1984) estimated the shortnose sturgeon population in the Delaware estuary between Trenton, New Jersey and Philadelphia, Pennsylvania to total 6,452 adults. Later data suggests that this estimate may be doubled (NMFS, 1985).

The shortnose sturgeon is an anadromous species. In the spring adults migrate from lower estuary and freshwater overwintering sites, upstream to upper tidal and lower non-tidal spawning grounds. In the Delaware River, the area below Scudder's Falls is commonly used by shortnose sturgeon to spawn (Brundage, 1984). After spawning, adults migrate downstream to summer foraging areas. Some remain in freshwater while others move to mid-estuary. Individuals have been captured throughout the Roebling to Trenton area during the summer, with Newbold Island and Duck Island being most productive. In the fall, the bulk of the population migrates to the lower estuary to overwinter. However, studies have indicated that many do overwinter in the Roebling to Trenton area. Juveniles generally remain in freshwater year-round until they reach maturity. Maturity is reached in three to seven years. The shortnose sturgeon is the smallest of all sturgeons, with a maximum length of about three feet. The shortnose sturgeon is a bottom feeder, consuming worms, crustaceans, larvae and some plants. In the freshwater portion of the Delaware estuary, the Asiatic

river clam (Corbicula manilensis) is considered to be a primary source of food for shortnose sturgeon (Hastings, 1985).

4.3.6 Ichthyoplankton

Sources of information of the ichthyoplankton population are relatively sparse in the Philadelphia district. Most of the information comes from near-field entrainment studies from power plants in the Philadelphia-Marcus Hook area of the River, specifically Southwark, Chester and Eddystone Generating Stations (PECO, 1977a, 1977b, 1977c). These data are relatively old (from 1976 through 1978), therefore, any increases in ichthyoplankton populations due to improvements in water quality in recent years would not be recorded. This information, however, is consistent throughout this reach of the river with respect to species and their abundance. Herrings (Clupeids, including Alosa spp.), white perch and striped bass (percichthyids), American eel, and minnows and carps (cyprinids) were the most abundant groups in ichthyoplankton samples. Bay anchovy, Lepomis sp. and killifish were also collected. In all three studies, herring larvae were the most abundant species collected. Minnows and carp were second in abundance at Chester and Eddystone, and white perch and striped bass were next in abundance at Southwark. Numbers of ichthyoplankton taken were greatest in May and June. Tyrawski (1979) reports that Potter et at. (1974) has similar findings when sampling near Eddystone in 1973.

Tyrawski (1979) reports that just north of the C&D Canal plankton collections were made from May 1972 through April 1973. Again, the most abundant fish larvae collected were the bay anchovy, white perch, river herrings and striped bass, and also Lepomis sp. Together, these species comprised 95.7 percent of the catch. Lepomis sp., white perch and bay anchovy dominated the catch in May, June and July, while bay anchovy dominated in August, September and October, and the American eel dominated in November through April (Tyrawski, 1979). Table 4-6 lists spawning and nursery locations of species of interest; these locations represent areas where ichthyoplankton would be expected to occur during the times indicated.

4.3.7 Wildlife

Many of the species of birds common to the Delaware River estuary can be considered inhabitants of the wetlands and tidewaters of the estuary. Other species use the wetlands and tidewaters of the estuary during their migrations. The Delaware River estuary is listed among the major shorebird and waterfowl migration, wintering and breeding areas in the Atlantic Flyway (Whitman and Cole, 1988). Because of its location on the Mid-Atlantic Coast, this portion of the Delaware estuary forms an important link in the Atlantic Flyway for these birds on their seasonal migrations from the Canadian north to major wintering areas in the southeastern United States. Several hundred thousand ducks and geese pass through the Delaware River basin annually during the fall and spring, with significant numbers remaining throughout the winter months (Whitman and Cole, 1988).

A variety of shorebirds use bay habitats over the course of the year. Many species nest in the area during the spring and summer months. Common nesting species include the common tern (Sterna hirundo), least tern (Sterna albifrons), herring gull (Larus argentatus), laughing gull (Larus atricilla) and black skimmer (Rynchops nigra). The area also provides habitat for a large number of wading birds. Common species include the snowy egret (Leucophoyx thula), glossy ibis (Plegadis falcinellus), little blue heron (Florida caerulea), black-crowned night heron (Nycticorax nycticorax) and yellow-crowned night heron (Nyctanassa violacea).

Wading birds typically arrive in mid-March and remain to mid-fall when they migrate south. Nesting is underway by early May and completed by mid-July. Other migratory species of shorebirds use the area for resting and feeding during the spring migration from South and Central America to breeding grounds in the Arctic. Over 20 species, primarily the red knot (Calidris canutus), ruddy turnstone (Arenaria interpres), sanderling (Calidris alba) and semipalmated sandpiper (Calidris pusilla), coincide their arrival with the horseshoe crab spawning season. Horseshoe crab eggs provide a valuable food source for these migrating birds. Other important migratory species observed in the area include dunlin (Calidris alpina), least sandpiper (Calidris minutilla), willet (Catoptrophorus semipalmatus), short-billed dowitcher (Limnodromus griseus), semipalmated plover (Charadrius semipalmatus) and black-bellied plover (Pluvialis squatarola).

Reedy Island and particularly Pea Patch Island are known for their importance to nesting wading birds. Species that utilize these islands include glossy ibis, great egret (Casmerodius albus), snowy egret, great blue heron (Ardea herodias), Louisiana heron (Hydranassa tricolor), black-crowned night heron and yellow-crowned night heron.

Delaware Bay wetland habitats are also valuable to overwintering waterfowl. An estimated 34 percent of the entire Atlantic Flyway black duck (Anas rubripes) population overwinter in New Jersey wetlands, particularly along Delaware Bay. These marshes also provide important breeding habitat for the black duck. In addition to black duck, the study area also supports large numbers of migrating waterfowl. Important species include the wood duck (Aix sponsa), blue-winged teal (Anas discors), green-winged teal (Anas crerra), American wigeon (Anas americana), mallard (Anas platyrhynchos), gadwall (Anas strepera), northern shoveler (Anas clypeata), northern pintail (Anas acuta), canvasback (Aythya valisineria), greater scaup (Aythya marila), lesser scaup (Aythya affinis), Canada geese (Branta canadensis) and snow geese (Chen caerulescens). Many individuals of these species remain in the area throughout the winter.

Over a dozen raptor species are known to migrate through the study area on an annual basis. An average of 75,000 hawks a year have been recorded by the Cape May Bird Observatory since 1976. These birds typically use the eastern shore of Delaware Bay as a migratory corridor. Important species include the sharp-shinned hawk (Accipiter striatus), Cooper's hawk (Accipiter cooperii), red-tailed hawk (Buteo jamaicensis), broad-winged hawk (Buteo platypterus), red-shouldered hawk (Buteo lineatus), northern harrier (Circus cyaneus), American kestrel (Falco sparverius) and merlin (Falco columbarius).

Many owls also migrate through the area on an annual basis. Typical species include the common barn-owl (Tyto alba), northern saw-whet owl (Aegolius acadicus) and long-eared owl (Asio otus).

Many mammals inhabit the shoreline of the Delaware estuary, especially the tidal marshes. Common mammals of the study area include white-tailed deer (Odocoileus viiginianus), gray fox (Urocyon cinereoargenteus), red fox (Vulpes vulpes), raccoon (Procyon lotor), long-tailed weasel (Mustela frenata), mink (Mustela vison), striped skunk (Mephitis mephitis), river otter (Lutra canadensis), muskrat (Ondatra zibethicus), southern flying squirrel (Glaucomys volans), gray squirrel (Sciurus carolinensis), red squirrel (Tamiasciurus hudsonicus), eastern chipmunk (Tamias striatus), eastern cottontail (Sylvilagus floridanus), Virginia opossum (Didelphis virginiana), and little brown bat (Myotis lucifugus). Typical small mammals include eastern mole (Scalopus aquaticus), white-footed mouse (Peromyscus leucopus), meadow jumping mouse (Zapus hudsonius), meadow vole (Microtus pennsylvanicus), pine vole (Microtus pinetorum), and marsh rice rat (Oryzomys palustris).

4.3.8 Threatened and Endangered Species

The Delaware estuary is within the historic range of 15 Federally listed threatened or endangered species, including six species of whale, three bird species, five turtles and one fish. Most of these are transients in the area.

There are six species of endangered whales that have been observed along the Atlantic coast, and occasionally within Delaware Bay. These include the sperm whale (Physeter catodon), fin whale (Balaenoptera physalus), humpback whale (Megaptera novaeangliae), blue whale (Balaenoptera musculus), sei whale (Balaenoptera borealis) and black right whale (Balaena glacialis). These are migratory animals that travel north and south along the Atlantic coast.

The five threatened or endangered sea turtles that occasionally enter the study area include 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 turtle, all of these species breed further south from Florida through the Caribbean and the Gulf of Mexico. The loggerhead may have historically nested along the coastal barrier beaches. No known nesting sites are within the project area.

Avian endangered species that inhabit or migrate through the area include the bald eagle (Haliaeetus leucocephalus), the American peregrine falcon (Falco peregrinus anatum) and the Arctic peregrine falcon (Falco peregrinus tundrius). The bald eagle nests within the states of New Jersey and Delaware; Peregrine falcons are transients, passing through the area during migration.

The shortnose sturgeon (Acipenser brevirostrum) is the only Federally endangered species of fish within the Delaware estuary. The shortnose sturgeon is an anadromous species that inhabits marine and estuarine waters, but spawns in freshwater. A population of shortnose sturgeon spawn in the Delaware River, upstream of Trenton, New Jersey. See section 4.3.5 for additional information regarding the shortnose sturgeon.

4.4 Cultural Resources

4.4.1 Paleogeography of the Delaware Valley and Estuary

The following discussion is based largely on Kraft (1988). Of the many geological processes affecting a system as complex as the Delaware Estuary, the present form of the estuary is largely the result of two principal events, one occurring over a hundred million years ago and the second occurring during the last twenty thousand years. The first event was the creation of the Fall Zone during the uplift of the Appalachian Mountains. This zone, which generally extends from Baltimore through Newark, Delaware, Philadelphia, and Trenton to New York City, marks the transition between the harder rocks of the Piedmont uplands and the softer sediments of the lower-lying coastal plain. The differences in elevation, stream gradient, and underlying rock structure between the two areas mean that the Fall Zone also represents changes in stream flow pattern and sediment deposition within the Delaware estuary. Not only does it represent the break between tidal and nontidal waters, the rapids coming off the highlands means it also marks the landward limit of ship travel. (Interestingly, many colonial cities were built along the Fall Zone). The second factor creating the present topography of the Delaware estuary was the dramatic change that took place at the end of the Ice Ages. Circa 15,000 years ago, with so much water locked up in glacial ice, sea level would have been over four hundred feet lower, and the mouth of the Delaware estuary 75 miles farther to the east, than at present. As the ice melted and the glaciers retreated, massive amounts of debris were washed downstream to the Fall Zone and then out over the coastal plains of New Jersey and the Delmarva Peninsula. By 10,000 years ago, the estuary mouth had moved inland to some 10-40 miles offshore, and sea level was rising at a rate of up to 6 feet every 100 years. As the climate continued to ameliorate, the ecology of the Delaware Valley began changing from a glacial environment of tundra and boreal forests to a more transitional environment of mixed forests and grasslands. It was sometime during this period that humans first entered the Delaware Valley. With the continued rise in sea level, the Delaware River and Bay eventually evolved from a freshwater glacial stream to the present drowned estuary system.

4.4.2 Prehistoric Peoples in the Delaware Valley

The archaeological record of the occupation of the Delaware Valley by prehistoric peoples, well summarized by Custer (1984), is consistent with the generalized patterns of cultural development for the Middle Atlantic states. Three major prehistoric periods are recognized: Paleoindian (15,000 years Before Present, or B.P., to 8,500 B.P.), Archaic (8,500 B.P. - 5,000 B.P.), and Woodland (5,000 B.P. - 400 B.P.). The first peoples into the Delaware Valley would have been Paleoindian hunter gatherers. Apart from the Zierdt (Werner 1964) and Shawnee-Minisink (McNett et al., 1977) sites, few Paleoindian-period sites have been found in the Delaware Valley, especially in the lower portion of the valley covered by the Philadelphia to the sea project. This low density of sites is partly the result of the low population density and nomadic lifestyle of the peoples from this period, but it is also attributable to the subsequent inundation of many sites by the rising water level in the Delaware Bay during the past 10,000 years, and the burial of sites under thick layers of alluvium and later cultural deposits.

Archaic period peoples responded to the changed environmental conditions of the post-Pleistocene by exploiting a greater variety of resources. The archaeological record from this period suggests an increased population size, a greater reliance on processing of plant foods, and exploitation of the newly available estuarine resources of the Delaware River. The relative abundance of sites from this period has led to the definition of the Delaware Valley Archaic complex (Kinsey 1972). Sites are known for the Upper Delaware, but the lack of information from the lower Delaware and Bay area reflects site inundation through sea level rise and the destruction of sites through flooding.

The prehistoric period that is best represented in the Delaware Valley is the Woodland period, which is characterized by the introduction of pottery, increasing cultural diversity, and the evolution of a sedentary lifestyle that increasingly relied on agriculture. Sites from the Woodland period are typically found in estuarine settings, including coastal marshes and brackish rivers. Several National Register listed prehistoric sites have been found in the Delaware River and Bay area within one mile of shore. By the 1600's the Delaware Basin had been settled by the Lenape Indians, one of the tribes of Algonquin Indians.

4.4.3 Historic Settlement of the Delaware Valley

The first recorded European exploration of the Delaware Bay was by Henry Hudson in 1609, under commission from the Dutch East India Company to seek a northwest passage to China and Japan. The following year the area was visited by an English captain in search of food for the settlement of Jamestown, who named the region in honor of the governor of the Virginia colony, the Baron DeLaWarr. The Dutch were the first Europeans to exploit the rich resources of the Delaware Valley and the first to settle in the area. They quickly set up a fur-trading network with the Indians along the Delaware River, and built outposts, such as Fort Nassau (1623), near present-day Gloucester Point, New Jersey, to support the trade network. In 1630, they also established a short-lived whaling colony named Zwaanendael, near present-day Lewes, Delaware. The Swedes put an end to the Dutch monopoly of the region in 1638 by building Fort Christina, near present-day Wilmington, Delaware. By the 1640's both the Dutch and the Swedes had established outposts as far upriver as Trenton, and battled each other for supremacy in the Delaware Valley. In 1651, the Dutch relocated their headquarters from Fort Nassau to Fort Casimir (now New Castle, Delaware), and founded the town of New Amstel adjacent to it. As the capital of the Dutch colony along the Delaware, New Amstel quickly grew into a thriving trade center. In 1654, the Dutch captured all Swedish posts, only to be conquered by armed British fleets in the 1660's during the Anglo-Dutch wars.

With the Treaty of Westminster in 1674, the British gained control of all Dutch North American colonies, including Delaware Bay. The lack of detailed mapping of the lands around the bay led to ambiguities in the royal grants for these lands, which resulted in long-running disputes over the ownership of lands along the western side of the bay. These disputes were not finally resolved until the eighteenth century, with the creation of the Mason-Dixon line (Heite 1988). By the latter part of the seventeenth century, the typical landholding

pattern along the shores of the Delaware consisted of long narrow tracts of land, each fronting along the river. In 1675, John Fenwick, one of the proprietors of western New Jersey, established a settlement at Salem, which quickly became the center of government along the eastern banks of the Delaware. In 1682 William Penn obtained his royal charter for the colony of Pennsylvania, which included a portion of the west bank of the Delaware. With the establishment of Philadelphia as the colony's capital, the political and commercial focus of the western side of the Delaware shifted northward from New Amstel (renamed New Castle under English dominion) to Philadelphia. By 1700, Philadelphia had a population of more than 20,000. During the ensuing decades, Philadelphia flourished not only as the commercial center in the Delaware Basin, but also as the principal port city on the Atlantic coast, and the center of trade with England. Philadelphia was doubly blessed by its location: the Delaware River and its tributaries provided easy transportation of goods into and out of the city, and the good soils and favorable climate of the region allowed grain, especially wheat, to become the principal export. Grain farming began the process of massive landscape alteration that continued over the next two centuries. Cutting the forests and plowing the soil to create farmland increased soil runoff and increased the silt load carried to the Delaware River and its tributaries. Processing the increasing quantity of grain being produced led to the development of mills to convert the grain into flour. While the earliest mills were tidally driven, eventually nearly every stream in the basin had been dammed to power a grist mill (Heite 1988). Towns and roads to support agriculture and trading appeared throughout the Delaware estuary, and by the time of the Revolution, the region was flourishing.

The more than one hundred years of English dominion came to an end with the Revolutionary War. Although the British captured Philadelphia in September, 1777, the colonists retained control of the Delaware River and effectively cut off the British from the only supply route available to them. In an effort to gain control of that supply route, the British launched a large fleet of naval warships to defeat the colonial forces controlling the river. Maps prepared at that time document the locations of the defensive structures used by the colonists to defend the river, including three forts and two tiers of submerged river obstructions, known as chevaux-de-frise, along with a fleet of 57 vessels. Several naval engagements between the British and the revolutionary forces took place along the Delaware River south of Philadelphia; more than 44 vessels were lost (Cox 1984).

As the new country entered the nineteenth century, new commercial activities developed in the Delaware Valley. In the upper estuary, the vast pine and hemlock forests supported thriving timber and tannery enterprises, which in turn necessitated more efficient means of transportation. Initially it was possible to simply raft items down the Upper Delaware. However, with the discovery of the rich mineral deposits in the region - coal, sand, clay, limestone, copper, and iron - a more reliable and economical method of transportation was required. There followed a series of transportation developments, all of which had their origin and/or florescence in the Delaware Valley region, beginning with turnpike construction, followed by the canal building era, and culminating with the appearance of the railroads.

By the mid-nineteenth century, the upper Delaware estuary was industrialized and experiencing rapid population growth. The Delaware Bay, however, with its tidal marshes and minimally navigable rivers, was not as well suited to industrial development, but rather remained principally tied to agriculture (Heite 1988) (This distinction between the lower and upper estuaries of the Delaware remains valid today.) The one commercial activity that was common to both the upper and lower estuaries was fishing, an activity that had flourished in the Delaware Basin since humans first settled in the region. Oysters, sturgeon, herring, and shad were abundant in the estuary and supported a thriving fishing industry into the twentieth century, and even up to the present, although at reduced levels.

By the late nineteenth century, industrial development in the Delaware Valley was in full swing. The development of the steam engine brought new industries to the region, ones that were no longer linked directly to the estuary, except as a transportation corridor (Heite 1988). Steam-powered railroad engines and cars were produced in Philadelphia and Wilmington; the canning industry thrived in Camden and Dover; and steamships were built in Philadelphia and Wilmington. With the invention of the Bessemer process of steel making, steel mills grew into massive industrial complexes at Bethlehem, New Castle, and Trenton. Finally, the success of the DuPont chemical company along the Brandywine River, and the discovery of oil led to a massive chemical and oil refining industry in the Delaware Valley.

4.4.4 Shipping and Shipbuilding

One Delaware Valley industry that deserves special mention is shipbuilding. Shipbuilding has been one of the most important and most famous industries of the Delaware Valley for more than three centuries. By 1700, at least four commercial shipyards were operating in Philadelphia (Cox 1988). Shipyards sprang up all along the Delaware River, and by the Revolutionary War, Philadelphia had eclipsed Boston as the shipbuilding capital of the colonies. John Fitch successfully operated the world's first steamboat along the Delaware River shoreline during the 1780's. By the nineteenth century, the shipyards of the Delaware Valley were the country's leaders in the production of iron-hulled steamships. Naval vessels for the Revolutionary War and Civil War were constructed at Delaware River shipyards. In 1900, the New York Shipbuilding Company began constructing the world's largest self-contained shipbuilding plant in south Camden. With the onset of World War I, the Philadelphia Navy Yard was expanded to become the largest navy yard with the largest drydock in the world. To help with the war effort, the American Shipbuilding Company converted Hog Island, in south Philadelphia, into the site of the largest shipbuilding plant in the world. Shipbuilding in the Delaware Valley is presently at the lowest level it has been since 1700.

Shipbuilding originally started along the Delaware River to enhance trade, which in turn increased settlement throughout the Delaware Valley. Because the Delaware River/Bay is situated roughly halfway between New York Bay and the mouth of the Chesapeake Bay, and provides the only break in a dangerous 295 mile stretch of the Atlantic coast, it was a natural site for port development.

By the colonial period, Delaware Valley port cities were engaged in trade with other colonies, Europe, and the Caribbean. Maritime commerce to and from the port cities along the Delaware River played a major role in the economic development of the entire Delaware Valley, and eventually led to Philadelphia's emergence as the lead port city on the river. In the early 1700's, Philadelphia ranked third behind Boston and New York in the volume of shipping clearing the port, and by the start of the Revolutionary War Philadelphia had surpassed both cities to become the most active port in North America. With the advent of steamships in the nineteenth century, passenger service became a major port activity.

4.4.5 Navigational Hazards and Improvements

The volume of shipping in the Delaware estuary over the last three centuries, in combination with the navigational hazards in the waterway, inevitably led to shipwrecks. Although the total number of wrecks will never be known, more than 145 documented shipwrecks have occurred in the Delaware River/Bay (Cox 1984). That there were hazards to be overcome in safely navigating the bay and river was soon learned by the early explorers. Soundings of the Delaware estuary, undertaken by the mid seventeenth century, enabled mariners to avoid at least some of the hazards, but better mapping was needed. Although Augustine Herrman, the person to first propose a canal to connect the Delaware and Chesapeake Bays, produced the first reliable map of the Delaware Estuary shoreline in the mid seventeenth century (Heite 1988), the first comprehensive navigational chart, with bottom contours, was not made until 1756 (Cox 1988).

By 1766, a single governmental body, the Wardens of the Port of Philadelphia, was established to direct channel and harbor improvements (GAI 1983). One of their first activities was to authorize the removal of the chevaux-de-frise, submerged wooden frames used by the colonists to defend the river during the Revolutionary War. Most had been removed by 1784, but during channel dredging in the 1940's dredges are reported to have struck one or more of the frames (Cox 1988). One of the earliest improvements to navigation on the Delaware was the 1803 construction of ice piers off New Castle, Delaware. Until the middle of the nineteenth century, the Delaware River froze over almost every winter, and the resulting ice floes posed a serious threat to ships. The ice piers served as refuge for sailing vessels and helped to break up ice floes as they came down the river (Cox 1988). Other early navigational improvements included the stabilization of river banks, the diking and in-filling of low-lying areas, and the removal of islands (GAI 1983).

However, the major navigation hazard in the Delaware River has always been shoaled waters (Cox 1988). Dredging the river to remove shoals and maintain a navigable channel has been ongoing since 1800. At that time limited, man-powered dredging was possible; by the 1840's, steam dredge boats were used to maintain channels and to build harbors (GAI 1983). Currently there are eighteen major shoals or sand bars near the main channel of the Delaware River. Historically, mariners were required to navigate through these shoals in a winding channel. To monitor the locations of shoals and to facilitate safe navigation, the National Ocean Survey and its predecessor has conducted regular hydrographic surveys of the Delaware River and Bay, since at least 1840.

In its natural state, the Delaware River downstream of Philadelphia had a natural depth of 20 feet (deeper in some places) and a controlling depth of approximately 17 feet (Boggs 1929). By the last quarter of the nineteenth century, the typical ocean-going vessel had a draft of 20-24, and could no longer safely negotiate past all the obstructions except at high tide. From 1877 to 1882, several of the major natural obstructions, large portions of the rock shoals between Chester and Marcus Hook and the shoals near Petty Island and Fort Mifflin, were removed. But it was not enough to permit safe passage of deep-draft ships. Finally, in 1885, Congress authorized the permanent and systematic improvement of the Delaware River, and gave the Army Corps of Engineers the responsibility of dredging and maintaining the channel, anchorages, dikes and harbors. The 1885 legislation called for a channel 26 feet deep and 600 feet wide from Philadelphia to deep water in Delaware Bay. The transition from sail to steam power rendered the 26 foot deep channel obsolete and led Congress in 1896 to authorize an increase in channel depth to 30 feet. The existing Delaware River, Philadelphia to the Sea Federal channel project was initially authorized by the River and Harbor Act of 1910 and has been modified several times to its presently authorized forty foot depth.

4.4.6 Cultural Resources Investigations

Philadelphia District has undertaken several investigations of cultural resources within the proposed project area. The "Cultural Resources Overview and Sensitivity Analysis for the Delaware River and Shoreline" (Gilbert/Commonwealth 1979) collected data for shoreline areas to assist in the development of suitable dredged material disposal areas. The study identified 162 historic sites and districts within one mile of the Delaware River and Bay area shoreline from Trenton, New Jersey to Lewes, Delaware. The "Delaware River Comprehensive Navigation Study (Interim): Cultural Resources Sensitivity Reconnaissance" (GAI 1983) assessed the potential for containing significant cultural resources of several proposed dredging and disposal sites between Wilmington and north of Philadelphia. This study added 30 new historic sites to the 1979 inventory. A "Sensitivity Level Investigation of Cultural Resources in the Vicinity of the Main Navigational Channel, Delaware River, Wilmington to the Sea, and a Proposed Deepwater Port" (Cox 1986) assigned cultural resource sensitivity designations of high, medium, or low to three segments of the waterway from Wilmington to the sea, to facilitate plans for deepening or widening the existing navigation channels and anchorages and creating a deepwater port.

A "Preliminary Cultural Resource Reconnaissance Investigation of Thirteen Disposal Areas" (Heite and Heite 1986) assessed the potential for significant prehistoric or historic resources at thirteen proposed disposal areas along the Delaware River in New Jersey and Delaware. Finally, "Submerged Cultural Resources Investigations, Delaware River Main Navigational Channel, Philadelphia, Pennsylvania to Artificial Island, New Jersey" (Cox 1988) presents the results of magnetometer and side scan sonar survey at fourteen locations, all found at the inside portion of the intersection of two ranges along the main channel, and each proposed for bend widening. This report documents sixty-six remotely sensed targets, six of which may represent

potentially significant submerged cultural resources. The results of this report, and the others discussed above, are presented in greater detail, as appropriate, in the Environmental Effects section (5.1.12) of the EIS. All reports are on file at the Philadelphia District office.

4.5 Candidate Dredged Material Disposal Sites

Based on the dredged material disposal site screening analysis discussed in the Plan Formulation section of the main report and section 3.4 of this Environmental Impact Statement, three additional sites were selected to meet the dredged material disposal requirements for construction and maintenance of the selected plan for the 50-year study period. These sites are 170 (Figure 3-4), located in Reach A, and 15D, and Raccoon Island (Figure 3-5), located in Reach B. The following provides ecological and cultural resource descriptions of these areas.

4.5.1 Ecological Description

Ecological descriptions of sites 170 and 15D are based on information provided by the U. S. Fish and Wildlife Service (FWS, 1989). This report is included in Appendix A of the main report.

Site 170

Site 170 is a 180-acre parcel of land located in West Deptford Township, Gloucester County, New Jersey (Figure 3-4). The site is bordered on the north by the Delaware River, on the east by Little Mantua Creek and on the south by railroad tracks north and parallel to State Route 44. Most of the site appears to have been used in the past for dredged material disposal. Site boundaries include tidal marshes and open water areas associated with Little Mantua Creek as well as developed industrial areas to the west.

Two overgrown fields, located in the central and south-central portions of the site, support a variety of grasses and herbaceous vegetation. A large forested area on the northern portion of the site is dominated by black willow, black cherry, and cottonwood (Populus deltoides). Other central and southern portions of the site support diverse habitat including overgrown fields dominated by common reed, shrubland dominated by black cherry, and forests of black cherry, ailanthus (Ailanthus altissima), sassafrass (Sassafras albidum) and hickory (Carya sp.).

Wetlands located in the vicinity of the site include an area of wetlands and open water, about 27 acres, associated with Little Mantua Creek, an approximately eight-acre area of red maple (Acer rubrum) dominated, forested wetlands located on the southeastern portion of the site, and an approximately 28-acre area of diverse emergent and forested wetland located on the southwestern portion of the site. Based on consultation with the U. S. Fish and Wildlife Service, these areas have been excluded from the site boundary.

Site 170 appears to support a great diversity and abundance of passerine birds. This can be attributed to the diversity and degree of interspersion of overgrown field, shrubland and forest habitats on the site. The U. S. Fish and Wildlife Service documented 39 species of birds during two site visits.

Site 15D

Site 15D is located in Logan Township, Gloucester County, New Jersey (Figure 3-5). Site 15D is approximately 575 acres in size, bordered on the north by the Delaware River and Raccoon Creek and on the south by State Route 130. An unnamed tributary to Raccoon Creek drains north from tidal wetlands largely encircled by, but not included within, the site. All of the site has been formerly used for dredged material disposal. A winding ditch, approximately 10 feet in width and 2,000 feet in length, is oriented generally north and south near the western boundary of the site. Near the northernmost terminus of this ditch are a series of borrow pits, some of which held water during summer, 1989. Other smaller ditches, apparently dug to drain agricultural fields, are located in the northeastern and eastern portions of the site and drain into Raccoon Creek.

Much of the eastern two-thirds of the site was planted in corn and soybeans in 1989. Exceptions include black willow-dominated areas in the southeastern and central portions of the site and some stands of common reed in areas not planted to crops. A small grass runway, used by ultralight aircraft, is present in the central portion of the site. The western third of this site is dominated by common reed interspersed with patches of various grasses and herbaceous vegetation. Additional forested areas, dominated by black willow, are limited to the extreme northwestern portion of the site and north-central areas just north of the encircled wetlands.

Wet areas encountered within the boundaries of the site include the drainage ditches and their banks, which comprise less than one acre, and an approximately 2-acre area of wet crop fields in the west-central portion of the site.

New Jersey Division of Fish, Game and Wildlife surveys of Raccoon Creek conducted in 1988 documented 19 species of fish including blueback herring, alewife, American shad, white perch, and striped bass (Howard, 1989). Due to their high value to waterfowl, marshes of Raccoon Creek have been designated focus areas for needed protection under the Atlantic Coast Joint Venture, an effort under the North American Waterfowl Management Plan. Raccoon Creek and adjacent marshes are of exceptional value to fish and wildlife resources.

Raccoon Island

The Raccoon Island site is located in Logan Township, Gloucester County, New Jersey (Figure 3-5). This site is approximately 480 acres in size. The site is bordered by the Delaware River to the north, State Route 130 to the south, Raccoon Creek to the west, and the American Dredging Company, White's Basin

dredged material disposal area to the east. The Commodore Barry Bridge, a fixed span bridge that crosses the Delaware River, cuts across the northeast portion of the site.

All of the Raccoon Island site has been used for dredged material disposal in the past, and is bounded by dikes. The site is predominantly vegetated by common reed (Phragmites communis). Interspersed throughout the site are areas covered by oldfield vegetation, which includes a mixture of forbs and grasses. Occasional stands of black willow (Salix nigra) and sumac (Rhus sp.) are also scattered throughout the area.

4.5.2 Cultural Resource Description

The screening process by which the list of potential candidate dredged material disposal sites was narrowed down to the currently proposed sites is thoroughly discussed in the Plan Formulation Section of the Main Report and Section 3.4 of this EIS. The presence of a property listed on the National Register of Historic Places was one of the criteria used during this screening process to eliminate sites. The potential for a disposal site under consideration to contain significant prehistoric or historic resources was taken into account as well. Toward that end the Corps commissioned a cultural resources reconnaissance of thirteen possible upland disposal areas in New Jersey and Delaware (Heite and Heite 1986). Information on several other candidate upland disposal areas was derived from cultural resources studies conducted as part of proposed private development plans. Candidate overboard disposal sites (aquatic sites) were assumed to be potentially sensitive for cultural resources, and were not tested. Of the three dredged material disposal sites selected for the proposed channel deepening project, 15D was included in those studied by Heite and Heite, and the discussion of this site, presented below, is based largely on their 1986 report. The discussion of the remaining two sites, 170 and Raccoon Island, is taken from reports produced by private developers. It should also be noted that ten existing Federal dredged material disposal sites would also be used for continued maintenance dredging of material attributed to the existing 40 foot channel. Proposed disposal sites are shown on Figures 3-4 through 3-10.

Disposal site 15D is located between Birch and Raccoon Creeks at their confluence with the Delaware River, in Gloucester County, New Jersey. It is a 575 acre area of former wetlands that is a previously used diked disposal area. Several archaeological sites are located partly or wholly within the boundaries of this disposal area. Here the rich resources of the tidal flats would have attracted prehistoric peoples. Use of the site 15D area by historic peoples is quite likely, since the nearby mouth of Raccoon Creek was settled by the Swedes and the British in the seventeenth century. A National Register property, the Salisbury Farm site, is located between Raccoon Creek and disposal area 15D. The Salisbury Farm site contains both prehistoric materials as well as a contact period historic component.

The proposed Raccoon Island site lies just north of Raccoon Creek, along the Delaware River, in Gloucester County, New Jersey. The eastern edge of this roughly 600 acre site lies beneath the Commodore Barry Bridge. A 1973 environmental impact statement (McCormick 1973), prepared as part of American Dredging Company's plan to create a dredged material disposal area immediately to the east of the Raccoon Island site, briefly discusses the Raccoon Island site. The site, as the name would suggest, was originally an island. It was known as Cadwalader Island up through 1925, but by 1936 the name had changed to Raccoon Island. Although no systematic archaeological investigation appears to have been done for the Raccoon Island area, prehistoric sites are known from adjacent areas and the island is likely to have been visited by prehistoric peoples. The site is also likely to have been visited by historic settlers. However, by the late 1930's, the Raccoon Island site had been converted from an island into part of the mainland, and was being routinely used by the American Dredging Company for the disposal of materials dredged for its clients along the Delaware and Schuylkill Rivers. The construction of piers for the Commodore Barry Bridge in the late 1960's necessitated a temporary halt to disposal activities, but they eventually resumed, and the site was actively used until the 1970's. The site has been filled to elevation 30 feet as a result of disposal activities.

Proposed disposal site 170 is located just east of the confluence of Mantua Creek and the Delaware River, in West Deptford, Gloucester County, New Jersey. The site, comprising some 180 acres, was investigated for cultural resources (Wilson 1976) as part of the planning by General American Transportation Corporation (GATX) to construct a terminal facility at that site. Although the terminal facility was never built, the land is still owned by GATX, and is referred to as the GATX site. Wilson's 1976 study found that in the area between Mantua Creek, Little Mantua Creek, and Crown Point Road there were eleven historic sites and four prehistoric sites. The prehistoric sites have yielded Archaic and Woodland period artifacts. Historic period sites, some now destroyed, originally included a railroad, a sunken ship, a Revolutionary War gun placement, and eighteenth and nineteenth century homesteads. One home in particular, that of Tench Francis, a Revolutionary War patriot, was considered of such architectural significance that the house and barn were formally recorded by the Historic American Buildings Survey in 1941. Several of the sites were partially or completely destroyed during land alteration activities in 1945-1948, when portions of the lands adjacent to Mantua Creek and Little Mantua Creek were bulldozed into dikes and dredged material was pumped into the enclosed area, changing the course of both waterways.

5.0 Environmental Effects

5.1 Effects of Plan Implementation on Environmental Resources

The tentatively selected plan of improvement is described in Section 3.5 of this Environmental Impact Statement, and the Plan Formulation Section of the main report. The plan consists of deepening the inbound and outbound lanes of the Delaware River, Philadelphia to the Sea navigation channel from its existing depth of 40 feet mean low water (mlw) to 45 feet mlw. Channel widths would range from 400 feet wide at the upstream end of the project (Beckett Street Terminal) to 1,000 feet wide in Delaware Bay. Based on a screening analysis performed to identify suitable sites for the disposal of dredged material (Refer to section 3.4 of this Environmental Impact Statement and the Plan Formulation section of the main report), three new upland sites have been selected for construction and maintenance of the proposed project. All or portions of these three sites, 170, 15D and Raccoon Island, have been previously used for dredged material disposal operations. In addition, two existing upland sites would be required, Reedy Point North and Reedy Point South. In Delaware Bay, a variety of beneficial use options have been developed for the disposition of sandy dredged material. These options include wetland restoration, island creation and sand stock piling for future beach nourishment efforts. Final selection of these options will await completion of detailed environmental studies to be conducted during the PED phase of planning. The following provides a discussion of the potential impacts associated with construction and maintenance of the proposed plan of improvement. To a degree these impacts currently exist, as dredging activities are employed to maintain the 40 foot channel. As such, the no action alternative would have similar impacts as those projected for the proposed plan of improvement, but to a lesser extent. Dredging related impacts would occur for a longer duration with the proposed project, as dredging operations would last longer.

5.1.1 Groundwater

An issue raised with regard to the proposed five-foot deepening of the existing Delaware River, Philadelphia to the sea navigation channel involves the potential impact to groundwater resources. Portions of the project are located in the New Jersey Coastal Plain Sole Source Aquifer. Accordingly, a goundwater assessment is required under Section 1424(e) of the Safe Drinking Water Act to evaluate the impacts to the aquifer resulting from this project. Channel deepening and dredged material disposal may provide the opportunity for chemical constituents within river sediments to enter underlying aquifers. An analysis of the chemical characteristics of river sediments is provided in Section 5.1.3 of this EIS. This section provides a summary of the pertinent facts concerning potential groundwater contamination within the proposed project area. Disposal area history, hydrogeologic conditions, and potential impacts to the regional sole source aquifer are discussed.

The selected plan of improvement requires the acquisition of three new, upland dredged material disposal sites. These sites are designated as 15-D, 17-O and Raccoon Island.

Area 15-D (Former Goose Island, Monsanto & Raccoon Creek D.A's)

Area 15-D consists of a combination of dredged material disposal areas formally used by Monsanto Chemical Company, American Dredging Company and the Corps of Engineers. The entire 575 acre site is now owned by Sun Oil Company and is located adjacent to the Delaware River. The entire area has been filled in the past by disposal of hydraulic fill. Initial disposal began in 1955 and continued into the late 1970's. Approximately 200 acres of the Monsanto property were filled by the Baur Dredging Company in 1965. The Corps placed material in the area from 1955 to 1975. Sun Oil Company has used the area since then for private dredging. Approximately 10-15, feet of fine-grained dredged material overlies the original ground. The disposal area overlies the Potomac-Raritan-Magothy formation. A majority of the area is presently diked. The original subsurface exploration program for the Long Range Disposal Area Study (1973) drilled 25 exploration holes in the disposal area. The holes ranged from 30, to 50 feet in depth and consisted of mainly silts and clays, which are relatively impermeable.

Area 17-O (Former Mantua Creek Disposal Area)

The 180 acre area, formerly owned by National Steel Company is located behind the Mantua Creek anchorage in New Jersey. In 1967, the Corps obtained a five year dredged material disposal easement with National Steel Corporation. Previously this area was filled in by private dredging. The subsurface exploration program for the Long Range Disposal Study (1973) drilled 14 exploration holes in the proposed area. The soil is mainly silt with some layers of clay and sand. The upper 5-10 feet of soil is fine-grained dredged material. This material is relatively impermeable. The disposal area overlies the Raritan-Magothy formation.

Raccoon Island Disposal Area

This area is an active, privately-owned disposal area located on the north side of Raccoon Creek adjacent to the Delaware River. The owner, American Dredging Company, has regularly used the area within the last 5 years for disposal of dredged materials. There is approximately 15 feet of fine-grained material overlying the original ground. This area also overlies the Raritan-Magothy formation.

Geology and Groundwater Resources

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 are progressively deeper toward the Atlantic Ocean. Rock outcrops will be encountered in reach B during the channel deepening. The unconsolidated sediments consist of pervious and impervious layers which form a series of aquifers and aquicludes.

The primary aquifer units along the Delaware River are the Potomac-Raritan-Magothy formations and the Cape May and Columbia formations. The Potomac-Raritan-Magothy 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 municipal water wells in southern New Jersey generally withdrawal their water from the Potomac-Raritan-Magothy formation. It is considered the sole source aquifer for the region.

The Potomac-Raritan-Magothy formation contain the most important and productive aquifers in southern New Jersey and is referred to as the regions sole source aquifer. The thickness of the combined formations is as much as 500 feet. Many industries and public water companies in the region obtain groundwater from this formation. There are four major aquifers within the formation. In the vicinity of the projects disposal areas the uppermost aquifer is 50 to 120 feet below the surface, the second ranges from 105 feet to 250 feet, the third from 300 feet to 390 feet, and the lowermost aquifer is 400 feet to 500 feet below the surface. The upper water bearing zone is usually artesian and is separated from the surface sediments by clay beds with a minimum ten-feet thickness in the vicinity of the disposal areas. Communities along the river obtain their water from the basal part of the lower aquifer. Impermeable clay layers separate all of the water bearing zones. There is no potential for intrusion from future disposal through the existing disposal area sediments and the clay layers of the Potomac-Raritan-Magothy formation.

United States Geologic Survey Report 90-4142, "Hydrogeology of, and Groundwater Quality in, the Potomac-Raritan-Magothy Aquifer System in the Logan Township Region, Gloucester, and Salem Counties, New Jersey " was published in 1991. The study area contains two of the three new disposal areas for the project; 15D and Raccoon Island; along with the existing, Pedricktown North, South, and Oldmans dredged material disposal areas. All of these areas border the Delaware River. Except in outcrop areas, water in the aquifer is confined by overlying impermeable layers as mentioned previously. In the areas where the outcrops coincide with disposal area locations, the ground water remains confined by Cenozoic deposits. This condition exists near the Delaware River where thick Upper Cenozoic clay- and silt-rich deposits overlie the potential outcrop area as shown in the hydrogeologic sections (Figures 5-1 to 5-5). Refer to Figure 5-6 for locations of these sections. Well logs and results of geophysical investigations suggest that the thick alluvial clay deposits are found all along the river downstream of the Raccoon Creek area, and combined with low vertical head gradients, prevent significant induced recharge of the aquifers from the river. These deposits form a confining unit that separates the river and the disposal areas from the aquifers of the Potomac-Raritan-Magothy formation. In addition, each disposal area contains 5 to 35 feet of deposited fine-grained material which acts as an additional barrier to seepage.

Figure 5-1
Hydrogeologic Section A - A'
Logan Township region, New Jersey

EXPLANATION

Lines dividing hydrogeologic units. Dividing lines are based on maps showing the altitude of the top of each hydrogeologic unit (pl. 1 - 5). Dashed where approximately located. In the northwestern part of the hydrogeologic section, dashed lines are based on data from nearby wells. In the southeastern part of the section, dashed lines are based on regional trends (Zapecza, 1989).

33-442 Well number

G-133 Number of geophysical trace (Duran, 1986)

— Bottom of geologic log or geophysical log or bottom of strata interpreted by using geophysical methods.

Hydrogeologic units

HPPM Undifferentiated upper Cenozoic deposits. Only deposits that are differentiable from underlying deposits are shown; deposits less than 10 feet thick are not shown because of scale. Clays, silts, and fine sands (confining materials) are shown shaded; coarser sands and gravels (aquifer materials) are shown unshaded.

MLRW Wenonah-Mount Laurel aquifer.

EGLS Englishtown aquifer system.

WBMV Merchantville-Woodbury confining unit.

MRPAU Upper aquifer of the Potomac-Raritan-Magothy aquifer system.

MRPAM Middle aquifer of the Potomac-Raritan-Magothy aquifer system.

MRPAL Lower aquifer of the Potomac-Raritan-Magothy aquifer system.

WSCK Bedrock confining unit.

Confining units between aquifers shown shaded.
Location of section, wells, and geophysical traces shown on figure 5-6

Figure 5-2
Hydrogeologic Section B - B'
Logan Township region, New Jersey

EXPLANATION

Lines dividing hydrogeologic units. Dividing lines are based on maps showing the altitude of the top of each hydrogeologic unit (pl. 1 - 3). Dashed where approximately located. In the northwestern part of the hydrogeologic section, dashed lines are based on data from nearby wells. In the southeastern part of the section, dashed lines are based on regional trends (Zapecza, 1989).

(5-163) Well number

G-127 Number of geophysical trace (Duran, 1986)

— Bottom of geologic log or geophysical log or bottom of strata interpreted by using geophysical methods.

Hydrogeologic units

HPPM Undifferentiated upper Cenozoic deposits. Only deposits that are differentiable from underlying deposits are shown; deposits less than 10 feet thick are not shown because of scale. Clays, silts, and fine sands (confining materials) are shown shaded; coarser sands and gravels (aquifer materials) are shown unshaded.

MLRW Vanonah-Mount Laurel aquifer.

EGLS Englishtown aquifer system.

WBMV Merchantville-Woodbury confining unit.

MRPAU Upper aquifer of the Potomac-Raritan-Magothy aquifer system.

MRPAM Middle aquifer of the Potomac-Raritan-Magothy aquifer system.

MRPAL Lower aquifer of the Potomac-Raritan-Magothy aquifer system.

WSCK Bedrock confining unit.

Confining units between aquifers shown shaded.
Location of section, wells, and geophysical traces shown on figure 5-6

Figure 5-3
Hydrogeologic Section C - C'
Logan Township region, New Jersey

EXPLANATION

Lines dividing hydrogeologic units. Dividing lines are based on maps showing the altitude of the top of each hydrogeologic unit (pl. 1 - 5). Dashed lines represent approximations made on the basis of regional trends (Zapecza, 1989).

Line dividing the areas where the Englishtown aquifer system is and is not differentiated from the confining units above and below it.

15-585 Well number

G-117 Number of geophysical trace (Duran, 1986)

Bottom of geologic log or geophysical log or bottom of strata interpreted by using geophysical methods.

Hydrogeologic units

HPPM Undifferentiated upper Cenozoic deposits. Only deposits that are differentiable from underlying deposits are shown; deposits less than 10 feet thick are not shown because of scale. Clays, silts, and fine sands (confining materials) are shown shaded; coarser sands and gravels (aquifer materials) are shown unshaded.

MLRW Wenonah-Mount Laurel aquifer.

EGLS Englishtown aquifer system.

WBMV Merchantville-Woodbury confining unit.

EGLS-WBMV Undifferentiated deposits of the Marshalltown-Wenonah confining unit, Englishtown aquifer system, and Merchantville-Woodbury confining unit.

MRPAU Upper aquifer of the Potomac-Raritan-Magothy aquifer system.

MRPAM Middle aquifer of the Potomac-Raritan-Magothy aquifer system.

MRPAL Lower aquifer of the Potomac-Raritan-Magothy aquifer system.

WSCK Bedrock confining unit.

Confining units between aquifers shown shaded.
Location of section, wells, and geophysical traces shown on figure 5-6

Figure 5-4
Hydrogeologic Section D - D'
Logan Township region, New Jersey

EXPLANATION

Lines dividing hydrogeologic units. Dividing lines are based on maps showing the altitude of the top of each hydrogeologic unit (pl. 1 - 5). Dashed where approximately located. In the northwestern part of the hydrogeologic section, dashed lines are based on data from nearby wells. In the southeastern part of the section, dashed lines are based on regional trends (Zapecza, 1989).

Line dividing the areas where the Englishtown aquifer system is and is not differentiated from the confining units above and below it.

15-398 Well number

G-100 Number of geophysical trace (Duran, 1986)

— Bottom of geologic log or geophysical log or bottom of strata interpreted by using geophysical methods.

Hydrogeologic units

HPPM Undifferentiated upper Cenozoic deposits. Only deposits that are differentiable from underlying deposits are shown; deposits less than 10 feet thick are not shown because of scale. Clays, silts, and fine sands (confining materiels) are shown shaded; coarser sands and gravels (aquifer materials) are shown unshaded.

MLRW Wenonah-Mount Laurel aquifer.

EGLS Englishtown aquifer system.

WBMV Merchantville-Woodbury confining unit.

EGLS-WBMV Undifferentiated deposits of the Marshalltown-Wenonah confining unit, Englishtown aquifer system, and Merchantville-Woodbury confining unit.

MRPAU Upper aquifer of the Potomac-Raritan-Magothy aquifer system.

MRPAM Middle aquifer of the Potomac-Raritan-Magothy aquifer system.

MRPAL Lower aquifer of the Potomac-Raritan-Magothy aquifer system.

WSCK Bedrock confining unit.

Confining units between aquifers shown shaded.
Location of section, wells, and geophysical traces shown on figure 5-6

Figure 5-5
Hydrogeologic Section E - E'
Logan Township region, New Jersey

Modified from Barton and Kozinski, 1991

SCALE 1:48,000

1 1/2 0 1 MILE

1 .5 0 1 KILOMETER

VERTICAL EXAGGERATION X40

EXPLANATION

\	Lines dividing hydrogeologic units. Dividing lines are based on maps showing the altitude of the top of each hydrogeologic unit (pl. 1 - 5). Dashed lines represent approximations made on the basis of data from nearby wells.
15-412	Well number
G-90	Number of geophysical trace (Duran, 1986)
—	Bottom of geologic log or geophysical log or bottom of strata interpreted by using geophysical methods.

Hydrogeologic units

HPPM	Undifferentiated upper Cenozoic deposits. Only deposits that are differentiable from underlying deposits are shown; deposits less than 10 feet thick are not shown because of scale. Clays, silts, and fine sands (confining materials) are shown shaded; coarser sands and gravels (aquifer materials) are shown unshaded.
WBMV	Merchantville-Woodbury confining unit.
MRPAU	Upper aquifer of the Potomac-Raritan-Magothy aquifer system.
MRPAM	Middle aquifer of the Potomac-Raritan-Magothy aquifer system.
MRPAL	Lower aquifer of the Potomac-Raritan-Magothy aquifer system.
WSCK	Bedrock confining unit.

Confining units between aquifers shown shaded.
Location of section, wells, and geophysical traces shown on figure 5-6

Figure 5-6
Location of Hydrogeologic Section A, B, C, D, E, Logan Township region, New Jersey

Base from U.S. Geological Survey, 1:24,000 quadrangles, Bridgeport, 1967; Marcus Hook, 1967; Paulsboro, 1967; Woodbury, 1967

EXPLANATION

LOCATION OF INDUSTRIES IN LOGAN TOWNSHIP FOR WHICH DOCUMENTED HISTORIES OF GROUND-WATER CONTAMINATION EXIST--Shaded areas are delineated by property boundaries.

A——A' TRACE OF HYDROGEOLOGIC SECTION.

•15-67 WELL LOCATION--Number is U.S. Geological Survey well number (see table 2).

• G-60 LOCATION WITH MARINE SEISMIC REFLECTION AND ELECTROMAGNETIC CONDUCTIVITY DATA--Duran, 1986.

SCALE 1:48,000

1 1/2 0 1 MILE

1 .5 0 1 KILOMETER

The U. S. Geological Survey, in cooperation with the U. S. Army Corps of Engineers, collected data on the lateral and vertical distribution of sediments within the Delaware River navigation channel, between northeast Philadelphia, Pennsylvania and Wilmington, Delaware (Duran, 1986). Data for the study were collected using the geophysical techniques of seismic reflection and electromagnetic conductivity, as well as by using available borehole logs, test-pit data and results from previous geophysical studies. Seismic reflection is a geophysical technique which makes use of the fact that different lithologies often have different densities and transmit sound at different velocities. This causes sound waves to reflect off of the lithologic boundaries. The graphical record of these reflections thus serves as a guide to the geologic structure below the seismic instruments. The electromagnetic conductivitiy method makes use of the fact that the earth acts like an electrical conductor. When an electromagnetic field is created near the current surface, an eletrical current is induced within the earth. This current then produces an electromagnetic field that is proportional to the degree of electrical conductivity of the ground. Since saturated sand or bedrock is usually a poor electrical conductor, and saturated clay is a relatively good conductor, electromagnetic conductivity was used to help locate clay deposits below the channel bottom.

Study data indicate that between the Benjamin Franklin Bridge in Camden and Monds Island the Delaware River navigation channel is predominantly underlain by sand. However, several deposits of silt were located within this reach of the river. These deposits were described as: a small deposit of silt underlain by sand immediately downstream of the Benjamin Franklin Bridge; a thin, continuous layer of silt over sand between the Walt Whitman Bridge and Big Timber Creek; two smaller, less continuous layers of silt above and within channel-bottom sands in the vicinity of League Island; interbedded silt and sand between Woodbury Creek and Mantua Creek; and silt below the channel at the upstream end of Little Tinicum Island. Between Monds Island and just downstream of Oldman's Creek the Delaware River navigation channel is underlain by bedrock, or bedrock overlain with thin layers of sand, silt or clay. Between Oldman's Creek and the Delaware Memorial Bridge, thick layers of clay exist below the navigation channel. In the vicinity of the Delaware Memorial Bridge the clay is overlain by at least 20 feet of silt.

Groundwater flow is generally toward the main river in a typical river basin. However, the groundwater regime in the project area, specifically the New Jersey side of the river, has been disturbed by urbanization. This information has been documented in numerous reports. The U.S.G.S. Atlas HA-697 dated 1986 estimates a leakage of 70 MGD from the Delaware River into the Potomac-Raritan-Magothy aquifer system in the project area. A reversal of the natural groundwater flow due to overpumping of the aquifer has occurred. Prior to municipal and industrial pumping, water flow in the aquifer was towards the river. Where large groundwater withdrawals have locally reversed the original aquifer flow patterns, aquifer recharge by river water results. 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. Although a large volume of river water is presently infiltrating the aquifer from the river, no contamination or salinity problems have been reported.

Deepening the navigation channel in areas underlain by sand, bedrock or clay would not increase the degree of aquifer exposure. Portions of the river underlain by sand are already exposed, while bedrock and clay provide an effective barrier to infiltration. In areas where silt was encountered, removal of the fine-grained sediments between the Walt Whitman Bridge and Big Timber Creek could potentially increase the degree of aquifer exposure. In other areas where silt was encountered, the layers are either too thin to serve as a hydrologic barrier, or too thick to be adversely impacted by the proposed dredging plan. 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 intrusion.

The groundwater regime in northern Delaware, as documented by the U.S. Geological Survey Water Resources Investigation Report 87-4185, is very similar to the situation in New Jersey. Brackish water is infiltrating the underlying Potomac Aquifers in the Cretaceous Potomac Formation in northern Delaware. The potential for infiltration of river water into the aquifers is suggested by groundwater levels below sea level and removal by erosion of confining units overlying the aquifers near the river. Pumping from wells has lowered heads in the Potomac aquifers below sea level, which has created a hydraulic gradient from the Delaware River towards the underlying aquifers. There is a direct correlation between the rate of infiltration of river water and the total well-field pumpage. Evidence that infiltration is actually occurring in Delaware includes chloride concentrations in the aquifers that are above ambient levels and chemical characteristics of ground water and river water that are similar. The deepening of the river channel in Delaware will have negligible impact on the amount of infitration that is occurring presently, since this amount is controlled by the rate of pumping from municipal and private wells.

Upland disposal areas will be utilized to provide 50 years of capacity for the selected plan 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 river edge, have similar subsurface conditions, contain varied amounts of fine-grained dredged material, and overlie the sole source aquifer. A typical area is Pedricktown disposal area. The area is located in the northwestern corner of Oldmans Township, Salem County, approximately 3 miles south of site 15-D. The 1000+ acre facility has been used for disposal of dredged material from the Delaware River since 1960. Presently the original ground is overlain by 20 to 40 feet of dredged material. Groundwater, discharge water, river sediment, and dredged slurry, have been tested to determine what effect the operation has on the surrounding area. To date, no detrimental effects have been realized (USACE, 1991). The new disposal areas will operate in the same manner as Pedricktown and therefore will not become a future source of groundwater contamination.

An investigation of New Jersey municipal water supply wells was conducted in the project area. Wells within two miles of the Delaware River channel or the disposal areas were considered. Thirty municipal wells are in operation from Westville Boro south to Pennsville Township. A list of these wells containing,total depth, screen depth and length, and aquifer is provided for

each well in Table 5-1. Of the thirty wells, 25 are screened in the Potomac-Raritan-Magothy formation. The remaining five withdrawal from the shallower Cape May formation, 40' to 60' below the surface. These wells are located in Penns Grove approximately two miles from the Pedricktown South disposal area, which will be used for the 45' project maintenance, and currently is being used for the 40' project. There has been no reported exceedance of maximum contaminant levels established by EPA and NJDEP in any of the wells, with the exception of high iron and manganese concentrations in the Salem County Wells. Published reports on ground water characteristics of the Potomac-Raritan-Magothy system and analysis of public and private wells in the vicinity of the site indicate high concentrations of iron and manganese. The high concentrations are attributed to natural conditions resulting form geological formations.

In summary, the selected plan requires the acquisition of 3 new disposal areas as previously discussed. Areas 17-O, 15-D, and Raccoon Island will be used for initial and maintenance dredged quantities. All of the new sites have been used in the past as dredged material disposal areas and contain 5 to 15 feet of fine-grained sediment which acts as an impermeable blanket. All of the areas overlie the Potomac-Raritan-Magothy formation. Due to the limited ponding time of water and minimum head in the disposal area, as well as the stratigraphy and nature of the sediments beneath the disposal areas, it is improbable that any substantial quantity of water will escape through the foundation into the sole source aquifer. Any water that does not flow directly back into the river through the sluice will reach the river via the shallow surface aquifers that underlie the areas. In addition, the drinking water aquifers of the Potomac-Raritan-Magothy are separated by multiple clay layers as mentioned previously.

Based on the available information it is concluded that the deepening of the Delaware River navigation channel within the project limits, and the ensuing disposal of material in the proposed areas, will have a negligible impact on the groundwater/aquifer system in the local and regional area.

Table 5-1. New Jersey Public Water Supply Wells Within Two Miles of Delaware River Channel or Disposal Areas

Public Water Supply Wells	Depth of Well	Depth of Screen	Length of Screen	Log	Aquifer
Westville Boro					
Well # 4	333'	No Info.	No Info.	No	Raritan
Well # 5	277' Double	{ 213' - 243'	30'	Yes	Raritan
		{ 267 - 274'	7'		
Well # 6	317'	267'	?	Yes	Lower Raritan
West Deptford Twp.					
Well # 6	371'	321' - 370'	49'	No	Raritan
Well # 7	366'	323' - 366'	43'	Yes	Raritan
National Park					
Well # 5	271'	236' - 268'	32'	Yes	Raritan
Well # 6	275'	240' - 272'	32'	Yes	Raritan
Paulsboro					
Well # 4	220'	194' - 220'	26'	No	Raritan
Well # 5	178'	135' - 175'	40'	No	Raritan
Well # 6	277' Double	{ 185' - 195'	10'	No	Raritan
		{ 211' - 227'	16'	No	Raritan
Greenwich Twp.					
Well # 4	168.2'	110' - 168'	58'	No	
Well # 5	122'	82' - 117'	35'	No	PRM (Middle)
Well # 6	138' Top of Screen	105' - 135'	30'	No	PRM (Upper)
Bridgeport					
Well # 1	Well No. 1 is similar to Well # 2 according to Pennsgrove Water Co. Personnel				
Well # 2	87'	69' - 84'	15'	No	Raritan (Upper)
Penns Grove					
Layton Field					
Well # 2	62'	47' - 62'	15'	No	Cape May
Well # 4	64.2'	44' - 54'	10'	Yes	Cape May
Well # 11	392'	372' - 392'	20'	No	Lower PRM

Table 5-1. New Jersey Public Water Supply Wells Within Two Miles of Delaware River Channel or Disposal Areas

Ranney Field						
Well #	1A	59'	39' - 59'	20'	No	Cape May
Well #	2A	61'	41' - 61'	20'	No	Cape May
Well #	3A	57.5'	47' - 57'	10'	No	Cape May
Well #	7	359'	319' - 359'	40'	No	Lower PRM
Logan Twp.						
Well #	1A	156'	121' - 148'	27'	No	PRM
Well #	2	87'	69' - 84'	15'	Yes	Upper Raritan
Well #	3	201'	161' - 201'	40'	No	Magothy & Raritan
Pennsville Twp.						
Well #	1	200'	175' - 200'	25'	No	Raritan
Well #	3A	104'	89' - 104'	15'	Yes	Raritan
Well #	4	137'	117' - 137'	20'	No	Raritan
Well #	5	124'	101' - 117'	16'	Yes	Upper Raritan
Well #	6	119'	102' - 117'	15'	Yes	Upper Raritan

5.1.2 Hydrology/Estuarine Salinity Patterns

An environmental concern raised with regard to the proposed deepening of the existing Delaware River navigation channel is the potential for change in the estuary's salinity regime. A change in the physical shape of the estuary may alter tidal flow, and result in increased penetration of saltwater upstream. Salinity is a key factor regulating the distribution of both fauna and flora in an estuarine environment. While salinities fluctuate seasonally and from year to year, a permanent shift in salinity patterns could adversely impact a variety of ecosystem components, depending on the magnitude of the change. In response to this concern the Philadelphia District of the U.S. Army Corps of Engineers has contracted with the Delaware River Basin Commission (DRBC) to compare Delaware estuary salinity patterns for the existing channel configuration and with a deepened channel through application of their Transient Salinity Intrusion Model (TSIM). The following presents relevant information pertaining to salinity distribution in the Delaware Estuary, and the results of the DRBC modelling effort.

Salinity distribution in the Delaware Estuary (Figure 5-7) is primarily the result of saltwater inflow from the adjacent Atlantic Ocean and freshwater flow from the Delaware Basin drainage area (Smullen et al., 1983). The mixing of fresh and salt water forms a gradient from less than 0.5 parts per thousand (ppt) in the tidal river to about 32 ppt at the mouth of the bay (Ichthyological Associates, 1980). The U.S. Fish and Wildlife Service (1981a) characterized four salinity zones within the Delaware Estuary. These are polyhaline (18 - 30 ppt) from the mouth of the bay to the vicinity of the Leipsic River (River mile 34), mesohaline (5 - 18 ppt) from the Leipsic River to the vicinity of the Smyrna River (River Mile 44), oligohaline (0.5 - 5 ppt) from the Smyrna River to the vicinity of Marcus Hook (River Mile 79), and fresh 0.0 - 0.5 ppt) from Marcus Hook to Trenton (Figure 5-8).

The Delaware Estuary salinity gradient is not a static environmental condition, but one subject to short and long-term change. Due to variations in factors such as freshwater flow, tidal height and stage, and weather conditions, specific salinities move within the estuary from 10 to greater than 20 miles. This is most simply demonstrated by a plot of salinity versus location in the estuary, with data points from all months of the year and from all depths (Figure 5-9). Figure 5-10 provides plots of salinity versus time for three specific locations in the estuary (Smullen et al., 1983). These locations represent the upper, middle and lower estuary. The upper station, located near the Port of Wilmington (approximately River Mile 70.5), had a salinity range between zero and four ppt over the five-year study period. The lower station, located near the mouth of the bay (approximately River Mile 0), had a salinity range between 28 and 31 ppt. The mid-estuary station, located near Ship John Light (approximately River Mile 36.5), had the greatest salinity variation with a range between four and 22 ppt. The upper and lower zones of the estuary are dominated by freshwater and saltwater flows, respectively. The extreme dominance of one type of water in each of these zones maintains relatively stable salinity levels over time. The mid-estuary serves as a mixing zone for fresh and salt water. As such, this zone is more heavily influenced by fluctuations in tidal and river flow, and subject to greater variations in salinity.

Figure 5-7 Vicinity map of the Delaware Estuary.

Figure 5-8 Zones of salinity in the Delaware Estuary. (Ichthyological Associates, 1980).

Figure 5-9 Salinity versus distance (statute miles) in the Delaware Estuary. Data from all months of the year and from all depths. (Culberson, 1988).

Figure 5-10 Typical differences in salinity variation over time for the upper (Port of Wilmington), middle (Ship John Light), and lower (Cape Henlopen) Delaware Estuary. (Smullen et al., 1983).

Vegetation, aquatic organisms, and to a lesser degree, wildlife distribute themselves within the estuary, based on their salinity tolerances. Freshwater organisms, those that can not tolerate high salinity, restrict their distribution to the freshwater portion of the estuary generally located above Wilmington, Delaware. Marine organisms, those that require high salinities, restrict their distribution to the lower bay. Organisms that can function over a broad range of salinity will inhabit the portion of the estuary that is within their tolerance range. It should be kept in mind that salinity is only one environmental factor affecting the distribution of organisms within the estuary. It would be necessary to consider a variety of other factors to precisely define the limits of a particular species within the estuary.

In 1981, 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, 1981a). 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 oligo-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."

The report goes on to conclude that a shift in salinity patterns could result in a variety of impacts, which would cumulatively lower the overall productivity of the estuarine system. While more stable, relative to salinity, the freshwater and polyhaline zones of the estuary could also be affected by extreme events of drought or flood.

The Delaware River Basin Commission employed their Transient Salinity Intrusion Model (TSIM) to evaluate the effects of the proposed deepening of the existing navigation channel on the salinity profile in the Delaware River Estuary. TSIM was originally developed by Dr. M. Llewellyn Thatcher at the Massachusetts Institute of Technology in 1972. Subsequently, the model was adapted for use in the Delaware Estuary. The model is used extensively by the DRBC for simulation of various scenarios for drought management and reservoir operation planning.

For this effort, salinity distribution was evaluated under two discrete navigation channel geometries. These geometries were the currently maintained 40-foot depth and the proposed 45-foot depth. The geometry of the existing salinity model was modified to represent a 5-foot deepening in the navigation channel from the entrance in Delaware Bay to the vicinity of the Walt Whitman Bridge in Philadelphia, Pennsylvania. Simulations were run with the hydrology observed during the 1960's drought of record (1961-1966). The observed hydrology or streamflows were modified to account for the estimated depletive water use in 1986 over that existing in 1965. The hydrology data were also corrected to represent the current operation of Delaware River Basin reservoirs, based on the recommendations of the parties to the Good Faith Agreement. These reservoirs include Beltzville, Blue Marsh and F.E. Walter with emergency storage.

The results of these initial runs are documented in: Investigation To Determine The Effects On The Salinity Of The Delaware Estuary From The 5-Foot Deepening Of The Navigation Channel From The Capes To The Walt Whitman Bridge (DRBC, 1989). This modelling effort was considered to be a "worst case" analysis of salinity intrusion to evaluate the potential impact on the Delaware River in the Philadelphia-Camden metropolitan area. The 1960's drought of record has an estimated recurrence interval of several hundred years in the upper Delaware River Basin and about 100 years for the Basin at the mouth of the Schuylkill River (DRBC, 1981). Since the hydrology of the drought of record was used, the regulated flow regime resulted in an abnormal intrusion of chlorides up the estuary. The purpose of running the hydrology data with and without the deepened channel was to determine what difference in salinity resulted solely because of the deepening. To evaluate potential impacts to water supplies, model output provided the maximum intrusion of the 250 mg/l isochlor, which is the definition of the "salt front", and the 30-day average of the maximum chloride concentration at River Mile 98. A maximum average 30-day chloride concentration of 180 mg/l at River Mile 98 is the current DRBC chloride standard for the estuary.

The initially reported results of this modelling effort indicated that in the 1961 water year simulation there was a maximum 3.0-mile increase in penetration of the 250 mg/l isochlor, and a maximum 17 mg/l increase in chloride concentration at River Mile 98, with a deepened channel. After further review, these differences were found to be incorrect and attributable to an error that occurred in transferring a file of initial conditions for the 1961 water year simulation (DRBC, 1990). The correct data for 1961 are a maximum 1.1-mile increase in penetration of the 250 mg/l isochlor, and a maximum 2 mg/l increase in chloride concentration at River Mile 98.

Results of the TSIM simulations are provided in Tables 5-2 and 5-3 for both the existing 40-foot navigation channel and a 45-foot channel. Table 5-2 provides the maximum instantaneous intrusion of the 250 mg/l isochlor for both channels for the simulated events of 1961 through 1965. In 1967, the DRBC adopted water quality standards to maintain reasonable salinity throughout the tidal portion of the Delaware River, and to protect both withdrawal and instream users (USACE, 1982). One of three salinity standards, measured in chlorides, was a maximum instantaneous concentration of 250 mg/l at the mouth of the Schuylkill

Table 5-2

Location of Maximum Instantaneous Intrusion of 250 mg/l Isochlor with Existing Reservoir Regulation and 1986 Depletive Uses

Year	Existing Channel		Deepened Channel		Change in Location of Isochlor River Mile
	Location River Mile	Date of Occurrence	Location River Mile	Date of Occurrence	
1961	87.3	21 Oct.	88.4	21 Oct.	+ 1.1
1962	88.2	27 Sept.	89.7	27 Sept.	+ 1.5
1963	94.7	6 Nov.	95.7	6 Nov.	+ 1.0
1964	96.5	19 Nov.	97.7	19 Nov.	+ 1.2
1965	96.5	23 Nov.	97.8	23 Nov.	+ 1.3

Table 5-3

Maximum 30-Day Average Concentration of Isochlor at River Mile 98 with Existing Reservoir Regulation and 1986 Depletive Uses

Year	Existing Channel		Deepened Channel		Change in Chloride Concentration mg/l
	Concentration mg/l	Date of Occurrence	Concentration mg/l	Date of Occurrence	
1961	43	15 Nov.	45	15 Nov.	+ 2
1962	48	5 Oct.	52	7 Oct.	+ 4
1963	96	7 Nov.	107	10 Nov.	+ 11
1964	136	29 Nov.	152	29 Nov.	+ 16
1965	130	9 Oct.	143	7 Oct.	+ 13

River (River Mile 92.5). The location of the 250 mg/l isochlor in the estuary is considered, along with Delaware River Basin reservoir storage, to manipulate reservoir releases to meet established flow objectives at Montague, New York and Trenton, New Jersey.

As can be seen in Table 5-2, under existing channel conditions, the maximum yearly intrusion of the 250 mg/l isochlor ranged between river miles 88.2 and 96.5 (i.e. approximately the upstream end of the Little Tinicum Island Range to just downstream of the Walt Whitman Bridge). For the deepened channel, the maximum intrusion ranged between river miles 89.7 and 97.8 (i.e. approximately the mouth of Mantua Creek, New Jersey to 0.97 miles upstream of the Walt Whitman Bridge. The 250 mg/l isochlor did penetrate further upstream each simulated year with a deepened channel. This additional penetration ranged between 1.0 and 1.5 miles. The salinity standard at River Mile 92.5 was met for both channel geometries for 1961 and 1962, but not met for both geometries for 1963 through 1965. In the midst of the drought, current reservoir storage would not be sufficient to keep maximum chloride concentrations at River Mile 92.5 below 250 mg/l, regardless of channel condition. With a deepened channel, the 250 mg/l isochlor would intrude an additional 1.0 to 1.3 miles upstream over existing conditions for the years 1963 through 1965. The biological impacts associated with this intrusion are discussed later in this report.

To more fully evaluate impacts to domestic water supplies it is necessary to consider the existing water quality standard at River Mile 98. This standard is a maximum 30-day average chloride concentration of 180 mg/l. The purpose of this standard is to protect the Potomac-Raritan-Magothy aquifer system, which is a significant water supply source for the Camden, New Jersey area. River Mile 98 is the estimated seaward limit of the major connection between the estuary and the aquifer system (DRBC, 1981). Within the area of major connection a significant portion of aquifer recharge is from the river. Maintenance of appropriate salinity concentrations at River Mile 98 is intended to protect the aquifer system from salt water intrusion.

Table 5-3 provides the 30-day average of the maximum chloride concentration at River Mile 98. Again, higher concentrations of chlorides were projected under the condition of the deepened channel. The 30-day averages ranged from 2 to 16 mg/l higher with a deepened channel, for the period of analysis. This is a 5 to 12 percent increase. The highest chloride concentration for the deepened channel was 152 mg/l, occurring in November of 1964. This chloride concentration was well below the existing 180 mg/l DRBC standard.

The U.S. Environmental Protection Agency criterion for chlorides in domestic water supplies is 250 mg/l (USEPA, 1986). This criterion is based more on palatability than on health protection. For health purposes it is more important to consider sodium intake. It has been determined that for very restricted sodium diets 20 mg/l in water would be the maximum, while for moderately restricted diets 270 mg/l would be maximum (USEPA, 1986). To date, the USEPA has not recommended maximum sodium concentrations for domestic water supplies. The State of New Jersey has adopted a sodium standard of 50 mg/l for drinking water.

The existing maximum 30-day average chloride standard of 180 mg/l at River Mile 98 is in place to protect groundwater supplies from sodium contamination. In sea-water, the ratio of sodium to chloride is 0.556 to 1.00 (USACE, 1982). This ratio has been found to apply to the Delaware Estuary with reasonable accuracy. A chloride concentration of 180 mg/l relates to a sodium concentration of 100 mg/l. Considering the maximum rate of aquifer recharge from the Delaware River, and the State of New Jersey drinking water standard of 50 mg/l for sodium, the existing chloride standard was set at River Mile 98 as a reasonable interim objective for protecting the aquifer system. The DRBC (1989) indicated that the Parties to the Good Faith Agreement for the Delaware River Basin recommended a more stringent salinity objective at River Mile 98 for aquifer protection. This objective is a maximum 30-day average of 150 mg/l of chlorides and a maximum 30-day average of 83 mg/l of sodium. In order to meet this more stringent objective, it has been determined that additional reservoir storage would be required to maintain the necessary streamflow within the Delaware River at Trenton, New Jersey (USACE, 1982). As such, this ultimate salinity objective will not be put in place until additional reservoir storage is available.

As can be seen from the data provided in Table 5-3, with a deepened channel the existing standard would be met throughout the drought of record, while the more restrictive salinity objective would be met throughout the drought of record, except in November 1964. At this time the proposed standard would be violated by two mg/l. This small violation during the drought of record is acceptable considering that the proposed standard would not be put in place until additional reservoir storage is available to maintain the standard.

Based on the computed movement of the 250 mg/l isochlor with a deepened channel, concerns were raised relative to a potential increase in salinities throughout the estuary, and the ecological impacts associated with such an increase. In order to address these concerns the DRBC was again contracted to run the TSIM and provide data pertaining to the movement of five other isochlors for the existing and deepened channel geometries. The same period of analysis was used to provide a "worst case" analysis. Isochlors were selected to cover various locations in the estuary and/or to correspond to salinities of significance relative to various components of the estuarine ecosystem. Isochlors were 8303 mg/l (15 ppt salinity), 5535 mg/l (10 ppt salinity), 2768 mg/l (5 ppt salinity), 1384 mg/l (2.5 ppt salinity) and 500 mg/l (0.9 ppt salinity).

The isochlor corresponding to 15 ppt salinity was selected because it is considered significant relative to the protection of the American oyster (Crassostrea virginica) in Delaware Bay. Traditionally, the Delaware Bay oyster industry has been dependent on two locations within the bay. Oyster seed beds are located in the upper portion of the bay, primarily between the Maurice River (River mile 21.03) and the Cohansey River (River mile 37.80). These low salinity areas provide a refuge for young oysters to grow, free from predation and competition that limits survival success in higher salinity, downbay water. It has been common practice to remove young oysters from these beds in May and June, and transplant them in privately leased grounds located in the vicinity of Maurice River Cove. The higher salinity in this area promotes faster growth of the oysters, bringing them to market size in less time.

A major predator of the oyster in Delaware Bay is the oyster drill (Urosalpinx sp.). The oyster drill can cause substantial damage to oyster beds when present in abundance. Reproductive success and distribution of the oyster drill is correlated with salinity levels (USFWS, 1979). Salinities below 15 ppt will control reproduction and limit drill infestation, thus minimizing damage to oyster beds.

Delaware Bay oysters are also subject to high mortalities during outbreaks of a sporozoan parasite classified as (Haplosporidium nelsoni). This parasite is commonly referred to as MSX. The initial MSX kill in Delaware Bay occurred, in 1957, when nearly half the oysters on the New Jersey leased grounds died within six weeks. A second kill in 1958 spread over all of the lower bay and onto the seed beds as far upbay as the Cohansey River. Patterns of MSX occurrence suggest that salinities of about 15 ppt or greater favor the spread of the organism. While salinity does not account for all phases of MSX activity, 15 ppt salinity or less appears to be sufficient to protect the oyster. Based on the above, the 15 ppt salinity was modelled to track potential impacts to oysters relative to the oyster drill and MSX.

The isochlor corresponding to a salinity of five ppt was selected because it relates to a shift in tidal wetland vegetation from freshwater to brackish. Walton and Patrick (1973) stated that salinity appears to be the principal factor influencing the composition of emergent vegetation along the Delaware Estuary. A variety of freshwater species such as wild rice, arrowhead, dotted smartweed and spatterdock cannot tolerate salinities above five ppt for extended periods of time (USFWS, 1981b). Prolonged exposure to high salinities would result in plant stress and ultimately death of vegetation. High salinities would also inhibit seed germination processes. The combined result of these impacts would be lower productivity. Freshwater tidal wetland habitats occur in the Delaware Estuary from Trenton, New Jersey to Wilmington, Delaware (Schuyler, 1988).

Isochlors corresponding to salinities of 2.5 and 0.9 ppt were selected to provide better coverage of the upper estuary, between Wilmington, Delaware and Philadelphia, Pennsylvania. This portion of the estuary is more constricted than lower areas. It was presumed that a change in channel geometry in this portion of the river would have a greater influence on river hydraulics than in lower reaches, because the channel in this area accounts for a larger percentage of the river's cross-section. Therefore, it was hypothesized that the magnitude of this upstream movement in salinity would decrease, moving down-river, to a point in the river where a five-foot deepening in the channel would have no affect on salinity movement.

The final isochlor to be tracked with the TSIM was one corresponding to a salinity of 10 ppt. This isochlor can fluctuate over a 30-mile stretch of the estuary, generally between Egg Island Point and Artificial Island. This portion of the estuary provides valuable spawning and nursery habitat for a variety of estuarine fishes. A shift in salinity patterns could reduce the amount of habitat available for spawning and early growth. This isochlor was also selected because it is midway between isochlors corresponding to five and 15 ppt, which were selected for the reasons stated above.

The results of this second DRBC analysis are provided in Figures 5-11 through 5-15 (DRBC, 1990). These figures show a comparison of the maximum intrusion in river miles of each isochlor, for each month from June 1961 to December 1965, with and without the deepened channel. As can be seen from Figures 5-11 through 5-15 the selected isochlors exhibit a similar pattern of movement within the estuary for both existing and deepened channel conditions. Salinities are generally lowest within the estuary in April, rising consistently to a maximum in October to November, and then declining to a low the following April. While salinity patterns are similar, there is an observed upstream movement with a deepened channel. This additional intrusion decreases in magnitude, moving downstream in the estuary. The average monthly increases for the entire period of analysis were as follows: 500 mg/l (0.45 miles $\pm$ 0.31); 2.5 ppt (0.36 miles $\pm$ 0.32); 5.0 ppt (0.33 miles $\pm$ 0.44); 10.0 ppt (0.19 miles $\pm$ 0.34); and 15.0 ppt (0.13 miles $\pm$ 0.35). Table 5-4 provides River Mile locations for the yearly, maximum instantaneous intrusion of the selected isochlors. These data also demonstrate that the additional intrusion resulting from a deepened channel decreases in magnitude, moving downstream. The maximum additional intrusion was 1.0 - 1.5 miles for the 250 mg/l isochlor (Table 5-2). The additional increments for the remaining isochlors were as follows: 500 mg/l (0.29 - 0.57 miles); 2.5 ppt (0.20 - 0.42 miles); 5.0 ppt (0.12 - 0.28 miles); 10.0 ppt (0.03 - 0.17 miles); and 15.0 ppt (0.02 - 0.08 miles).

It is important to note that the salinity fluctuations observed in this modelling effort represent the hydrology of the drought of record, which is not a normal event. As such, the data were considered to be representative of the magnitude of change that would occur with a deepened channel, but not a typical salinity gradient within the estuary with a deepened channel. The yearly mean natural flows at Trenton, New Jersey for the years 1962 - 1965 were 50 to 76 percent of the median flow calculated for the years 1923 - 1976. These low flows resulted in much higher than normal salinity levels within the estuary, regardless of channel condition.

The observed upstream shift in salinities with a deepened channel is not expected to adversely impact biological components of the estuarine ecosystem. This statement is made for several reasons. First, the incremental increases are not significant. In the mesohaline section of the estuary (5 - 18 ppt salinity) the average increase would range between 0.13 miles in the lower portion of this area to 0.33 miles in the upper portion, or approximately 250 to 600 yards. In the oligohaline section of the estuary (0.5 - 5 ppt) the average increase would range between 0.33 miles in the lower portion to 0.45 miles in the upper portion, or approximately 600 to 800 yards. These two sections of the estuary extend from approximately the Leipsic River in upper Delaware Bay to the vicinity of Marcus Hook, Pennsylvania. As such, they constitute the entire brackish portion of the estuary.

The relatively minor shift in the salinity gradient in this area is not large enough to have a perceptible impact on the ecosystem. The 15 ppt isochlor, which is considered important to the survivability of the American oyster, would shift the least. The average upstream movement was calculated to be about 250 yards, however, the maximum instantaneous intrusion within the estuary, shown on Table 5-4, was only 0.02 to 0.08 miles, or about 35 to 150 yards.

Figure 5-11 **Maximum monthly intrusion of the 500 mg/l isochlor within the Delaware Estuary for existing and deepened channel conditions. Period of analysis was June 1961 to December 1965. Data from DRBC (1990).**

Figure 5-12 Maximum monthly intrusion of the 2.5 ppt isochlor within the Delaware Estuary for existing and deepened channel conditions. Period of analysis was June 1961 to December 1965. Data from DRBC (1990).

Figure 5-13 Maximum monthly intrusion of the 5.0 ppt isochlor within the Delaware Estuary for existing and deepened channel conditions. Period of analysis was June 1961 to December 1965. Data from DRBC (1990).

Figure 5-14 Maximum monthly intrusion of the 10.0 ppt isochlor within the Delaware Estuary for existing and deepened channel conditions. Period of analysis was June 1961 to December 1965. Data from DRBC (1990).

Figure 5-15 Maximum monthly intrusion of the 15.0 ppt isochlor within the Delaware Estuary for existing and deepening channel conditions. Period of analysis was June 1961 to December 1965. Data from DRBC (1990).

Table 5-4 **Location of Maximum Instantaneous Intrusion of Specified Isochlors with Existing Reservoir Regulation and 1986 Depletive Uses.**

Date	Existing Channel River Mile Location	Deepened Channel River Mile Location	Change in Location of Isochlor
		500 mg/l	
Oct 1961	84.49	84.78	+0.29
Nov 1962	84.63	85.04	+0.41
Nov 1963	90.15	90.58	+0.43
Nov 1964	91.21	91.69	+0.48
Nov 1965	91.33	91.90	+0.57
		2.5 ppt	
Oct 1961	76.75	76.95	+0.20
Nov 1962	77.26	77.54	+0.28
Nov 1963	81.70	81.92	+0.22
Nov 1964	83.24	83.66	+0.42
Nov 1965	83.53	83.94	+0.41
		5.0 ppt	
Oct 1961	70.02	70.14	+0.12
Nov 1962	70.86	71.04	+0.18
Nov 1963	73.09	73.31	+0.22
Nov 1964	74.67	74.95	+0.28
Nov 1965	75.15	75.43	+0.28
		10.0 ppt	
Oct 1961	58.21	58.27	+0.06
Nov 1962	59.74	59.89	+0.15
Nov 1963	62.03	62.06	+0.03
Nov 1964	63.98	64.15	+0.17
Nov 1965	64.58	64.73	+0.15
		15.0 ppt	
Oct 1961	48.09	48.11	+0.02
Nov 1962	50.60	50.67	+0.07
Nov 1963	51.58	51.62	+0.04
Nov 1964	53.75	53.84	+0.08
Nov 1965	54.25	54.32	+0.07

In their 1981 Planning Aid Report the U.S. Fish and Wildlife Service indicated that a shift in salinity zones would also shift spawning and nursery areas for estuarine fishes. Such a shift could move eggs and larvae closer to the Salem Nuclear Generating Station, which could possibly result in greater impingement and entrainment losses. Eggs and larvae of some species could also be moved closer to the Philadelphia pollution zone, which could result in lower survivability. A shift of 600 to 800 yards is not considered significant relative to these concerns. Yearly variations in river flow would far outweigh the magnitude of this alteration.

The U.S. Fish and Wildlife Service (1981) also indicated that higher salinities could result in lower plant productivity, which could reduce food supplies for waterfowl and other wildlife. Again, the magnitude of shift predicted for the deepened channel would not be sufficient to result in a perceptible reduction in plant productivity.

In the freshwater portion of the estuary (0.0 - 0.5 ppt) the salinity shift would be on the order of 0.45 to possibly as great as 1.5 miles. This portion of the estuary typically extends from Marcus Hook, Pennsylvania to Trenton, New Jersey. While this shift is more substantial than downstream areas, the relatively low salinities are not considered significant. Freshwater wetland vegetation can generally tolerate salinities up to 5.0 ppt. Salinities less than 0.5 ppt would not stress wetland vegetation in this portion of the estuary. Likewise, freshwater fishes can also tolerate low salinities. Many freshwater species that occur in the Delaware River are found in salinities as high as 10 ppt. Salinities less than 0.5 ppt would not influence the distribution of freshwater fishes in this portion of the estuary.

To this point, the discussion has focused on the predicted upstream shift in salinity patterns. As can be seen in Figures 5-11 through 5-15 there is a natural salinity cycle within the estuary that reflects freshwater flow. Salinities increase in the estuary from a minimum in April to a maximum in October or November, and then decrease to the following April. For most of the year, a salinity shift with a deepened channel means that a particular salinity would reach a particular point in the estuary a little earlier than it would with the existing channel condition. On average, deepened channel salinities would be 250 to 800 yards ahead of existing channel salinities, at any particular time of the year. This small time shift is not considered large enough to diminish estuarine productivity, and is likely to be less than salinity fluctuations resulting from daily tidal changes. The only time of the year when a particular salinity would intrude into an area that it would not reach with the existing channel is the October or November peak for the year. This time of the year is not considered significant relative to biological activity such as plant growth, fish spawning or nursery activities, blue crab spawning or nursery activities, or benthic productivity.

A final point to be made relative to the impact of predicted salinity movement with a deepened channel is that the magnitude of change was calculated with the drought of record hydrology. It is likely that the change would be less in years when freshwater flows in the river approach the median flow. An illustration of this is comparison of the average monthly change in 1962 with

that of 1965. In 1962 river flow at Trenton, New Jersey was 76 percent of the median flow, while in 1965 river flow was only 50 percent of the median. Table 5-5 lists the average monthly movement of the five isochlors for each of these years. The average upstream movement of isochlors with a deepened channel are 30 to 70 percent lower in 1962 than in 1965. In 1962 the average location of the 15.0 ppt isochlor was actually 0.04 miles lower in the estuary with a deepened channel than with the existing channel. Data for two of the 12 months showed the isochlor lower in the estuary with a deepened channel, which skewed the average for the entire year.

Based on the results of the two TSIM data sets provided by the DRBC, it is concluded that the predicted changes in Delaware Estuary salinity patterns, from a five-foot deepening of the existing navigation channel, would not result in a perceptible decline in estuarine productivity or adversely impact water supplies in the vicinity of Philadelphia. The predicted upstream movement in salinity would be minor in comparison to yearly fluctuations in salinities resulting from variations in river flow. An average shift in salinities ranging from 250 yards in upper Delaware Bay to 800 yards in the vicinity of Marcus Hook, Pennsylvania would not be sufficient to effect species distribution or reduce productivity. In the freshwater portion of the estuary, above Marcus Hook, a predicted shift ranging between 800 yards to as much as 1.5 miles could occur. Salinities in this area are too low to impact freshwater organisms. Because of the natural salinity cycle within the estuary, salinities would only intrude further up-river than under existing conditions during October or November, which is the time of year when salinities are highest. Significant biological functions such as spawning and nursery activities, and plant growth do not occur at this time of year. It is also likely that the predicted upstream movement in salinity is exaggerated because the hydrology of the drought of record was used to calculate the change. It is expected that salinity increases would be even less than predicted during normal water years.

With respect to water supplies in the vicinity of the Philadelphia-Camden metropolitan area, the main concern is protection of the Potomac-Raritan-Magothy aquifer system in the Camden, New Jersey area. A maximum 30-day average chloride concentration of 180 mg/l at River Mile 98 is the current standard set for protecting this aquifer system from salinity intrusion. Predicted 30-day average chloride concentrations at River Mile 98 were well below this standard for the drought of record. The DRBC has indicated that they plan on lowering this standard to 150 mg/l when additional reservoir storage is available to insure that the standard can be maintained. This more restrictive salinity standard was also met with a deepened channel throughout the drought of record, except in November 1964. The 30-day average chloride concentration for this month violated the proposed standard by two mg/l. This one violation in a worst case analysis was considered acceptable since this more restrictive standard is dependent on additional reservoir storage, which was not included in this effort.

Table 5-5 Comparison of Average Upstream Movement of Selected Isochlors with a Deepened Channel for 1962 and 1965.

Isochlor	1962[a] Movement (Miles)	1965[b] Movement (Miles)
500 mg/l	0.33 ± 0.11	0.48 ± 0.24
2.5 ppt	0.23 ± 0.07	0.38 ± 0.32
5.0 ppt	0.14 ± 0.08	0.47 ± 0.66
10.0 ppt	0.06 ± 0.12	0.17 ± 0.28
15.0 ppt	-0.04 ± 0.20	0.12 ± 0.38

a. In 1962 the mean natural runoff calculated at Trenton, New Jersey was 9180 cfs or 76 percent of the median flow of 12,100 cfs.

b. In 1965 the mean natural runoff calculated at Trenton, New Jersey was 6,050 cfs or 50 percent of the median flow of 12,100 cfs.

5.1.3 Water Quality/Sediment Contamination

The recommended plan of improvement for the Delaware River Comprehensive Navigation Study, Main Channel Deepening Project is a two way, full width channel with a depth of 45 feet below mean low water (mlw). From the Beckett Street Terminal located in Camden, New Jersey through Philadelphia Harbor, the 400-500 foot width west side channel, now at a depth of 40 feet below mlw, would be deepened while the east side channel would remain 37 feet deep. Between the Philadelphia Navy Yard and Delaware Bay the existing 40 foot deep channel would be deepened for its full 800-foot width. In the bay, the full 1,000-foot width channel would be deepened from 40 to 45 feet deep at mlw. In addition, the Marcus Hook and Mantua Creek Anchorages would be partially deepened, and 17 channel bends would be widened to improve navigational safety.

Coordination of the draft Interim Feasibility Report and Environmental Impact Statement for the project resulted in several Federal and State resource agencies commenting on the lack of recent sediment quality data to characterize channel sediments. It was viewed that up-to-date data would be required to more adequately evaluate potential environmental impacts associated with proposed dredging and dredged material disposal. The following describes the sediment testing program conducted during the summer of 1991 to characterize the chemical quality of sediments that would be dredged during construction of the proposed plan.

An important first step in developing a sample plan is to subdivide the project area into segments that represent distinct areas. Samples collected within these segments, or reaches, can then be viewed collectively to evaluate sediment quality. Reaches can be established through a number of considerations. Appropriate considerations for the Delaware River, Philadelphia to the Sea channel include population density, industrial development, Delaware River Basin Commission (DRBC) water quality zones and State boundaries. Based on these, it is considered appropriate to divide the Delaware River project area into four reaches. These reaches will be defined as A, B, C, and D, and are depicted on Figures 5-16 and 5-17.

<u>Reach A:</u> Reach A extends from the upstream portion of the project area to approximately the Pennsylvania-Delaware State line. This reach is characterized by a relatively high population density through the Philadlephia-Camden area, and a high degree of industrial development along the shorelines. Reach A encompasses a portion of water quality zone 3 and all of water quality zone 4, as designated by the DRBC. This portion of the Delaware River is considered to be the most degraded with respect to water quality, although significant improvements have been documented in recent years. In zone 3 and 4, 14 major industries including oil-refineries and paper manufacturing discharge directly into the river after treatment (DRBC, 1990). Sediments within Reach A were considered to have the highest potential for pollution.

DELAWARE RIVER
SEDIMENT TESTING PROGRAM
REACHES A, B AND C

Figure 5-16

N3
Sheet No. 2
N
NEW JERSEY
DELAWARE BAY
ATLANTIC OCEAN
DELAWARE
CUMBERLAND CO
SALEM CO
Arnold Point
To Philadelphia
Cohansey River
Millville
Maurice River
PRSL
CRR OF NJ
Channel flares to 1000' here
Ship John Lt.
Leipsic River
Leipsic
CUMBERLAND CO
CAPE MAY CO
Elbow of Cross Ledge Lt.
Little R.
Little Creek
DOVER
St Jones River
PCRR
Mish Mouth Lt.
14-Ft. Bank Lt.
Brandywine Lt
Murderkill R.
KENT CO.
Mispillion River
SUSSEX CO.
Milford
CAPE MAY CANAL
CAPE MAY HARBOR
N.J. Intracoastal Waterway
Cape May
Roosevelt Inlet
Cape Henlopen
D
Broadkill R.
Milton
Lewes
Fort Miles
Rehoboth Cond
LEGEND
Channel indicated thus
NOTE:
Distance in miles below Allegheny Ave., Phila., show along side of channel
DELAWARE BAY
SEDIMENT TESTING PROGRAM
REACH D
SCALE OF MILES
5 0 5 10
U.S. ARMY ENGINEER DISTRICT, PHILA

Figure 5-17

Reach B: Reach B extends from approximately the Pennsylvania-Delaware state line to Deepwater Point Range in the Delaware River. Population density within Reach B can be characterized as moderate, with the City of Wilmington, Delaware as the only major urban center. Industrial development is still high, with inorganic and petrochemical plants, oil-refineries and steel manufacturing plants located within the area. Reach B is entirely within the DRBC's water quality zone 5. Water quality within zone 5 is characterized by the DRBC as fair to good. While some DRBC water quality standards are occasionally violated (i.e. minimum dissolved oxygen levels during the summer) most standards are met throughout the year.

Reach C: Reach C extends from New Castle Range to approximately Arnold Point, New Jersey. Population density is low, with Delaware City, Delaware being the only city located along the shorelines. Industrial development is much less than in Reaches A and B, but can be characterized as moderate. Reach C contains the Salem Generating Station, a two unit nuclear facility, and the Hope Creek Generating Station, which are both located on Artificial Island. The Texaco oil-refinery is also located in Delaware City. Reach C is predominantly within the DRBC's water quality zone 5. Reach C is approximately the lower half of zone 5, with Reach B being the upper half. The DRBC indicates that the lower portion of zone 5 supports an important sport and commercial fishery (DRBC, 1990). Native oyster populations are also found in the lower portion of zone 5, however, there are no designated shellfish-taking areas.

Reach D: Reach D encompasses the Delaware Bay portion of the project. Population density and industrial development can both be characterized as low within Reach D. The Delaware Bay region is primarily comprised of small towns, farmland and salt marshes, with few towns located directly adjacent to the bay. The Delaware Bay is designated as water quality zone 6 by the DRBC. Water quality within zone 6 is considered good, however, it is recognized that this designation is based on limited data (DRBC, 1990).

Within each reach a series of sediment cores were collected to provide coverage of the various areas proposed for dredging. These areas included both the existing channel and channel bend widening locations. A total of 57 sediment cores were collected throughout the project area. Chemical analyses were conducted on 28 cores collected in channel bend widening locations and 18 cores collected in the existing channel. An additional 11 cores were collected in the Delaware Bay portion of the existing channel. These cores were used for grain size analyses to determine the location of sandy material for beneficial uses. Sediment sampling locations and chemical analysis parameters were determined through coordination with Regions II and III of the U.S. Environmental Protection Agency.

Figures 5-18 through 5-21 provide the approximate locations of the 46 cores that were analyzed for chemical quality. Figures 5-18 and 5-19 show the location of cores collected within the existing navigation channel. These samples are referenced by DRV (Delaware River Vibracore), and a sample number. Figures 5-20 and 5-21 show the location of cores collected at channel bends.

Figure 5-18 DELAWARE RIVER SEDIMENT TESTING PROGRAM CHANNEL SAMPLING LOCATIONS

Figure 5-19 DELAWARE BAY SEDIMENT TESTING PROGRAM CHANNEL SAMPLING LOCATIONS

CHANNEL DIMENSIONS		
LOCATION	DEPTH	WIDTH
A-B WEST SIDE	40 FT	400'-500'
A-B EAST SIDE	37 FT	500'-600'
B-C	40 FT	800'
C-D	40 FT	1000'

Figure 5-20 DELAWARE RIVER SEDIMENT TESTING PROGRAM BEND SAMPLING LOCATIONS

PHILADELPHIA DISTRICT, CORPS OF ENGINEERS

Figure 5-21 DELAWARE BAY SEDIMENT TESTING PROGRAM BEND SAMPLING LOCATIONS

These samples are referenced by the Corps' letter designation for the bend, and a sample number. Note that bends A through F and bends P and Q were treated as single bends, even though there is more them one turn at each of these locations. Figures 5-18 through 5-21 also provide the location of Delaware River water samples that were collected for the purpose of preparing sediment elutriates.

Sediment cores were collected with vibracoring equipment that employed a collection tube, approximately three inches in diameter. Samples for chemical analysis were selected from the cores based on observed sediment stratification. Each sediment strata greater than six inches constituted a separate sample. Sediment was removed from the interior portion of the core to minimize chemical contamination associated with the core tube. If a core consisted of a single, homogenous unit, the interior portion of the core was removed over the entire length of the core, thoroughly homogenized, and sub-sampled. Sediment from the exterior portion of the core was used for grain size analyses.

Sediment samples were analyzed using both bulk and elutriate analysis procedures. Bulk analysis provides the total concentration of a chemical parameter within the sediments. This type of information provides a general indication of the quality of sediments, and the environmental concerns associated with dredging and disposal operations. The elutriate analysis (Palermo, 1986) is a simulation of the physical and chemical changes that occur when sediments are dredged and placed in an upland dredged material disposal site. These changes affect the behavior of chemical parameters associated with the dredged sediment, and dictate their movement from the sediment to the water column. The test is an accepted predictive technique for evaluating the quality of effluent that would be discharged from a confined, upland dredged material disposal site during a disposal operation. This type of information provides a clearer understanding of the environmental concerns associated with dredging and disposal than does the bulk information.

Based on coordination with the U.S. Environmental Protection Agency, two sets of chemical parameters were used to evaluate sediment quality. The standard list used for all cores included metals, pesticides, PCB's and polynuclear aromatic hydrocarbons (Table 5-6). A longer list that also included volatile organics, acid extractable organics and additional base neutral organics, was used for three cores collected in bend AF and one core collected in bend L (Table 5-7). These locations were considered to have the greatest potential for contamination. All parameters were run for both bulk and elutriate tests. Water samples were also analyzed for the same set of chemical parameters as sediment elutriates for comparison.

All laboratory procedures followed an analytical quality assurance/quality control program that included:

a. use of analytical test procedures and detection limits for sediments that conformed to those set forth in SW 846;

b. use of analytical test procedures and detection limits for water that conformed to those set forth in 40 CFR 136;

Table 5-6 Basic Chemical Parameter List for Sediment Quality Analysis

METALS
- antimony
- arsenic
- beryllium
- cadmium
- chromium
- copper
- lead
- mercury
- nickel
- selenium
- silver
- thallium
- zinc

PESTICIDES
- aldrin
- dieldrin
- chlordane
- DDT
- endosulfan
- endrin
- endrin aldehyde
- heptachlor
- heptachlor epoxide
- alpha-hexachlorocyclohexane
- beta-hexachlorocyclohexane
- delta-hexachlorocyclohexane
- gamma-hexachlorocyclohexane
- toxaphene
- mirex
- methoxychlor
- parathion
- malathion
- guthion
- demeton

POLYCHLORINATED BIPHENYLS (PCB) AS AROCHLORS
- PCB-1242
- PCB-1254
- PCB-1221
- PCB-1232
- PCB-1248
- PCB-1260
- PCB-1016

LOW MOLECULAR WEIGHT POLYNUCLEAR AROMATIC HYDROCARBONS (PAH)
- acenaphthene
- naphthalene
- acenaphthylene
- anthracene
- phenanthrene
- fluorene

HIGH MOLECULAR WEIGHT (PAH)
- fluoranthene
- benzo(a)anthracene
- benzo(a)pyrene
- benzo(b)fluoranthene
- benzo(k)fluoranthene
- chrysene
- benzo(ghi)perylene
- dibenzo(a,h)anthracene
- ideno(1,2,3-cd)pyrene
- pyrene

Table 5-7 Full Chemical Parameter List for Sediment Quality Analysis

METALS

- antimony
- arsenic
- beryllium
- cadmium
- chromium
- copper
- lead
- mercury
- nickel
- selenium
- silver
- thallium
- zinc

PESTICIDES

- aldrin
- dieldrin
- chlordane
- DDT
- endosulfan
- endrin
- endrin aldehyde
- heptachlor
- heptachlor epoxide
- alpha-hexachlorocyclohexane
- beta-hexachlorocyclohexane
- delta-hexachlorocyclohexane
- gamma-hexachlorocyclohexane
- toxaphene
- mirex
- methoxychlor
- parathion
- malathion
- guthion
- demeton

POLYCHLORINATED BIPHENYLS (PCB) AS AROCHLORS

- PCB-1242
- PCB-1254
- PCB-1221
- PCB-1232
- PCB-1248
- PCB-1260
- PCB-1016

VOLATILE ORGANICS

VOLATILE HALOGENATED ALKANES	tetrachloromethane
	1,2-dichloroethane
	1,1,1-trichloroethane
	1,1-dichloroethane
	1,1,2-trichloroethane
	1,1,2,2-tetrachloroethane
	chloroethane
	chloroform
	1,2-dichloropropane
	dichloromethane
	chloromethane
	bromomethane
	bromoform
	dichlorobromoethane
	fluorotrichloromethane
	dichlorodifluoromethane
	chlorodibromomethane
VOLATILE HALOGENATED ALKENES	1,1-dichlorethylene
	1,2-trans-dichlorethylene
	trans-1,3-dichloropropene
	cis-1,3-dichloropropene
	tetrachlorethene
	trichlorethene
	vinyl chloride
VOLATILE AROMATIC HYDROCARBONS	benzene
	ethylbenzene
	toluene
VOLATILE CHLORINATED AROMATIC HYDROCARBONS	chlorobenzene
VOLATILE UNSATURATED CARBONYL COMPOUNDS	acrolein
	acrylonitrile
VOLATILE ETHERS	2-chlorethylvinylether
	bis(chloromethyl)ether

ACID EXTRACTABLE ORGANICS

PHENOLS	phenol
	2,4-dimethylphenol
SUBSTITUTED PHENOLS	2,4,6-trichlorophenol
	para-chloro-meta-cresol
	2-chlorophenol
	2,4-dichlorophenol
	2-nitrophenol
	4-nitrophenol
	2,4-dinitrophenol

Table 5-7 Full Chemical Parameter List for Sediment Quality Analysis - con't.

BASE NEUTRAL ORGANICS

ORGANONITROGEN COMPOUNDS	benzidine 3,3'-dichlorobenzidine 2,4-dinitrotoluene 2,6-dinitrotoluene 1,2-diphenylhydrazine nitrobenzene N-nitrosodimethylamine N-nitrosodiphenylamine N-nitroso di-n-propylamine
LOW MOLECULAR WEIGHT POLYNUCLEAR AROMATIC HYDROCARBONS (PAH)	acenaphthene naphthalene acenaphthylene anthracene phenanthrene fluorene
HIGH MOLECULAR WEIGHT (PAH)	fluoranthene benzo(a)anthracene benzo(a)pyrene benzo(b)fluoranthene benzo(k)fluoranthene chrysene benzo(ghi)perylene dibenzo(a,h)anthracene ideno(1,2,3-cd)pyrene pyrene
CHLORINATED AROMATIC HYDROCARBONS	1,2,4-trichlorobenzene hexachlorobenzene 2-chloronaphthalene 1,2-dichlorobenzene 1,3-dichlorobenzene 1,4-dichlorobenzene
CHLORINATED ALIPHATIC HYDROCARBONS	hexachlorobutadiene hexachloroethane hexachlorocyclopentadiene
HALOGENATED ETHERS	bis(2-chloroethyl)ether 4-chlorophenyl phenyl ether 4-bromophenyl ether bis(2-chloroisopropyl)ether bis(2-chlorethoxy)methane
PHTHALATES	bis(2-ethylhexy)phthalate butyl benzyl phthalate di-n-butyl phthalate di-n-octyl phthalate diethyl phthalate dimethyl phthalate
MISCELLANEOUS	TCDD (dioxin)

c. use of a sample labeling system that ensured proper tracking of samples from collection through analysis;

d. use of standard quality assurance protocols including blanks, duplicates and spiked samples, as described in Handbook for Analytical Quality Control in Water and Wastewater Laboratories (USEPA, 1979); and

e. maintenance of accurate quality control records including at least daily analytical instrument calibration data.

The results of the chemical analyses are presented in Tables 5-8 through 5-21. These tables report the concentrations (parts per million) of chemical parameters that were detected in samples. Parameters that were not detected were omitted from the tables to simplify the presentation. The tables also report the concentrations of chemical parameters detected in Delaware River water samples that were used to prepared sediment elutriates. Tables 5-8 through 5-12 present chemical data from sediment cores collected within the existing navigation channel. Tables 5-13 through 5-21 present chemical data from sediment cores collected within channel bend widening areas. Sediment core data were grouped on tables to characterize specific portions of the river.

The existing navigation channel is a minimum of 40 feet deep at mean low water (mlw). While some portions of the channel are deeper, there are no areas that are shallower. The proposed navigation channel would deepen the existing channel to 45 feet at mlw, with allowances for two feet of overdepth dredging. As such, a maximum of seven feet of material would be removed from any particular location within the channel. While approximately 20-foot cores were collected from the existing channel, only the top seven feet of sediment was analyzed for chemical quality. The lower 13 feet of these cores were only evaluated for grain size. There was no sediment stratification observed in the top seven feet of cores collected from the existing channel, only one set of results is reported for each core. Approximately 20-foot cores were also collected in channel bend areas that are proposed for widening. These areas vary in depth, but are all shallower than 40-feet at mlw (depths generally range between 25 and 35 feet). The entire length of these cores was used for chemical analysis. Some of these cores did exhibit sediment stratification. More than one set of results are reported for cores where sediment stratification was observed. Where stratification occurred, the depth (in feet) from the bottom surface is provided for reference.

Tables 5-22 and 5-23 summarize the grain size analyses conducted on the sediment cores. Table 5-22 provides information on the cores collected within the navigation channel. Table 5-23 provides information on cores collected within channel bend widening locations. Figures 5-18 through 5-21 provide the approximate locations of the 57 cores that were analyzed. Sediment cores collected within the Delaware River portion of the project area indicate that the material is predominantly fine-grained. Sediment cores collected within the Delaware Bay indicate that approximately 78 percent of the material that would be dredged for the deepening project is coarse-grained, and approximately 22 percent is fine grained.

Table 5-8 Chemical test results of sediment cores collected in the existing Delaware River, Philadelphia to the sea navigation channel, between the Philadelphia Naval Base and Chester, PA.
All values reported as parts per million.

	DRV-1		DRV-2		DRV-3		DRV-4		WS-1A
	Total	Elutriate	Total	Elutriate	Total	Elutriate	Total	Elutriate	Total
Antimony	24.0	ND	7.5	ND	21.0	ND	25.5	ND	ND
Arsenic	4.15	ND	2.20	ND	1.22	ND	ND	ND	ND
Beryllium	0.50	ND	0.50	ND	0.50	ND	0.50	ND	ND
Cadmium	0.50	ND	1.0	ND	0.50	0.01	1.0	ND	ND
Chromium	6.0	ND	9.0	0.09	5.5	ND	4.5	ND	ND
Copper	4.5	0.03	12.5	0.09	4.0	0.02	10.5	0.02	ND
Lead	7.0	0.0159	21.0	0.0999	5.5	0.0113	11.0	0.0132	0.0086
Mercury	0.0481	ND	0.172	ND	0.0267	ND	ND	ND	ND
Nickel	5.5	ND	9.0	ND	4.5	ND	13.5	ND	ND
Zinc	15.0	0.10	95.0	0.34	14.0	0.06	35.0	0.06	0.03
Total Organic Carbon	170.0	---	1100.0	---	1200.0	---	550.0	---	---
Total Suspended Solids	---	19.0	---	464.0	---	9.0	---	25.0	---
Heptachlor Epoxide	ND	ND	0.055	ND	ND	ND	ND	ND	ND

ND = Not detected
--- = No sample data

Table 5-9 Chemical test results of sediment cores collected in the existing Delaware River, Philadelphia to the sea navigation channel, in the vicinity of Marcus Hook, PA. All values reported as parts per million.

	DRV-5		DRV-6		DRV-7		WS-2A
	Total	Elutriate	Total	Elutriate	Total	Elutriate	Total
Antimony	22.0	ND	21.5	ND	32.0	ND	ND
Arsenic	1.29	ND	2.65	0.0121	ND	ND	ND
Beryllium	0.50	ND	1.0	ND	1.0	ND	ND
Cadmium	1.0	0.01	1.0	ND	1.0	ND	ND
Chromium	8.0	ND	12.0	ND	6.5	ND	ND
Copper	13.5	0.03	21.0	0.02	13.5	0.03	ND
Lead	14.5	0.0104	36.5	0.0189	10.0	0.0036	0.0085
Mercury	0.019	ND	0.153	ND	0.056	ND	ND
Nickel	14.5	ND	17.0	ND	24.5	ND	ND
Silver	0.50	ND	0.50	ND	0.50	ND	ND
Thallium	ND	ND	ND	ND	9.0	ND	ND
Zinc	56.0	0.07	115.0	0.08	47.0	0.05	0.03
Total Organic Carbon	2500.0	---	16000.0	---	---	ND	---
Total Suspended Solids	---	11.0	---	24.0	---	6.0	---
Malathion	ND	0.0063	ND	ND	ND	ND	ND

ND = Not detected
--- = No sample data

Table 5-10 Chemical test results of sediment cores collected in the existing Delaware River, Philadelphia to the sea navigation channel, between Oldmans Point, NJ and the Delaware Memorial Bridge. All values reported as parts per million.

	DRV-8		DRV-9		DRV-10		WS-2A
	Total	Elutriate	Total	Elutriate	Total	Elutriate	Total
Antimony	13.5	ND	20.5	ND	23.0	ND	ND
Arsenic	4.44	0.0929	1.38	ND	1.45	ND	ND
Beryllium	1.5	ND	1.0	ND	1.0	ND	ND
Cadmium	1.5	0.01	1.0	0.01	1.0	0.01	ND
Chromium	34.0	0.13	10.0	ND	8.5	ND	ND
Copper	51.0	0.13	1.0	0.03	8.5	0.02	ND
Lead	120.0	0.26	10.0	0.0418	12.0	0.0238	0.0085
Mercury	0.555	0.000948	0.0439	ND	0.0542	ND	ND
Nickel	21.5	0.06	16.5	ND	15.0	ND	ND
Selenium	0.385	ND	ND	ND	ND	ND	ND
Silver	1.0	ND	0.50	ND	0.50	ND	ND
Thallium	5.5	ND	8.0	ND	7.0	ND	ND
Zinc	120.0	0.30	42.0	0.08	43.5	0.10	0.03
PCB-1254	1.19	ND	ND	ND	ND	ND	ND
PCB-1248	0.53	ND	ND	ND	ND	ND	ND
Endosulfan	0.59	ND	ND	ND	ND	ND	ND
Malathion	ND	0.0026	ND	ND	ND	ND	ND
Total Organic Carbon	11000.0	---	8100.0	ND	6700.0	ND	---
Total Suspended Solids	---	452.0	---	7.0	---	14.0	---

ND = Not detected
--- = No sample data

Table 5-11 Chemical test results of sediment cores collected in the existing Delaware River, Philadelphia to the sea navigation channel, between Killcohook and Arnold Point, NJ.
All values reported as parts per million.

	DRV-11		DRV-12		DRV-13		DRV-14		WS-3A
	Total	Elutriate	Total	Elutriate	Total	Elutriate	Total	Elutriate	Total
Antimony	12.5	ND	19.0	ND	16.0	ND	13.5	ND	ND
Arsenic	2.32	ND	1.73	ND	2.77	ND	3.32	ND	ND
Beryllium	1.0	ND	1.0	ND	0.50	ND	0.50	ND	ND
Cadmium	1.0	0.02	1.0	0.02	1.0	0.02	0.50	0.02	0.02
Chromium	12.5	ND	8.0	ND	10.5	ND	13.0	ND	0.08
Copper	20.0	0.03	13.0	0.03	9.0	0.03	7.0	0.03	0.04
Lead	27.5	0.0089	19.5	0.0060	12.5	0.0056	8.5	ND	0.0046
Mercury	0.172	ND	0.1321	0.000261	ND	ND	ND	ND	ND
Nickel	16.5	0.05	13.0	0.04	15.0	0.04	12.0	0.04	0.04
Selenium	ND	ND	ND	ND	ND	ND	ND	ND	0.005
Silver	0.50	ND	0.50	0.01	ND	0.01	ND	0.01	ND
Thallium	ND	ND	ND	ND	10.5	ND	7.0	ND	ND
Zinc	110.0	0.04	80.0	0.03	43.0	0.07	36.0	0.05	0.03
Total Organic Carbon	11000.0	---	9500.0	---	6700.0	---	4300.0	---	---
Total Suspended Solids	---	15.5	---	12.0	---	12.0	---	15.0	---

ND = Not detected
--- = No sample data

Table 5-12 Chemical test results of sediment cores collected in the existing Delaware River, Philadelphia to the sea navigation channel, within Delaware Bay.
All values reported as parts per million.

	DRV-16		DRV-19		DRV-24		DRV-28		WS-4A
	Total	Elutriate	Total	Elutriate	Total	Elutriate	Total	Elutriate	Total
Arsenic	1.03	ND	1.42	ND	0.36	ND	2.33	ND	ND
Beryllium	0.50	0.01	0.50	0.01	ND	0.01	ND	ND	ND
Cadmium	0.50	0.04	0.50	0.04	0.50	0.04	0.50	0.04	0.04
Chromium	5.0	ND	10.5	ND	ND	ND	7.0	ND	ND
Copper	5.5	0.06	4.0	0.07	2.0	0.08	4.0	0.05	0.05
Lead	0.20	0.0002	2.28	0.0123	5.00	0.0034	4.81	0.17	0.0070
Nickel	9.0	0.15	7.5	0.17	2.5	0.16	4.0	0.11	0.12
Silver	ND	0.03	0.50	0.03	0.50	0.04	0.50	0.02	0.03
Zinc	19.0	0.04	20.5	0.09	11.0	0.07	25.0	0.04	ND
Total Organic Carbon	4000.0	---	2200.0	---	200.0	---	2100.0	---	---
Total Suspended Solid	---	24.0	---	23.5	---	28.1	---	19.0	---

ND = Not detected
--- = No sample data

Table 5-13 Chemical test results of sediment cores collected in channel bends A through F (vicinity of Philadelphia Naval Base) of the existing Delaware River, Philadelphia to the sea navigation channel.
All values reported as parts per million.

	AF1			AF2			AF3			WS1
	DEPTH	TOTAL	ELUTRIATE	DEPTH	TOTAL	ELUTRIATE	DEPTH	TOTAL	ELUTRIATE	TOTAL
Bis (2-ethylhexyl) phthalate	0 - 8.5	ND	0.134	0 -	ND	ND	0 -	ND	0.015	ND
	8 - 11	ND	0.101							
	11-14	ND	ND							
Di-n-butyl phthalate	0 - 8.5	ND	ND	0 -	0.614	ND	0 -	2.67	ND	ND
	8 - 11	ND	ND							
	11-14	ND	ND							
Fluoranthene	0 - 8.5	ND	ND	0 -	ND	ND	0 -	0.520	ND	ND
	8 - 11	ND	ND							
	11-14	ND	ND							
Methylene Chloride	0 - 8.5	0.875	0.030	0 -	ND	0.023	0 -	0.794	0.021	ND
	8 - 11	0.774	0.013							
	11-14	ND	0.009							
Arsenic	0 - 8.5	ND	ND	0 -	3.85	ND	0 -	26.6	ND	ND
	8 - 11	ND	ND							
	11-14	5.53	ND							
Chromium	0 - 8.5	6.52	ND	0 -	8.24	ND	0 -	59.3	ND	ND
	8 - 11	4.13	ND							
	11-14	14.4	ND							
Copper	0 - 8.5	3.17	0.0935	0 -	3.99	ND	0 -	29.7	ND	ND
	8 - 11	2.30	ND							
	11-14	6.09	ND							
Lead	0 - 8.5	3.34	0.0645	0 -	3.67	ND	0 -	53.4	ND	ND
	8 - 11	ND	ND							
	11-14	6.17	ND							
Mercury	0 - 8.5	ND	ND	0 -	ND	ND	0 -	0.671	ND	ND
	8 - 11	ND	ND							
	11-14	ND	ND							
Nickel	0 - 8.5	7.28	ND	0 -	8.38	ND	0 -	13.0	ND	ND
	8 - 11	5.85	ND							
	11-14	13.3	ND							
Zinc	0 - 8.5	2.31	0.108	0 -	28.7	ND	0 -	278	ND	0.0204
	8 - 11	21.6	ND							
	11-14	39.0	ND							
Total Suspended Solids	0 - 8.5	—	2700	0 -	—	5180	0 -	—	1130	—
	8 - 11	—	1300							
	11-14	—	5040							
Total Organic Carbon	0 - 8.5	11050	—	0 -	5790	—	0 -	35700	—	—
	8 - 11	6485	—							
	11-14	12900	—							

ND = Not detected
--- = No sample data

Table 5-14 Chemical test results of sediment cores collected in channel bend G (mouth of Schuylkill River) of the existing Delaware River, Philadelphia to the sea navigation channel. All values reported as parts per million.

	G1			G2			G3			G4			G5			WS2
	DEPTH	TOTAL	ELUTRIATE	DEPTH	TOTAL	ELUTRIATE	DEPTH	TOTAL	ELUTRIATE	DEPTH	TOTAL	ELUTRIATE	DEPTH	TOTAL	ELUTRIATE	TOTAL
Benzo(b) fluoranthene	0 - 4	ND	ND	0 - 3	ND	ND	0	0.667	ND							
	4 - 19.5	ND	ND	3 -	ND	ND	1.75	ND	ND	0 -	ND	ND	0 -	ND	ND	ND
	19.5 -	ND	---				3.25	ND	ND							
Fluoranthene	0 - 4	ND	ND	0 - 3	ND	ND	0	0.557	ND							
	4 - 19.5	ND	ND	3 -	ND	ND	1.75	ND	ND	0 -	ND	ND	0 -	ND	ND	ND
	19.5 -	ND	---				3.25	ND	ND							
Pyrene	0 - 4	ND	ND	0 - 3	ND	ND	0	0.616	ND							
	4 - 19.5	ND	ND	3 -	ND	ND	1.75	ND	ND	0 -	ND	ND	0 -	ND	ND	ND
	19.5 -	ND	---				3.25	ND	ND							
Antimony	0 - 4	ND	ND	0 - 3	ND	ND	0	ND	ND							
	4 - 19.5	ND	ND	3 -	ND	ND	1.75	2.33	ND	0 -	ND	ND	0 -	ND	ND	ND
	19.5 -	ND	--				3.25	ND	ND							
Arsenic	0 - 4	ND	ND	0 - 3	ND	ND	0	16.1	0.065							
	4 - 19.5	ND	ND	3 -	ND	ND	1.75	10.7	ND	0 -	ND	ND	0 -	ND	ND	ND
	19.5 -	ND	---				3.25	ND	ND							
Cadmium	0 - 4	ND	ND	0 - 3	ND	ND	0	5.24	ND							
	4 - 19.5	ND	ND	3 -	ND	ND	1.75	2.82	ND	0 -	ND	ND	0 -	ND	ND	ND
	19.5 -	ND	---				3.25	ND	ND							
Chromium	0 - 4	3.73	0.056	0 - 3	1.93	0.053	0	83.2	0.160							
	4 - 19.5	12.2	0.038	3 -	16.5	0.048	1.75	50.6	0.032	0 -	11.1	ND	0 -	10.1	0.028	ND
	19.5 -	3.32	---				3.25	8.69	ND							
Copper	0 - 4	1.89	0.029	0 - 3	1.34	0.10	0	107	0.032							
	4 - 19.5	5.21	0.043	3 -	6.30	0.064	1.75	60.6	0.069	0 -	5.46	0.022	0 -	4.65	ND	0.021
	19.5 -	ND	---				3.25	4.12	0.027							
Lead	0 - 4	4.25	0.022	0 - 3	ND	0.013	0	146	0.127							
	4 - 19.5	7.17	ND	3 -	ND	ND	1.75	93.1	ND	0 -	9.27	ND	0 -	7.49	ND	ND
	19.5 -	ND	---				3.25	7.04	0.090							
Mercury	0 - 4	ND	ND	0 - 3	ND	ND	0	0.443	ND							
	4 - 19.5	ND	ND	3 -	ND	ND	1.75	0.359	ND	0 -	ND	ND	0 -	ND	ND	ND
	19.5 -	ND	---				3.25	ND	ND							
Nickel	0 - 4	4.16	0.042	0 - 3	4.63	ND	0	24.8	0.124							
	4 - 19.5	13.2	0.098	3 -	17.2	0.138	1.75	14.1	ND	0 -	12.8	ND	0 -	11.9	ND	ND
	19.5 -	4.04	---				3.25	11.5	0.092							
Zinc	0 - 4	24.5	0.340	0 - 3	13.3	1.16	0	607	1.09							
	4 - 19.5	32.6	0.264	3 -	42.4	0.245	1.75	328	0.374	0 -	35.9	0.852	0 -	32.0	0.693	ND
	19.5 -	16.4	---				3.25	33.6	0.610							
Total Suspended Solids	0 - 4	---	50	0 - 3	---	90.6	0	---	31600							
	4 - 19.5	---	7360	3 -	---	13200	1.75	---	16.0	0 -	---	62.1	0 -	---	65.8	---
	19.5 -	---	---				3.25	---	167							
Total Organic Carbon	0 - 4	3960	--	0 - 3	15600	---	0	329000	---							
	4 - 19.5	21900	--	3 -	24600	---	1.75	121000	---	0 -	25600	---	0 -	15200	---	---
	19.5 -	2070	--				3.25	14600	---							

ND = Not detected
--- = No sample data

Table 5-15 Chemical test results of sediment cores collected in channel bends H and I (vicinity of Paulsboro, NJ) of the existing Delaware River, Philadelphia to the sea navigation channel. All values reported as parts per million.

	H1			I1			I2			WS2
	DEPTH	TOTAL	ELUTRIATE	DEPTH	TOTAL	ELUTRIATE	DEPTH	TOTAL	ELUTRIATE	TOTAL
Anthracene	0 - 7	ND	ND	0	ND	ND	0	0.507	—	
	7 - 16.5	ND	ND	6.75	ND	ND	1.25	ND	ND	ND
	16.5 -	ND	ND				4.75	ND	ND	
Benzo(a) anthracene	0 - 7	ND	ND	0	ND	ND	0	1.82	—	
	7 - 16.5	ND	ND	6.75	ND	ND	1.25	ND	ND	ND
	16.5 -	ND	ND				4.75	ND	ND	
Benzo(b) fluoranthene	0 - 7	ND	ND	0	ND	ND	0	1.02	—	
	7 - 16.5	ND	ND	6.75	ND	ND	1.25	ND	ND	ND
	16.5 -	ND	ND				4.75	ND	ND	
Benzo(k) fluoranthene	0 - 7	ND	ND	0	ND	ND	0	0.825	—	
	7 - 16.5	ND	ND	6.75	ND	ND	1.25	ND	ND	ND
	16.5 -	ND	ND				4.75	ND	ND	
Benzo(ghi) perylene	0 - 7	ND	ND	0	ND	ND	0	0.474	—	
	7 - 16.5	ND	ND	6.75	ND	ND	1.25	ND	ND	ND
	16.5 -	ND	ND				4.75	ND	ND	
Benzo(a) pyrene	0 - 7	ND	ND	0	ND	ND	0	1.12	—	
	7 - 16.5	ND	ND	6.75	ND	ND	1.25	ND	ND	ND
	16.5	ND	ND				4.75	ND	ND	
Chrysene	0 - 7	ND	ND	0	ND	ND	0	1.27	—	
	7 - 16.5	ND	ND	6.75	ND	ND	1.25	ND	ND	ND
	16.5 -	ND	ND				4.75	ND	ND	
Fluoranthene	0 - 7	ND	ND	0	ND	ND	0	2.25	—	
	7 - 16.5	ND	ND	6.75	ND	ND	1.25	ND	ND	ND
	16.5 -	ND	ND				4.75	ND	ND	
Indeno (1,2,3-c,d) pyrene	0 - 7	ND	ND	0	ND	ND	0	0.531	—	
	7 - 16.5	ND	ND	6.75	ND	ND	1.25	ND	ND	ND
	16.5 -	ND	ND				4.75	ND	ND	
Phen-anthrene	0 - 7	ND	ND	0	ND	ND	0	0.949	—	
	7 - 16.5	ND	ND	6.75	ND	ND	1.25	ND	ND	ND
	16.5 -	ND	ND				4.75	ND	ND	
Pyrene	0 - 7	ND	ND	0	ND	ND	0	1.76	—	
	7 - 16.5	ND	ND	6.75	ND	ND	1.25	ND	ND	ND
	16.5 -	ND	ND				4.75	ND	ND	
Antimony	0 - 7	ND	ND	0	ND	ND	0	ND	—	
	7 - 16.5	ND	ND	6.75	5.29	ND	1.25	ND	ND	ND
	16.5 -	ND	ND				4.75	ND	ND	
Chromium	0 - 7	ND	0.085	0	5.24	ND	0	19.4	—	
	7 - 16.5	1.45	0.028	6.75	24.4	0.077	1.25	23.7	ND	ND
	16.5 -	4.19	0.059				4.75	16.4	ND	
Copper	0 - 7	ND	0.082	0	2.11	ND	0	16.1	—	
	7 - 16.5	ND	0.119	6.75	7.45	ND	1.25	12.0	ND	0.021
	16.5 -	2.54	0.052				4.75	7.88	0.034	
Lead	0 - 7	ND	ND	0	4.82	ND	0	41.8	—	
	7 - 16.5	ND	0.010	6.75	12.6	ND	1.25	21.3	0.012	ND
	16.5 -	2.98	ND				4.75	ND	ND	
Nickel	0 - 7	ND	ND	0	7.90	ND	0	21.1	—	
	7 - 16.5	ND	0.680	6.75	19.4	ND	1.25	38.0	ND	ND
	16.5 -	5.52	0.057				4.75	22.4	ND	
Zinc	0 - 7	1.38	0.227	0	22.3	0.735	0	208	—	
	7 - 16.5	3.54	0.302	6.75	48.0	0.921	1.25	109	0.676	ND
	16.5 -	16.9	0.264				4.75	48.5	0.700	
Total Suspended Solids	0 - 7	—	320	0	—	74.1	0	—	—	
	7 - 16.5	—	450	6.75	—	55.9	1.25	—	68.5	—
	16.5 -	—	548				4.75	—	62.1	
Total Organic Carbon	0 - 7	ND	—	0	14400	—	0	2560	—	
	7 - 16.5	392	—	6.75	18000	—	1.25	8690	—	—
	16.5 -	10800	—				4.75	21300	—	

ND = Not detected

— = No sample data

Table 5-16 Chemical test results of sediment cores collected in channel bends J and K (vicinity of Chester, PA) of the existing Delaware River, Philadelphia to the sea navigation channel. All values reported as parts per million.

	J1			J2			K1			WS3
	Depth	Total	Elutriate	Depth	Total	Elutriate	Depth	Total	Elutriate	Total
Antimony	0 - 6.4	1.9	ND	0	4.6	ND	0	1.7	ND	ND
	6.4 -	5.3	ND							
Arsenic	0 - 6.4	ND	0.0060	0	4.9	ND	0	ND	ND	ND
	6.4 -	ND	ND							
Beryllium	0 - 6.4	0.54	ND	0	1.1	ND	0	1.1	ND	ND
	6.4 -	1.2	ND							
Cadmium	0 - 6.4	ND	ND	0	ND	ND	0	ND	ND	ND
	6.4 -	0.11	ND							
Chromium	0 - 6.4	20.2	ND	0	49.2	ND	0	41.6	ND	ND
	6.4 -	51.3	ND							
Copper	0 - 6.4	16.3	ND	0	15.0	ND	0	14.7	ND	0.018
	6.4 -	21.7	ND							
Lead	0 - 6.4	4.7	ND	0	10.3	ND	0	7.5	ND	0.0097
	6.4 -	11.9	ND							
Nickel	0 - 6.4	12.4	ND	0	26.4	ND	0	23.7	ND	ND
	6.4 -	29.0	ND							
Zinc	0 - 6.4	40.3	0.049	0	69.0	0.023	0	63.0	ND	0.065
	6.4 -	74.8	ND							
Total Suspended Solids	0 - 6.4	---	5420	0	---	7590	0	---	3540	---
	6.4 -	---	13600							

ND = Not detected
--- = No sample data

Table 5-17 Chemical test results of a sediment core collected in channel bend L (vicinity of Racoon Island, NJ) of the existing Delaware River, Philadelphia to the sea navigation channel.
All values reported as parts per million.

	L1			WS4
	DEPTH	TOTAL	ELUTRIATE	TOTAL
Bis (2-ethylhexyl) phthalate	0	0.129	0.018	ND
Di-n-butyl phthalate	0	1.51	ND	ND
Arsenic	0	7.39	ND	ND
Chromium	0	15.1	ND	ND
Copper	0	7.47	ND	ND
Lead	0	36.4	ND	ND
Nickel	0	13.2	ND	ND
Zinc	0	37.4	0.159	0.028
Total Organic Carbon	0	23250	---	---
Total Suspended Solids	0	---	156	---

ND = Not detected
--- = No sample data

Table 5-18 Chemical test results of sediment cores collected in channel bends M, N and O (located between Oldmans Point, NJ and the Delaware Memorial Bridge) of the existing Delaware River, Philadelphia to the sea navigation channel.
All values reported as parts per million.

	M1			M2			N1			O1			O2			WS5
	Depth	Total	Elutriate	Depth	Total	Elutriate	Depth	Total	Elutriate	Depth	Total	Elutriate	Depth	Total	Elutriate	Total
Naphthalene	0 - 9.75	.180J	ND	0-	ND	ND	0-	ND	ND	0-	ND	ND	0-	ND	ND	ND
	9.75 -	ND	ND													
Phenanthrene	0 - 9.75	.490J	ND	0-	ND	ND	0-	ND	ND	0-	ND	ND	0-	ND	ND	ND
	9.75 -	ND	ND													
Anthracene	0 - 9.75	.200J	ND	0-	ND	ND	0-	ND	ND	0-	ND	ND	0-	ND	ND	ND
	9.75 -	ND	ND													
Fluoranthene	0 - 9.75	.860J	ND	0-	ND	ND	0-	ND	ND	0-	ND	ND	0-	ND	ND	ND
	9.75 -	ND	ND													
Pyrene	0 - 9.75	.810J	ND	0-	ND	ND	0-	ND	ND	0-	ND	ND	0-	ND	ND	ND
	9.75 -	ND	ND													
Benzo(a)anthracene	0 - 9.75	.590J	ND	0-	ND	ND	0-	ND	ND	0-	ND	ND	0-	ND	ND	ND
	9.75 -	ND	ND													
chrysene	0 - 9.75	.710J	ND	0-	ND	ND	0-	ND	ND	0-	ND	ND	0-	ND	ND	ND
	9.75 -	ND	ND													
Benzo(b)fluoranthene	0 - 9.75	.490JL	ND	0-	ND	ND	0-	ND	ND	0-	ND	ND	0-	ND	ND	ND
	9.75 -	ND	ND													
Benzo(k)fluoranthene	0 - 9.75	.490JL	ND	0-	ND	ND	0-	ND	ND	0-	ND	ND	0-	ND	ND	ND
	9.75 -	ND	ND													
Benzo(a)pyrene	0 - 9.75	.530J	ND	0-	ND	ND	0-	ND	ND	0-	ND	ND	0-	.370	ND	ND
	9.75 -	ND	ND													
Benzo(g,h,i)perylene	0 - 9.75	.320J	ND	0-	ND	ND	0-	ND	ND	0-	ND	ND	0-	ND	ND	ND
	9.75 -	ND	ND													
Indeno(1,2,3-cd)pyrene	0 - 9.75	.330J	ND	0-	ND	ND	0-	ND	ND	0-	ND	ND	0-	ND	ND	ND
	9.75 -	ND	ND													
Endosulfan II	0 - 9.75	ND	.008	0-	ND	ND	0-	ND	ND	0-	ND	ND	0-	ND	ND	ND
	9.75 -	ND	ND													
Antimony	0 - 9.75	2.8	ND	0-	3.4	ND	0-	2.5	ND	0-	1.6	ND	0-	4.3	ND	ND
	9.75 -	2.8	ND													
Arsenic	0 - 9.75	13.2	0.053	0-	10.9	ND	0-	ND	ND	0-	8.7	ND	0-	10.9	ND	ND
	9.75 -	4.1	ND													
Beryllium	0 - 9.75	0.91	ND	0-	1.1	ND	0-	1.3	ND	0-	1.2	ND	0-	1.2	ND	ND
	9.75 -	1.1	ND													
Cadmium	0 - 9.75	0.2	ND	0-	0.25	ND	0-	ND	ND	0-	ND	ND	0-	0.42	ND	ND
	9.75 -	ND	ND													
Chromium	0 - 9.75	63.7	ND	0-	46.9	ND	0-	51.0	ND	0-	48.3	ND	0-	48.6	ND	ND
	9.75 -	43.0	ND													
Copper	0 - 9.75	31.6	ND	0-	15.3	ND	0-	16.7	ND	0-	15.0	ND	0-	12.6	ND	0.010
	9.75 -	13.3	ND													
Lead	0 - 9.75	46.4	ND	0-	9.7	ND	0-	10.5	ND	0-	8.1	ND	0-	12.7	ND	ND
	9.75 -	6.3	ND													
Nickel	0 - 9.75	20.6	ND	0-	23.9	ND	0-	27.8	ND	0-	24.9	ND	0-	25.7	ND	ND
	9.75 -	24.9	ND													
Zinc	0 - 9.75	198	ND	0-	67.7	ND	0-	74.5	.075	0-	69.0	ND	0-	70.5	.024	0.041
	9.75 -	60.5	0.039													
Total Suspended Solids	0 - 9.75	---	398	0-	---	1310	0-	---	7400	0-	---	7660	0-	---	1200	---
	9.75 -	---	916													

J = Result is detected below the reporting limit or is an estimated concentration.
L = The components are not separable and are therefore quantified together.

ND = Not detected
--- = No sample data

Table 5-19 Chemical test results of sediment cores collected in channel bends P and Q (vicinity of Killcobook, NJ) of the existing Delaware River, Philadelphia to the sea navigation channel.
All values reported as parts per million.

	PQ1			PQ2			WS6
	Depth	Total	Elutriate	Depth	Total	Elutriate	Total
Pyrene	0-1.75	.053J	ND	0-2	.870J	ND	ND
	1.75-8.5	ND	ND	2-17.5	ND	ND	
	8.5-	ND	ND	17.5-	ND	ND	
Benzo(a)pyrene	0-1.75	ND	ND	0-2	.490J	ND	ND
	1.75-8.5	.220J	ND	2-17.5	.200J	ND	
	8.5-	.057J	ND	17.5-	.170J	ND	
Indeno(1,2,3-cd)pyrene	0-1.75	ND	ND	0-2	0.470J	ND	ND
	1.75-8.5	ND	ND	2-17.5	ND	ND	
	8.5-	ND	ND	17.5-	ND	ND	
chrysene	0-1.75	.050J	ND	0-2	.620J	ND	ND
	1.75-8.5	ND	ND	2-17.5	ND	ND	
	8.5-	ND	ND	17.5-	ND	ND	
Naphthalene	0-1.75	ND	ND	0-2	.420J	ND	ND
	1.75-8.5	ND	ND	2-17.5	ND	ND	
	8.5-	ND	ND	17.5-	ND	ND	
Phenanthrene	0-1.75	ND	ND	0-2	0.650J	ND	ND
	1.75-8.5	ND	ND	2-17.5	ND	ND	
	8.5-	ND	ND	17.5-	ND	ND	
Fluoranthene	0-1.75	ND	ND	0-2	0.850J	ND	ND
	1.75-8.5	ND	ND	2-17.5	ND	ND	
	8.5-	ND	ND	17.5-	ND	ND	
Benzo(b)fluoranthene	0-1.75	ND	ND	0-2	0.820JL	ND	ND
	1.75-8.5	ND	ND	2-17.5	ND	ND	
	8.5-	ND	ND	17.5-	ND	ND	
Benzo(k)fluoranthene	0-1.75	ND	ND	0-2	0.820JL	ND	ND
	1.75-8.5	ND	ND	2-17.5	ND	ND	
	8.5-	ND	ND	17.5-	ND	ND	
Benzo(g,h,i)perylene	0-1.75	ND	ND	0-2	0.530J	ND	ND
	1.75-8.5	ND	ND	2-17.5	ND	ND	
	8.5-	ND	ND	17.5-	ND	ND	
Antimony	0-1.75	1.8	ND	0-2	3.8	ND	ND
	1.75-8.5	5.6	ND	2-17.5	2.5	ND	
	8.5-	1.7	ND	17.5-	1.5	ND	
Arsenic	0-1.75	3.7	.044	0-2	52.8I	.053	.0057
	1.75-8.5	9.4	.011	2-17.5	7.1	.040	
	8.5-	3.9	.028	17.5-	1.0	.057	
Beryllium	0-1.75	0.34	ND	0-2	1.5	ND	ND
	1.75-8.5	1.1	ND	2-17.5	.81	ND	
	8.5-	0.35	ND	17.5-	.10	ND	
Cadmium	0-1.75	0.30	ND	0-2	2.6	ND	ND
	1.75-8.5	0.29	ND	2-17.5	.20	ND	
	8.5-	0.091	ND	17.5-	1.2	ND	
Chromium	0-1.75	13.1	ND	0-2	145	ND	ND
	1.75-8.5	42.3	ND	2-17.5	31.1	ND	
	8.5-	11.7	ND	17.5-	7.4	ND	
Copper	0-1.75	6.6	ND	0-2	131	ND	.022
	1.75-8.5	10.0	ND	2-17.5	11.3	ND	
	8.5-	4.9	ND	17.5-	1.9	ND	
Lead	0-1.75	17.1	ND	0-2	173	ND	.010
	1.75-8.5	11.4	ND	2-17.5	10.3	ND	
	8.5-	4.1	ND	17.5-	2.9	ND	
Mercury	0-1.75	ND	ND	0-2	1.4	ND	ND
	1.75-8.5	ND	ND	2-17.5	ND	ND	
	8.5-	ND	ND	17.5-	ND	ND	
Nickel	0-1.75	8.2	ND	0-2	29.7	ND	ND
	1.75-8.5	20.5	ND	2-17.5	17.2	ND	
	8.5-	7.5	ND	17.5-	5.5	ND	
Selenium	0-1.75	ND	ND	0-2	3.06	ND	ND
	1.75-8.5	ND	ND	2-17.5	ND	ND	
	8.5-	ND	ND	17.5-	ND	ND	
Zinc	0-1.75	74.3	ND	0-2	630	ND	.052
	1.75-8.5	60.8	ND	2-17.5	49.3	ND	
	8.5-	22.2	ND	17.5-	8.5	.15	
Total Suspended Solids	0-1.75	—	5	0-2	—	18	—
	1.75-8.5	—	7	2-17.5	—	13	
	8.5-	—	6	17.5-	—	5	

Note : I = Analyte present at a concentration above the calibratrion range, therefore a dilution of the sample was required & reporting limits were decreased
J = results detected below the reporting limit or is an estimated concentration
L = These components are not separable using this mehtod and are therefore quantified together
S = Reported value determined by method of standard addition

ND = Not detected
— = No sample data

Table 5-20 Chemical test results of sediment cores collected in channel bends R, S and T (located between the mouth of the Salem River, NJ and Artificial Island, NJ) of the existing Delaware River, Philadelphia to the sea navigation channel. All values reported as parts per million.

	R1			S1			T1			W57
	Depth	Total	Elutriate	Depth	Total	Elutriate	Depth	Total	Elutriate	Total
Benzo(a)pyrene	0-	.330J	ND	0-8.75	.370	ND	0-	.350	ND	ND
				8.75-14.67	ND	ND				
				14.67-	.070J	ND				
Phenanthrene	0-	ND	ND	0-8.75	ND	ND	0-	ND	ND	ND
				8.75-14.67	ND	ND				
				14.67-	.092J	ND				
Anthracene	0-	ND	ND	0-8.75	ND	ND	0-	ND	ND	ND
				8.75-14.67	ND	ND				
				14.67-	.046J	ND				
Fluoranthene	0-	ND	ND	0-8.75	ND	ND	0-	.110J	ND	ND
				8.75-14.67	ND	ND				
				14.67-	.069J	ND				
Pyrene	0-	ND	ND	0-8.75	ND	ND	0-	.120J	ND	ND
				8.75-14.67	ND	ND				
				14.67-	.095J	ND				
Benzo(a)anthracene	0-	ND	ND	0-8.75	ND	ND	0-	.110J	ND	ND
				8.75-14.67	ND	ND				
				14.67-	.098J	ND				
chrysene	0-	ND	ND	0-8.75	ND	ND	0-	.088J	ND	ND
				8.75-14.67	ND	ND				
				14.67-	.095J	ND				
Benzo(b)fluoranthene	0-	ND	ND	0-8.75	ND	ND	0-	.069J	ND	ND
				8.75-14.67	ND	ND				
				14.67-	.082J	ND				
Benzo(k)fluoranthene	0-	ND	ND	0-8.75	ND	ND	0-	.080J	ND	ND
				8.75-14.67	ND	ND				
				14.67-	.082J	ND				
Dibenz(a,h)anthracene	0-	ND	ND	0-8.75	ND	ND	0-	ND	ND	ND
				8.75-14.67	ND	ND				
				14.67-	.082J	ND				
Benzo(g,h,i)perylene	0-	ND	ND	0-8.75	ND	ND	0-	ND	ND	ND
				8.75-14.67	ND	ND				
				14.67-	.063J	ND				
Indeno(1,2,3-cd)pyrene	0-	ND	ND	0-8.75	ND	ND	0-	ND	ND	ND
				8.75-14.67	ND	ND				
				14.67-	.081J	ND				
Antimony	0-	ND	ND	0-8.75	6.5	ND	0-	ND	ND	ND
				8.75-14.67	4.6	ND				
				14.67-	1.1	ND				
Arsenic	0-	15.8	.027	0-8.75	13.0	ND	0-	12.6	.033	.0091
				8.75-14.67	17.5	ND				
				14.67-	2.8	ND				
Beryllium	0-	1.5	ND	0-8.75	1.4	ND	0-	1.4	ND	ND
				8.75-14.67	1.2	ND				
				14.67-	0.30	ND				
Cadmium	0-	0.36	ND	0-8.75	.35	ND	0-	ND	ND	ND
				8.75-14.67	ND	ND				
				14.67-	ND	ND				
Chromium	0-	60.6	ND	0-8.75	55.6	ND	0-	56.4	ND	ND
				8.75-14.67	46.3	ND				
				14.67-	10.8	ND				
Copper	0-	14.6	ND	0-8.75	13.7	ND	0-	14.2	ND	ND
				8.75-14.67	11.9	ND				
				14.67-	5.4	ND				
Lead	0-	12.0	ND	0-8.75	13.8	ND	0-	12.0	ND	.0071
				8.75-14.67	10.6	ND				
				14.67-	3.5	ND				
Nickel	0-	31.0	ND	0-8.75	29.2	ND	0-	30.2	ND	ND
				8.75-14.67	30.6	ND				
				14.67-	7.2	ND				
Zinc	0-	82.6	ND	0-8.75	79.2	ND	0-	77.4	ND	.026
				8.75-14.67	73.0	ND				
				14.67-	17.2	ND				
Total Suspended Solids	0-	—	164	0-8.75	—	16	0-	—	11	—
				8.75-14.67	—	800				
				14.67-	—	7				

Note : J = results detected below the reporting limit or is an estimated concentration

ND = Not detected

— = No sample data

Table 5-21 Chemical test results of sediment cores collected in channel bends U, V and W (Delaware Bay) of the existing Delaware River, Philadelphia to the sea navigation channel. All values reported as parts per million.

	U1			V1			W1			WS8
	DEPTH	TOTAL	ELUTRIATE	DEPTH	TOTAL	ELUTRIATE	DEPTH	TOTAL	ELUTRIATE	TOTAL
Fluoranthene	0 - 4.25	ND	ND	0 - 4.5	ND	ND	0 - 3	ND	0.003	
	4.25 -	ND	ND	4.5-15.5	ND	ND	3 - 17.75	ND	ND	ND
				15.5-	ND	ND				
Pyrene	0 - 4.25	ND	ND	0 - 4.5	ND	ND	0 - 3	ND	0.003	
	4.25 -	ND	ND	4.5-15.5	ND	ND	3 - 17.75	ND	ND	ND
				15.5-	ND	ND				
Chrysene	0 - 4.25	ND	ND	0 - 4.5	ND	ND	0 - 3	ND	0.003	
	4.25 -	ND	ND	4.5-15.5	ND	ND	3 - 17.75	ND	ND	ND
				15.5-	ND	ND				
Benzo(b)	0 - 4.25	ND	ND	0 - 4.5	ND	ND	0 - 3	ND	0.002	
fluoranthene	4.25 -	ND	ND	4.5-15.5	ND	ND	3 - 17.75	ND	ND	ND
				15.5-	ND	ND				
Benzo(k)	0 - 4.25	ND	ND	0 - 4.5	ND	ND	0 - 3	ND	0.002	
fluoranthene	4.25 -	ND	ND	4.5-15.5	ND	ND	3 - 17.75	ND	ND	ND
				15.5-	ND	ND				
Arsenic	0 - 4.25	6.5	0.21	0 - 4.5	2.5	0.20	0 - 3	2.2	0.22	
	4.25 -	1.5	0.22	4.5-15.5	5.9	0.20	3 - 17.75	0.75	0.21	0.35
				15.5-	3.4	0.19				
Beryllium	0 - 4.25	0.78	ND	0 - 4.5	ND	ND	0 - 3	ND	ND	
	4.25 -	ND	ND	4.5-15.5	0.84	ND	3 - 17.75	ND	ND	ND
				15.5-	ND	ND				
Chromium	0 - 4.25	38.4	ND	0 - 4.5	12.9	ND	0 - 3	6.0	ND	
	4.25 -	3.8	ND	4.5-15.5	39.6	ND	3 - 17.75	2.9	ND	ND
				15.5-	11.1	ND				
Copper	0 - 4.25	18.7	ND	0 - 4.5	6.4	ND	0 - 3	19.7	ND	
	4.25 -	4.1	ND	4.5-15.5	12.2	ND	3 - 17.75	9.0	ND	0.15
				15.5-	4.8	ND				
Lead	0 - 4.25	ND	ND	0 - 4.5	6.1	ND	0 - 3	ND	ND	
	4.25 -	ND	ND	4.5-15.5	7.7	ND	3 - 17.75	ND	ND	0.034
				15.5-	ND	ND				
Nickel	0 - 4.25	20.7	ND	0 - 4.5	5.6	ND	0 - 3	ND	ND	
	4.25 -	ND	ND	4.5-15.5	20.4	ND	3 - 17.75	ND	ND	ND
				15.5-	ND	ND				
Zinc	0 - 4.25	106	ND	0 - 4.5	48.2	ND	0 - 3	26.2	ND	
	4.25 -	9.8	ND	4.5-15.5	51.2	ND	3 - 17.75	13.3	ND	ND
				15.5-	11.3	ND				
Total	0 - 4.25	—	1080	0 - 4.5	—	62.0	0 - 3	—	270	
Suspended	4.25 -	—	282	4.5-15.5	—	237	3 - 17.75	—	238	—
Solids				15.5-	—	57.0				

ND = Not detected
--- = No sample data

Table 5-22
Grain Size Analyses of Sediment Cores Collected
in the Sea Navigation Channel

DRV Location	Sample No.	Depth in Ft.	Description	Symbols	%		
					Gravel	Sand	Fines
1	1	0-1.0	Grey fine to medium SAND	SP	4	94	2
	2	1.0-4.3	Grey sandy GRAVEL	GP	90	10	0
	3	6.3-10.0	Grey medium SAND	SP	0	97	3
	4	10.0-14.7	Grey medium SAND	SP	1	93	6
	5	14.0-18.0	Grey fine to medium SAND	SP	5	92	3
2	1	1.0-2.3	Grey silty SAND	SM-SP	1	71	28
	2	2.3-4.4	Grey fine to medium SAND	SP	3	96	1
	3	4.4-8.2	Grey CLAY w/Gravel layers*	GP*	62	26	12
	4	8.8-10.0	Grey gravelly SAND	SP	22	74	4
	5	12.4-16.0	Dk. grey sandy SILT	ML	0	45	55
3	1	0.4-5.0	Brown sandy coarse to fine GRAVEL	GP	50	49	1
	2	7.9-9.1	Brown fine to medium SAND	SP	7	91	2
	3	11.0-15.0	Brown fine to coarse GRAVEL	GW	60	40	0
	4	15.0-19.5	Brown gravelly SAND	SP	30	68	2
4	1	0.7-2.6	Brown silty SAND	SM	0	61	39
5	1	0.0-1.7	Dk. grey fine SAND	SP	0	91	9
6	1	0.0-5.0	DK grey SILT (Sand lenses)*	ML	0	83*	17
	2	7.1-10.0	Grey SILT (Sand lenses)*	ML	0	60*	40
	3	11.6-15.0	Red-Brown fine to med SAND & GRAVEL	SP-GP	45	52	3
	4	15.0-19.5	Brown gravelly SAND	SP	42	55	3
7	1	1.3-3.7	Sandy GRAVEL	GP	-	-	-
8	1	0.0-5.0	Grey silty CLAY (w/f. Sand lenses)*	CL	0	65*	35
	2	5.0-10.0	Grey silt w/fine SAND lenses	ML	0	52	48
	3	10.0-15.0	Grey sandy CLAY	CL	0	36	64
9	1	0-5.0	Grey silty CLAY* (w/few f. Sand pockets)	CL	0	55*	45
	2	5.5-11.0	Grey silty CLAY	CL	0	43	57
	3	12.3-16.0	Grey silty CLAY	CL	0	62*	48
10	1	0.0-5.0	Grey silty CLAY (w/f. Sand layers)*	CL	0	59*	41
	2	5.0-10.0	Grey silty CLAY (" ")*	CL	0	67*	33
	3	13.3-15.0	Grey silty clay (Interbedded SAND)*	CL	0	80*	20
11	1	0.0-5.0	Grey clayey SILT (w/f. Sand lenses)*	ML	0	73*	27
	2	5.0-10.0	Grey clayey SILT (w/f. Sand Lenses)*	ML	0	70*	30
	3	10.0-15.0	Grey clayey SILT (w/f. Sand Lenses)*	ML	0	59*	41
	4	15.0-19.0	Grey clayey SILT (w/f Sand Lenses)*	ML	0	76*	24
12	1	0.0-5.0	Grey clayey SILT (w/f. sand lenses)*	ML	0	58*	42
	2	8.9-10.0	Grey clayey SILT (w/f. Sand lenses)*	ML	0	71*	29
	3	10.0-15.0	Grey clayey SILT (w/f. Sand lenses)*	ML	0	61*	39
	4	15.0-17.0	Grey sandy SILT	ML	0	47	53
13	1	0.0-5.0	Grey CLAY w/sand faces *	CL	0	73*	27
	2	5.0-9.2	Grey CLAY	CH	0	14	86
	3	10.0-12.4	Grey silty SAND	SP	2	93	5
	4	12.4-15.0	Grey gravelly SAND	SP	47	53	0
	5	17.1-20.0	Grey fine to medium SAND w/ some silt	SP	0	87	13
14	1	0.0-5.0	Grey silty CLAY (w/sand faces)*	CH	0	64*	36
	2	7.4-10.0	Grey firm CLAY	CH	0	14	86
	3	12.2-15.0	Grey firm CLAY	CL	0	25	75

Table 5-22
Grain Size Analyses of Sediment Cores Collected
in the Sea Navigation Channel

DAV Location	Sample No.	Depth in Ft.	Description	Symbols	%		
					Gravel	Sand	Fines
	4	15.0-20.0	Grey CLAY (w/sand lenses)*	CL	0	52*	48
15	1	0.0-3.4	Brown medium SAND	SP	0	98	2
	2	3.4-5.0	Brown gravelly fine to coarse SAND	SP	30	69	1
	3	7.5-9.2	Orange fine SAND w/ trace silt	SP	2	88	10
	4	10.8-14.0	Orange & Lt. grey silty SAND w/organic pods	SP	7	90	3
16	1	0.0-5.0	Dk. grey sandy SILT (w/sand lenses)*	ML	0	66*	34
	2	5.0-10.0	Dk. grey sandy SILT	ML	0	36	64
	3	10.0-15.0	Dk. grey SILT (w/sand lenses)*	ML	0	63*	37
	4	5.0-19.0	Dk. grey SILT	ML	0	33	67
17	1	0.0-1.2	Brown fine to medium gravelly SAND	SP	33	65	2
	2	1.2-2.4	Grey silty SAND	SM	0	58	42
	3	2.4-3.7	Grey fine SAND w/trace silt	SM	0	88	12
	4	3.7-10.0	Grey SILT (w/sand & shell layers)*	ML	0	75	25
18	1	0.0-4.1	Grey fine SAND	SP	0	97	3
	2	5.2-9.1	Grey sandy GRAVEL	GP	55	43	2
	3	9.1-10.0	Grey fine SAND w/trace silt	SM	0	88	12
	4	10.7-11.7	Grey silty fine SAND w/some gravel	SP	15	65	20
19	1	0.0-2.1	Grey sandy SILT (sand lenses)*	ML	0	85*	15
	2	2.1-5.0	Grey CLAY (w/sand lenses)*	CL	0	50	50
	3	5.0-10.0	Grey CLAY (w/sand lenses)*	CL	2	80*	18
	4	11.0-15.0	Grey CLAY (w/sand & shell layers)*	CL	0	66*	34
	5	15.7-16.7	Grey gravelly SAND	SP	26	68*	6
20	1	1.1-5.0	Brown fine to medium SAND	SP	0	96	4
	2	8.1-10.0	Grey fine SAND	SP	0	86	14
	3	13.4-15.0	Grey fine SAND	SP	0	78	22
	4	15.9-20.0	Dk. Grey CLAY	CL	-	-	-
21	1	0.0-4.3	Red-Brown medium SAND	SP	18	80	2
	2	4.3-5.7	Dk. grey silty SAND *	SM	1	96*	3
	3	5.7-10.0	Dk. grey silty SAND	SM	0	80	20
	4	10.0-14.0	Dk. grey CLAY (w/sand layers)*	CL	0	71	29
22	1	0.0-1.0	Coarse gravelly SAND	SP	40	60	0
	2	1.6-5.3	Dk. grey sandy SILT	ML	0	35	65
	3	7.0-9.2	Dk. grey sandy SILT	ML	0	24	76
23	1	0.0-3.7	Light grey fine SAND	SP	0	94	6
	2	3.7-5.0	Sandy GRAVEL	GP	57	41	2
	3	8.3-9.2	Red Brown CLAY	CL	0	22	78
	4	9.2-13.0	Grey clayey SILT (w/sand layer)*	ML	0	60*	40
24	1	0.0-3.0	Dk. grey fine to medium SAND	SP	0	97	3
	2	5.0-10.0	Lt. grey fine to medium SAND	SP	2	97	1
	3	11.6-13.6	Grey fine to medium SAND	SP	0	98	2
	4	13.6-15.6	Grey gravelly SAND	SP	27	71	2
25	1	0.0-5.0	Brown medium SAND	SP	0	97	3
	2	5.0-7.8	Brown fine to medium SAND	SP	0	95	5
	3	7.8-10.0	Grey fine SAND	SP	0	96	4
	4	10.0-15.0	Grey medium SAND	SP	0	97	3
	5	16.7-17.5	Grey gravelly SAND	SP	38	61	1

Table 5-22
Grain Size Analyses of Sediment Cores Collected in the Sea Navigation Channel

DEV Location	Sample No.	Depth in Ft.	Description	Symbols	%		
					Gravel	Sand	Fines
	6	17.5-20.0	Dk. grey SILT	ML	0	16	84
26	1	0.0-5.0	Grey fine to medium SAND	SP	0	95	5
	2	8.3-10.0	Red-Brown SAND	SP	0	95	5
	3	12.0-14.6	Dk. grey SILT	ML	0	44	56
	4	14.6-16.0	Red Brown sandy SILT*	ML	0	75*	25
27	1	0.0-0.8	Brown fine SAND	SP	0	97	3
	2	1.8-5.0	Grey sandy SILT (sand lenses)*	ML	0	91*	9
	3	7.2-10.0	Grey sandy SILT (sand lenses)*	ML	0	75*	25
	4	11.3-15.0	Brown silty SAND *	SM	0	95	5
	5	15.0-16.5	White fine to medium SAND	SP	0	96	4
	6	16.5-18.0	Yellow-brown fine SAND	SP	0	94	6
28	1	1.0-5.0	Grey silty SAND*	SM	0	99	1
	2	5.0-10.0	Grey silty SAND	SM	0	85	15
	3	10.0-16.5	Grey sandy SILT	ML	0	45	55
29	1	0.0-1.8	Brown & black sandy* SILT	ML	0	92*	8
	2	1.9-5.0	Black sandy* SILT	ML	0	91*	9
	3	7.7-10.0	Brown sandy* SILT	ML	0	94*	6
	4	10.4-15.0	Black sandy* SILT	ML	0	96	4
	5	15.0-20.0	Black sandy* SILT	ML	0	93	7

*Granular portion of sample analyzed

Table 5-23
Grain Size Analyses of Sediment Cores Collected
in Channel Bend Widening Locations along the Delaware River,
Philadelphia to the Sea Navigation Channel

Bend Location	Sample No.	Depth in Ft.	Description	Symbols	%		
					Gravel	Sand	Fines
AF-1	1	2.2	Dk. grey organic SILT w/some sand	OL	0	28	72
	2	6.6	Dk. grey sandy SILT	ML	0	30	70
	3	10.0	Dk. grey sandy CLAY	CL	0	47	53
	4	13.1	Dk. grey sandy SILT	ML	0	42	58
AF-2	1	2.5	Dk. grey sandy organic SILT	OL	0	37	63
	2	7.5	Dk. grey silty SAND	SM	0	54	46
	3	12.5	Dk. grey sandy SILT	ML	0	25	75
AF-3	1	2.5	Dk. grey silty SAND	SM	0	55	45
	2	7.5	Dk. grey sandy organic CLAY	OL	0	34	66
	3	12.5	Dk. grey silty SAND	SM	0	56	44
	4	14.0	Gravelly SAND w/trace silt	SP	33	55	12
G-1	1	1.0	Olive fine to medium SAND	SP	2	97	1
	2	5.0	Dk. grey sandy SILT	ML	0	36	64
	3	10.0	Dk. grey organic SILT	OH	0	0	100
	4	15.0	Dk. grey organic SILT	OH	0	2	98
	5	18.5	Dk. grey organic SILT	OH	0	2	98
	6	20.0	Grey medium gravelly SAND	SP	32	62	6
G-2	1	1.0	Dk. grey silty SAND	SM	0	74	26
	2	5.0	Dk. grey organic SILT	OH	0	8	92
	3	10.0	Dk. grey organic SILT	OH	0	7	93
	4	19.5	Dk. grey SILT w/some organic sand	ML	0	20	80
G-3	1	1.0	Black organic Clay w/some sand	OH	0	27	73
	2	2.5	Black sandy organic SILT	OL	0	34	66
	3	5.0	Dk. grey organic CLAY w/some sand	OH	0	22	78
	4	10.0	Dk. grey fine SAND (layer)	SP	0	93	7
	5	15.0	DK. grey silty SAND	SM	0	54	46
	6	19.0	Dk. grey clayey SAND	SC	0	53	47
G-4	1	0.2	Dk. grey organic CLAY	OH	0	7	93
	2	5.0	Dk. grey organic SILT	OH	0	4	96
	3	10.0	Dk. grey organic SILT	OH	0	12	88
	4	15.0	Dk. grey organic SILT	OH	0	10	90
	5	19.5	Dk. grey sandy SILT	OL	0	29	71
G-5	1	1.0	Dk. grey SILT w/some sand	OL	0	23	77
	2	5.0	Dk. grey organic SILT	OH	0	8	92
	3	10.0	Dk. grey organic SILT w/some sand	OH	0	15	85
	4	15.0	Dk. grey organic SILT w/some sand	OH	0	22	78
	5	19.5	Dk. grey organic SILT	OH	0	6	94
H-1	1	2.0	Grey SAND w/some gravel	SP	15	83	2
	2	5.0	Grey fine to coarse SAND	SW	11	87	2
	3	10.0	Grey gravelly SAND	SP	25	75	0
	4	15.0	Dk. grey medium SAND	SP	5	90	5
	5	17.0	Dk grey sandy SILT	ML	0	44	56

Table 5-23
Grain Size Analyses of Sediment Cores Collected
in Channel Bend Widening Locations along the Delaware River,
Philadelphia to the Sea Navigation Channel

Bend Location	Sample No.	Depth in Ft.	Description	Symbols	%		
					Gravel	Sand	Fines
	6	19.0	Grey fine to coarse SAND	SW	10	86	4
I-1	1	1.0	Dk. grey fine SAND	SP	0	96	4
	2	5.0	Dk. grey sandy SILT	ML	0	45	55
	3	10.0	Dk. grey organic SILT	OH	0	5	95
	4	15.0	Dk. grey organic SILT	OH	0	2	98
	5	19.0	Dk. grey organic SILT	OH	0	12	88
I-2	1	0.5	Yellow-brown medium SAND	SP	4	93	3
	2	3.0	Dk. grey sandy SILT	ML	0	40	60
	3	5.0	Dk. grey organic SILT w/some sand	OH	0	18	82
	4	10.0	Dk. grey sandy CLAY	CL	0	23	77
	5	15.0	Dk. grey organic CLAY	OH	0	4	96
J-1	1	1.0	Dk. grey silty SAND	SP	0	81	19
	2	5.0	Dk. grey fine SAND	SP	0	88	12
	3	10.0	Dk, grey sandy SILT	OH	0	29	71
	4	15.0	Dk. grey organic SILT	OH	0	3	97
	5	19.0	Dk. grey organic SILT	OH	0	4	96
J-2	1	1.0	DK. grey silty SAND	SM	0	67	33
	2	5.0	Dk. grey sandy organic SILT	OH	0	31	69
	3	10.0	Dk. grey organic SILT	OH	0	3	97
	4	15.0	Dk. grey organic SILT	OH	0	2	98
	5	20.0	Dk. grey CLAY	CH	0	3	97
K-1	1	1.0	Dk. grey CLAY w/some sand	CH	0	16	84
	2	5.0	Dk. grey sandy CLAY	CH	0	26	74
	3	10.0	Dk. grey CLAY	CH	0	9	91
	4	15.0	Dk. grey CLAY	CH	0	13	87
	5	20.0	Dk. grey organic SILT	OH	0	1	99
L-1	1	2.5	DK. grey organic SILT	OH	0	13	87
	2	7.5	Dk. grey organic SILT	OH	0	10	90
	3	12.5	Dk. grey sandy organic SILT	OH	0	31	69
M-1	1	1.0	Dk. grey SILT w/some sand	MH	0	17	83
	2	5.0	Dk. grey sandy SILT	ML	0	50	50
	3	10.0	Dk. grey CLAY	CH	0	5	95
	4	15.0	Dk. grey CLAY	CH	0	2	98
	5	18.0	Dk. grey organic SILT	OH	0	2	98
M-2	1	1.0	Dk. grey CLAY	CH	0	2	98
	2	5.0	Dk. grey CLAY	CH	0	4	96
	3	10.0	Dk. grey CLAY	CH	0	6	94
	4	15.0	Dk. grey gravelly CLAY	CL	25	12	63
	5	18.0	Dk. grey CLAY	CL	0	7	93
N-1	1	1.0	Dk. grey organic SILT	OH	0	4	96
	2	5.0	Dk. grey organic SILT	OH	0	3	97
	3	10.0	Dk. grey organic SILT	OH	0	1	99

Table 5-23
Grain Size Analyses of Sediment Cores Collected
in Channel Bend Widening Locations along the Delaware River,
Philadelphia to the Sea Navigation Channel

Bend Location	Sample No.	Depth in Ft.	Description	Symbols	%		
					Gravel	Sand	Fines
	4	15.0	Dk. grey organic SILT	OH	0	5	95
	5	19.0	Dk. grey organic SILT	OH	0	2	98
O-1	1	1.0	Dk. grey organic CLAY	OH	0	2	98
	2	5.0	Dk. grey organic CLAY	OH	0	2	98
	3	10.0	Dk. grey organic CLAY	OH	0	5	95
	4	15.0	Dk. grey organic SILT	OH	0	3	97
	5	20.0	Dk. grey organic CLAY	OH	0	11	89
O-2	1	1.0	Dk. grey organic CLAY	OH	0	2	98
	2	5.0	Dk. grey organic CLAY	OH	0	2	98
	3	10.0	Dk. grey organic CLAY	OH	0	5	95
	4	15.0	Dk. grey organic CLAY	OH	0	4	96
	5	20.0	Dk. grey organic SILT	OH	0	4	96
PQ-1	1	1.0	Black fine to medium SAND	SP	0	97	3
	2	3.0	Dk. grey sandy organic CLAY	OH	0	32	68
	3	8.0	Dk. grey organic CLAY w/some sand	OH	0	17	83
	4	10.0	Dk. grey fine to medium SAND	SP	0	94	6
	5	15.0	Dk. grey fine to medium SAND	SP	8	87	5
	6	19.0	Olive grey med SAND w/some gravel	SP	23	72	5
PQ-2	1	1.0	Black CLAY w/some sand	OH	0	20	80
	2	5.0	Dk. grey SILT w/some sand	ML	0	21	79
	3	10.0	Dk. grey fine SAND lense	SP	0	92	8
	4	15.0	Dk. grey organic CLAY	OH	0	8	92
	5	18.0	Olive-yellow SAND w/some gravel	SP	11	85	4
R-1	1	1.0	Dk. grey organic CLAY	OH	0	3	97
	2	5.0	Dk. grey organic CLAY	OH	0	1	99
	3	10.0	Dk. grey organic CLAY	OH	0	0	100
	4	15.0	Dk. grey organic CLAY	OH	0	0	100
	5	18.5	Dk. grey organic CLAY	OH	0	0	100
S-1	1	1.0	Dk. grey organic CLAY	OH	0	7	93
	2	5.0	Dk. grey organic CLAY	OH	0	3	97
	3	10.0	Dk. grey organic SILT	OH	0	9	91
	4	14.0	Dk. grey organic CLAY	OH	0	8	92
	5	16.0	Dk. grey sandy GRAVEL	GP	52	43	5
	6	19.0	Dk. grey sandy GRAVEL	GP	53	44	3
T-1	1	1.0	Dk. grey organic CLAY	OH	0	2	98
	2	5.0	Dk. grey organic CLAY	OH	0	0	100
	3	10.0	Dk. grey organic CLAY	OH	0	1	99
	4	15.0	Dk. grey organic CLAY	OH	0	0	100
	5	18.0	Dk. grey organic CLAY	OH	0	2	98
U-1	1	2.0	Dk. grey organic CLAY	OH	0	2	98
	2	5.0	Olive fine to medium SAND	SP	0	96	4
	3	10.0	Olive-yellow medium SAND	SP	0	100	0

Table 5-23
Grain Size Analyses of Sediment Cores Collected
in Channel Bend Widening Locations along the Delaware River,
Philadelphia to the Sea Navigation Channel

Bend Location	Sample No.	Depth in Ft.	Description	Symbols	%		
					Gravel	Sand	Fines
	4	13.5	Olive-yellow medium SAND	SP	0	98	2
	5	15.1	Dk. brown medium SAND	SP	0	98	2
V-1	1	0.5	Black fine to medium SAND	SP	0	93	7
	2	5.0	Dk. grey organic CLAY	OH	0	6	94
	3	10.0	Dk. grey sandy CLAY	CL	0	37	63
	4	15.0	Dk. grey sandy organic CLAY	OH	0	43	57
	5	16.5	Dk. grey silty SAND	SM	7	67	26
	6	19.5	Pale Olive medium SAND	SP	0	94	6
W-1	1	1.5	Black fine SAND	SP	0	93	7
	2	4.5	Lt. grey fine SAND w/some silt	SP	0	83	17
	3	9.5	'Lt. grey fine SAND	SP	0	90	10
	4	14.5	Olive yellow fine SAND	SP	0	93	7
	5	17.2	Lt. Brown fine to Medium SAND	SP	0	92	8
	6	17.7	Grey sandy organic CLAY	OL	0	37	63

In order to evaluate the results of the chemical analyses, two sets of sediment criteria were considered. These criteria are currently used by the State of New Jersey, Department of Environmental Protection (NJDEP) to evaluate the potential hazard of soil contamination at project sites within New Jersey. It is recognized that these criteria have no regulatory authority behind them, and may not be used by other agencies for similar evaluations. In the absence of Federal or State standards for sediments, these criteria were employed to complete this evaluation. The first set of criteria are Interim NJDEP Soil Action Levels (Table 5-24). These criteria were derived by considering background concentrations, and selecting a multiple of the background concentration to ensure that groundwater concentrations would not violate drinking water standards (USFWS, 1990). These criteria are not necessarily cleanup objectives, higher concentrations may be allowed at certain sites (USFWS, 1990). The second set of criteria used by the NJDEP were initially developed to classify dredged sediments from the Great Lakes (Bowden, 1977). The criteria provide non-polluted, moderately polluted and heavily polluted concentration ranges for various contaminants (Table 5-25). The NJDEP uses these ranges to consider if special handling requirements are necessary for the disposal of sediments. A sediment with a chemical constituent in the heavily polluted range, but below the Interim NJDEP Soil Action Level, may not be acceptable fill material. The NJDEP has indicated in previous coordination efforts that this type of material would be more appropriate for a Corps dredged material disposal site.

Polychlorinated Biphenyls (PCB's): All sediment samples collected in the channel and from channel bend widening locations were analyzed for the presence of PCB's. Sample DRV-8, collected in the Bellevue Range of the channel (Reach B), was the only sample where PCB's were detected. PCB arochlors 1254 and 1248 were detected, at a combined concentration of 1.72 part per million (ppm). PCB's were not detected in the sediment elutriate. The Interim NJDEP Soil Action Level for PCB's is set at 1-5 ppm. Past coordination with the NJDEP with respect to PCB's has indicated that concern is raised above the 5 ppm level. The EPA, 1977 criteria lists total PCB's as heavily polluted at a concentration of 10 ppm. No values are provided for non-polluted or moderately polluted.

Pesticides: All samples collected in the channel and from channel bend widening locations were analyzed for the presence of pesticides. Heptachlor epoxide, malathion and endosulfan were the only pesticides detected. In Reach A, heptachlor epoxide was detected in one bulk sample (DRV-2) collected in the vicinity of Mantua Creek, NJ. The total concentration of 0.055 ppm is below the Interim NJDEP Soil Action Levels for pesticides, which are at 1 ppm or higher. Heptachlor epoxide was not detected in the sediment elutriate for that sample. Malathion and endosulfan were both detected in Reach B. Malathion was detected in the sediment elutriates for DRV-5 (Marcus Hook Range) and DRV-8 (Bellevue Range) at concentrations of 0.0063 and 0.0026 ppm, respectively. Malathion was not detected in direct analysis of these sediment samples. Endosulfan was also detected in the sediment of the Bellevue Range (DRV-8) at a concentration of 0.59 ppm. A second observation of endosulfan was in channel bend M, located between the Marcus Hook and Bellevue Ranges. The sediment elutriate from sample M1 had an endosulfan concentration of 0.006 ppm. Endosulfan was not detected in direct analysis of this sediment sample. Pesticides were not detected in any other samples.

Table 5-24 INTERIM NJDEP SOIL ACTION LEVELS

Total Petroleum Hydrocarbons (TPHC)	100 ppm
Surrogate Levels:	
Acid Extractables (AE)	Case-by-Case
Base Neutrals (BN)	10 ppm
Volatile Organics (VOC)	1 ppm
Pesticides:	
DDT	1-10 ppm
Chlordane	1 ppm
Other	Case-by-Case
Polychlorinated Biphenyls (PCBs)	1-5 ppm
Polycyclic Aromatic Hydrocarbons (PAH)	10 ppm
Inorganics	
Antimony	10 ppm
Arsenic	20 ppm
Barium	400 ppm
Beryllium	1 ppm
Cadmium	3 ppm
Chromium	100 ppm
Copper	170 ppm
Lead	250-1,000 ppm
Nickel	100 ppm
Mercury	1 ppm
Molybdenum	1 ppm
Selenium	4 ppm
Silver	5 ppm
Thallium	5 ppm
Vanadium	100 ppm
Zinc	350 ppm

ppm = Parts per million (mg/kg)

Table 5-25 EPA SEDIMENT CLASSIFICATION CRITERIA OF 1977

PARAMETER	NONPOLLUTED	MODERATELY POLLUTED	HEAVILY POLLUTED
Volatile Solids	<5%	5% - 8%	>8%
COD	<40,000	40,000 - 80,000	>80,000
TKN	<1,000	1,000 - 2,000	>2,000
Oil & Grease (Hexane Solubles)	<1,000	1,000 - 2,000	>2,000
Lead	<40	40 - 60	>60
Zinc	<90	90 - 200	>200
Ammonia	<75	75 - 200	>200
Cyanide	<0.10	0.10 - 0.25	>0.25
Phosphorus	<420	420 - 650	>650
Iron	<17,000	17,000 - 25,000	>25,000
Nickel	<20	20 - 50	>50
Manganese	<300	300 - 500	>500
Arsenic	<3	3 - 8	>8
Cadmium	*	*	>6
Chromium	<25	25 - 75	>75
Barium	<20	20 - 60	>60
Copper	25	25 - 50	>50
Mercury			≥1
Total PCB			≥10

Note: All values in mg/kg weight unless otherwise noted

*Pollutional classification of sediments with total (PCB) between 1.0 and 10.0 mg/kg dry weight determined on case-by-case basis.

Source: International Joint Commission, Dredging Subcommittee. 1982. Guidelines and Register for Evaluation of Great Lakes Dredging Projects

Volatile Organics: Only four sediment cores were analyzed for volatile organics. These include three in the vicinity of the Philadelphia Naval Base (bend AF) and one in the vicinity of Raccoon Creek, NJ (bend L). The only volatile organic detected was methylene chloride. Methylene chloride was detected in all three samples collected in the vicinity of the Naval Base. Concentrations in sediments ranged between 0.774 and 0.875 ppm. Concentrations in sediment elutriates ranged between 0.009 and 0.030 ppm. The Interim NJDEP Soil Action Level for volatile organics is 1 ppm. This level was not exceeded.

Base Neutral Organics: The only base neutral organics detected in sediment samples were polynuclear aromatic hydrocarbons (PAH's) and phthalates. All sediment cores were analyzed for the presence of PAH's. They were not detected in any of the samples collected in the navigation channel. However, PAH's were detected in 11 of 28 channel bend samples. All PAH's listed in Table 5-6 were detected except acenaphtylene, fluorene and dibenzo (a,h) anthracene. The Interim NJDEP Soil Action Level for PAH's is 10 ppm. This concentration was exceeded in one sample. Sample I2, collected at the upstream end of Tinicum Island in Reach A, had a PAH concentration of 12.23 ppm in the top 1.25 feet of the sediment core. PAH's were not detected below this strata. Of the 10 remaining samples, six had a PAH concentration less than 1.0 ppm. The other four samples had concentrations ranging between 1.21 and 6.54 ppm. The only sample that had PAH's in the sediment elutriate was collected at channel bend W, located in Delaware Bay. Five separate PAH's were detected in this sample at a total concentration of 0.013 ppm. PAH's were not detected in direct analysis of that sediment sample.

Phthalates were only evaluated in the four cores that were analyzed for the full chemical parameter list provided in Table 5-7. Phthalates were found in all four samples. These samples included three collected in the vicinity of the Philadelphia Naval Base (bend AF), and one collected in the vicinity of Raccoon Creek, NJ (bend L). Bis (2-ethylhexyl) phthalate and di-n-butyl phthalate were the only two detected. These phthalates were detected in three sediment samples at concentrations ranging between 0.614 and 2.67 ppm, and three sediment elutriates at concentrations ranging between 0.015 and 0.134 ppm. The NJDEP Interim Soil Action Level for base neutral organics, which included phthalates, is 10 ppm.

Metals: All samples collected in the channel and from channel bend widening locations were analyzed for the presence of metals. As expected, various metals were widely distributed throughout all four reaches. Eight metals were found at concentrations that exceeded Interim NJDEP Soil Action Levels. These were antimony, arsenic, beryllium, cadmium, chromium, mercury, thallium and zinc. Antimony, thallium and beryllium were most frequently above Soil Action Levels. As such, these metals will be discussed separately from a reach by reach analysis.

The Interim NJDEP Soil Action Level for antimony is 10 ppm. This level was exceeded in 13 of 18 sediment cores collected in the channel. Antimony concentrations ranged between 7.5 and 32.0 ppm in Reaches A, B and C. The highest concentration was found in a sample collected in the vicinity of

Oldmans Creek, NJ. Concentrations in Reach C were lower than Reaches A and B, ranging between 12.5 and 19.0 ppm. Antimony was not found in Delaware Bay samples. Concentrations of antimony in channel bend samples were lower, ranging between 1.1 and 6.5 ppm. Antimony was not detected in any sediment elutriates.

Antimony is a silvery-white metal that is seldom found pure in nature. It predominately occurs as a sulfide or oxide. The metal is used for alloys and other metallurgical purposes. The salts, sulfides, oxides, chlorides and fluorides, are used in the rubber, plastic, textile, paint, ceramic, glass and dyeing industries. It's major applications is as a flame retardant for plastics and textiles. Some salts of antimony are soluble in water, however, the antimony tends to precipitate as an oxide that is insoluble in water. Antimony sulfides are also insoluble. As such, any dissolved antimony that is discharged to natural water soon precipitates, and is removed from the water column by sedimentation or adsorption. This held true in the Delaware River sampling, as no antimony was detected in sediment elutriates.

Beryllium has an Interim NJDEP Soil Action Level of 1 ppm. This concentration was exceeded in 14 of 46 cores with a range of 1.1 to 1.5 ppm. These concentrations were observed between Chester and Monds Islands (lower portion of Reach A) and Artificial Island (middle of Reach C). Concentrations in Delaware Bay (Reach D) were below 1 ppm. Beryllium was found in only three sediment elutriates, at a concentration of 0.01 ppm. All three of these were from Delaware Bay channel samples.

Thallium has an Interim NJDEP Soil Action Level of 5 ppm. Thallium was detected in six channel samples, at concentrations ranging between 5.5 and 10.5 ppm. Thallium was detected in Reaches B and C, between Oldmans Creek, NJ and Arnolds Point, NJ. The highest concentration (10.5 ppm) was detected in the vicinity of Artificial Island, NJ. Thallium was not detected in any channel bend samples, or in sediment elutriates.

Arsenic, cadmium, chromium and mercury were each above Interim NJDEP Soil Action Levels once. Zinc was above the Soil Action Level twice. Except for mercury, these metals will be addressed in a reach by reach discussion of metal content of sediments. Mercury will be discussed separately because it is a contaminant of concern.

Mercury was detected in 11 of 14 channel samples between the Philadelphia Naval Base and the Salem River, NJ (Reaches A-C). Concentrations ranged between 0.02 and 0.56 ppm. The highest sediment concentration of mercury was detected in the Bellevue Range of the channel (Reach B). This site also had the highest concentration of seven other metals. Mercury was also detected in sediment elutriates prepared from samples collected at Bellevue and near the mouth of the Salem River, NJ. Concentrations of mercury in sediment elutriates were 0.0003 and 0.0009 ppm.

Mercury was detected in three channel bend samples. Samples collected in the vicinity of the Philadelphia Naval Base and at the mouth of the Schuylkill River had concentrations of 0.359 and 0.671 ppm. One sample collected from channel bend PQ, located in the vicinity of Killcohook, NJ, had a mercury concentration of 1.4 ppm. The Interim NJDEP Soil Action Level for mercury is 1 ppm. Mercury was detected in the top two feet of sample PQ2. Two other strata located below the top two feet did not contain mercury. No mercury was found in sediment elutriates from channel bend samples.

Reach A: A total of 14 sediment cores were collected from channel bends in Reach A of the study area. Arsenic, cadmium and zinc were detected at concentrations above the Interim NJDEP Soil Action Levels. One sample in the vicinity of the Philadelphia Naval Base has an arsenic concentration of 26.6 ppm, which is above the Soil Action Level of 20 ppm. One of five samples taken at the mouth of the Schuylkill River had a cadmium concentration of 5.24 ppm and a zinc concentration of 607 ppm, which are above the Soil Action Levels of 3 and 350 ppm for cadmium and Zinc, respectively. These concentrations were detected in the top 1.75 feet of the G3 sediment core. At 3.25 feet of that core concentrations of cadmium and zinc dropped to non-polluted levels, based on the values provided in Table 5-25. The G3 cones also had concentrations of arsenic, chromium, copper, lead and nickel that were in the moderately and heavily polluted ranges. These levels were again found at the surface, with non-polluted levels found at 3.25 feet below the surface. The majority of core G3 and the other four cores collected in this area did not exhibit high concentrations of metals. Arsenic, chromium, copper, lead and nickel were found at moderately polluted levels at other sample locations within Reach A. Two cores had concentrations of zinc in the heavily polluted range.

Four cores were collected in the channel portion of Reach A. One sample collected in the vicinity of the Philadelphia Naval Base had an arsenic concentration of 4.15 ppm, which was in the moderately polluted range of 3-8 ppm. One sample collected in the vicinity of Mantua Creek, NJ had a zinc concentration of 95 ppm, which is in the moderately polluted range of 90-200 ppm. Concentrations of arsenic and zinc in other Reach A channel samples were within the non-polluted range.

Arsenic, cadmium, chromium, copper, lead, nickel and zinc were detected in sediment elutriates. Arsenic and cadmium were each detected once, at concentrations of 0.006 and 0.01 ppm, respectively. The remaining metals were detected more than once. Concentration ranges included chromium 0.028 to 0.18 ppm; copper 0.02 to 0.119 ppm; lead 0.01 to 0.127 ppm; nickel 0.042 to 0.66 ppm; and zinc 0.023 to 1.16 ppm.

Reach B: Twelve sediment cores were collected in Reach B of the project area. Six cores were from the channel, and six were from channel bend widening locations. Except for antimony, beryllium and thallium, no metals were above Interim NJDEP Soil Action Levels. Sample DRV-8, collected in the Bellevue Range of the channel, had the highest concentrations of eight metals detected in the channel. These metals were arsenic, beryllium, cadmium, chromium, copper, lead, mercury and zinc. Arsenic, chromium, nickel and zinc fell into the moderately polluted category, as defined by the values in Table 5-25.

Copper and lead fell into the heavily polluted category. Concentrations of zinc (115 ppm) in DRV-6 and nickel (24.5 ppm) in DRV-7 were also within the moderately polluted range. These samples were collected in the vicinity of Marcus Hook, PA and Oldmans Creek, NJ, respectively. These were the only other two metal readings in Reach B channel samples that were above non-polluted levels.

Arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc were detected in sediment elutriates from Reach B channel samples. Except for sample DRV-8, concentrations were all less than or equal to 0.1 ppm. Sample DRV-8 had the highest metal concentrations for all eight metals. It was also the only sample in Reach B where chromium, mercury and nickel were detected in sediment elutriates. Maximum concentrations for chromium, copper, lead, and zinc were 0.13, 0.13, 0.26 and 0.30 ppm, respectively.

Six cores were also collected in channel bend widening locations within Reach B. Arsenic, chromium, copper, lead, nickel and zinc had concentrations above non-polluted levels, according to values in Table 5-25. Arsenic was the only one with concentrations in the heavily polluted range (>8 ppm). Arsenic concentrations ranged from not detected to 13.2 ppm. Only arsenic and zinc were detected in sediment elutriates from channel bends. Arsenic was detected once at a concentration of 0.053 ppm. Zinc was detected twice at concentrations of 0.039 and 0.159 ppm.

Reach C: Nine sediment cores were collected in Reach C of the project area. Four of these cores were collected in the channel. Except for antimony and thallium, all metals were below Interim NJDEP Soil Action Levels. Sample DRV-11, collected in the vicinity of Killcohook, NJ, had a zinc concentration of 110 ppm, which is within the moderately polluted range according to the values provided in Table 5-25. Sample DRV-14, collected in the vicinity of Arnold Point, NJ, had an arsenic concentration of 3.32 ppm, which is also in the moderately polluted range. All other values were within non-polluted levels. Cadmium, copper, lead, mercury, nickel, silver and zinc were detected in sediment elutriates. Concentrations of metals in sediment elutriates were all below 0.07 ppm.

Five cores were collected in channel bends located in Reach C. Arsenic concentrations were in the heavily polluted range (>8 ppm) for all five cores. Chromium and nickel concentrations were in the moderately polluted range for all five cores. One core collected in the vicinity of Killcohook, NJ (PQ2) had high concentrations of several metals in the top two feet. The chromium concentration of 145 ppm, the zinc concentration of 630 ppm and the arsenic concentration of 52.8 ppm were above the Soil Action Levels of 100, 350 and 20 ppm, respectively. Below two feet, chromium, zinc and arsenic concentrations fell to 31.1, 49.3 and 7.1 ppm, respectively. The top strata of this core also had the only mercury concentration (1.4 ppm) above the Soil Action Level of 1 ppm. Copper and lead had concentrations in the heavily polluted range, while nickel was in the moderately polluted range. These concentrations again fell to non-polluted levels below the two-foot strata. Arsenic and zinc were the only elements detected in sediment elutriates from these five cores. Zinc was detected in one core at a concentration of 0.15 ppm. Arsenic was detected in four cores at concentrations ranging between 0.011 and 0.057 ppm.

Reach D: Four channel samples and three channel bend samples were collected in the Delaware Bay portion of the project area. Metal concentrations were all below Interim NJDEP Soil Action Levels. Concentrations of arsenic (3.4 to 6.5 ppm); chromium (38.4 to 39.6 ppm); nickel (20.4 to 20.7 ppm); and zinc (106 ppm) in channel bends U and V were within the moderately polluted range, based on values provided in Table 5-25. All other concentrations were within the non-polluted range.

Arsenic was the only contaminant detected in sediment elutriates prepared from channel bend samples. Concentrations ranged between 0.19 and 0.22 ppm. The concentration of arsenic in the water sample used to prepare the sediment elutriates was 0.35 ppm. The arsenic concentration in these sediment elutriates may not be directly attributable to sediment concentrations. Cadmium, copper, lead, nickel, silver and zinc were found in sediment elutriates from channel samples. Concentrations of cadmium, copper, lead, nickel and silver in the water sample used to prepare the sediment elutriates were within the range of concentrations found in the elutriates. Again, sediment elutriate concentrations may not be totally attributable to sediment concentrations. Zinc was not detected in the water sample used to prepare these sediment elutriates. Concentrations of zinc in the elutriates ranged between 0.04 and 0.09 ppm.

Two types of chemical quality concerns can be raised with regard to dredging and dredged material disposal operations. The first type of concern is long-term contamination problems associated with the dredged material disposal site. Placement of hazardous material in an unconfined situation can have a long-lasting impact on the surrounding environment. One potential impact is groundwater contamination, which is addressed in Section 5.1.1 of this EIS.

The second concern is potential water quality degradation arising from disturbance of bottom sediments, and ensuring impacts to aquatic biota. Aquatic ecosystems concentrate biological and chemical substances such as organic matter, nutrients, heavy metals and toxic chemical compounds in bottom sediments. When introduced to the water column, these substances tend to bind with suspended particulate matter and eventually settle to the bottom. Dredging operations typically elevate levels of suspended particulates in the water column through agitation of the sediment. Suspension of sediment exposes associated biological and chemical constituents to dissolved oxygen, which can result in a variety of chemical reactions. Adverse impacts to water quality may include oxygen depletion and the release of chemical substances, making them biologically available to aquatic organisms through ingestion or respiration.

It is generally believed that carefully designed and conducted dredging operations do not pose a significant adverse environmental threat primarily because dredging is a temporary localized phenomena that does not supply a persistent load of suspended sediment (DACE, 1983; Allen and Hardy, 1980). The turbidity associated with temporary dredging activities is usually less than the turbidity associated with natural flooding (Allen and Hardy, 1980). In addition, most rivers that are used for navigation are naturally turbid (Allen and Hardy, 1980).

The nature and magnitude of suspended material plumes at the dredging site vary with dredging technique, the character of the substrate, and the density and current regime. Studies have demonstrated that dredge-related suspended material plumes are localized phenomena with initial concentrations on the order of 500 to 1,000 mg/l/ Background concentrations are usually obtained within 500 to 1,000 m downstream from the source and 20 to 40 m perpendicular to the axis of the plume (Bohlen, 1978; USACE, 1980). Although hydraulic dredging operations will increase turbidity, hydraulic pipeline dredging has been demonstrated to induce the lowest near-and-far-field suspended material concentrations of the conventional dredging techniques. Additionally, studies indicate that optimum productivity of the hydraulic dredge also corresponds to minimum resuspension of bottom sediments. Other hydraulic pipeline dredging activities that can resuspend bottom sediment are bank undercutting, tug propwash, and spud and anchor movements. Hopper dredging with no pumping beyond overflow, the established practice in the Delaware estuary results in minimal turbidity increases at the draghead.

Environmental effects from the resettling of suspended sediments from dredging activities are expected to occur for only a short distance downstream of the activity, approximately, 500-1,000 m downstream and 30-40 m perpendicular to the axis of the plume (USAEWES, 1986; DACE, 1983). Stern and Stickle (1978) concluded that typical dredged-created water column conditions generally do not cause irreversible ecological impacts (Peddicord and McFarland, 1978).

Sediment samples collected during the 1991 testing program were analyzed via the elutriate test, which was developed by the Corps and the U.S. Environmental Protection Agency to predict the soluble release of contaminants from bottom sediments during the dredging process. The elutriate test mimics dredging by oxygenating sediments through agitation, to promote release of chemical constituents from sediment particles. The liquid fraction of the sample is then analyzed to determine contaminant concentrations. The validity of the elutriate test as a predictor of dissolved contaminant release from sediment particles has been demonstrated through extensive laboratory and field studies conducted by the U.S. Army Engineer Waterways Experiment Station.

Surface water quality impacts associated with the use of selected upland dredged material disposal sites are limited to the discharge of effluent during a disposal operation. A hydraulic or hopper dredging operation pumps a significant amount of water along with dredged material into a confined disposal site. This water must be drained from the site so that the dredged material can settle and consolidate in an appropriate manner. An efficiently drained disposal site maximizes capacity and insures site stability at higher elevations.

Excess water drained from the selected sites would be released back to the Delaware River. This water typically contains suspended sediment, and has the potential to contain dissolved inorganic and organic constituents previously associated with the dredged sediments. Depending on the nature of this effluent, water quality in the vicinity of the disposal site can temporarily be

degraded during a disposal operation. Potential impacts include increased levels of turbidity, decreased dissolved oxygen concentrations and increased concentrations of chemical contaminants. These impacts would be similar to those discussed in relation to the water quality impacts associated with dredging practices.

The concentration of suspended sediment in the effluent discharged from an upland disposal site can be controlled through proper operation of the weir structure. The elevation of the weir can be raised to increase the time water remains in the site before being discharged. As water remains within the disposal site suspended sediments settle out of the water column. Through monitoring of the effluent leaving the site, the weir can be appropriately set to achieve the desired degree of settling. The effluent discharge from existing dredged material disposal sites during disposal operations is currently monitored and controlled to insure that it contains no more than eight grams per liter of suspended sediment above the background level of the Delaware River receiving water. While this is the current standard, it is possible to achieve much lower concentrations. The observed range of suspended sediment concentrations in effluent draining from Cohansey River, New Jersey dredged material disposal sites during 1990 maintenance dredging was 0.1 to 2.6 grams per liter.

Bulk Analysis Organic Contaminants: Direct analysis of sediments did not identify high concentrations of organic contaminants within the channel or bend widening locations. PCB's were only detected in one sample at a concentration of 1.72 ppm. Pesticides were only detected in two samples at concentrations below 1 ppm. These contaminants were detected in Reach A and the upper half of Reach B, with no observations below Wilmington, DE. Polynuclear aromatic hydrocarbons were detected in several channel bends from all four Reaches. Concentrations were generally low with only one reading above the Interim NJDEP Soil Action Level of 10 ppm. PAH's were detected at a concentration of 12.23 ppm at one sample location in Reach A. This reading was from the upper 1.25 feet of the sediment core, with no PAH's detected below this strata. Four cores in Reaches A and B were analyzed for other base neutral organics and volatile organics, but little was identified. Methylene chloride at concentrations less than 1 ppm, and phthalates at concentrations between 0.614 and 2.67 ppm were well below NJDEP Soil Action Levels.

Elutriate Analysis Organic Contaminants: The presence of organic contaminants in sediment elutriates was also limited. PCB's were not detected. Pesticides were only detected in three samples, collected in Reach B, at concentrations ranging between 0.0026 and 0.0063 ppm. Polynuclear aromatic hydrocarbons were only detected in one sample (Reach D) at a concentration of 0.013 ppm. Methylene chloride (0.009-0.030 ppm) and phthalates (0.015-0.134 ppm) were again the only other contaminants detected in samples analyzed for the full parameter list. Based on these data it is concluded that organic contaminants would not degrade water quality during dredging operations, or cause long-term contamination problems at dredged material disposal sites.

Bulk Analysis Metals: Metals were found to be widely distributed throughout the project area, which was to be expected. While Interim NJDEP Soil Action Levels were exceeded for some metals, the overall metal content of channel sediments was within reasonable limits. Cadmium, chromium and mercury each exceeded the Soil Action Levels once. Zinc and arsenic exceeded the Soil Action Levels twice. All of these values, except arsenic, were found at the surface of sediment cores. Lower metal concentrations were found below the top strata. Two channel bend samples had arsenic concentrations above the Soil Action Level of 20 ppm. One sample collected in bend PQ had an arsenic concentration of 52.8 ppm in the top 1.75 feet of the sediment core. Two additional strata were present in this core, with arsenic concentrations of 7.1 ppm and 1.0 ppm. A sediment core collected in bend AF had an arsenic concentration of 26.6 ppm. There was no stratification in this sediment core, consequently no further data is available. These few spot occurrences do not demonstrate contamination trends, and are not considered significant relative to the overall quality of channel sediments. Antimony beryllium and thallium were the only metals above the Soil Action Levels at several locations. The Soil Action Levels for antimony, beryllium and thallium are 10, 1, and 5 ppm, respectively. The observed concentrations of antimony (7.5-32.0 ppm). beryllium (0.5-1.5 ppm) and thallium (5.5-10.5 ppm) are not considered excessive in comparison to these criteria. Antimony and thallium were not present in sediment elutriates. Beryllium was found in three elutriates at a concentration of 0.01 ppm in each, these metals would not cause water quality problems during the dredging process, or create hazardous conditions with disposal at confined, upland sites.

Some sediment samples had metal concentrations within the moderately to heavily polluted range, relative to the sediment criteria provided in Table 5-25. As previously stated, the NJDEP use these classifications to determine sediment disposal requirements. Again, disposal at confined, upland dredged material disposal sites, as is proposed for this project, is the preferred disposal alternative for this type of sediment. In Delaware Bay (Reach D), where sandy material is proposed for beneficial uses, the sediments are considered clean. There were no metals present above Soil Action Levels, or within the heavily polluted category.

Elutriate Analysis Metals: The metal content of sediment elutriates was low in all four Reaches. Concentrations of metals that were found were generally below 0.1 ppm. These observed concentrations suggest that the presence of metals in channel sediments would not significantly affect water quality during the dredging or disposal process.

In order to implement the requirements of Section 404 of the Clean Water Act an exemption is being sought under Section 404(r) as part of the Congressional authorization process in lieu of obtaining Section 401 Water Quality Certificates from the state(s) in which the disposal of dredged material is taking place.

5.1.4 Delaware River and Bay Wetlands and Shallows

The proposed dredging is confined to areas within the existing 40-foot navigation channel, and a total of 16 channel bends at the intersection of the various channel ranges. Proposed work within channel bends consists of bend widening to improve the navigational safety of ships negotiating these turns. Of the 16 areas to be dredged for bend widening, 12 areas have existing depths greater than 30 feet mlw. Three of the remaining four areas have existing depths that range between 20 and 40 feet mlw. The remaining Horseshoe Bend, located opposite of the Philadelphia Naval Base, has existing spot elevations of 15 feet mlw, but is predominantly 20 to 45 feet deep. All of these bends are located immediately adjacent to the existing navigation channel, and are considered to provide aquatic habitat of low value. Project design also includes channel side slopes that are 3H:1V. A review of survey data for the existing channel, the Marcus Hook Anchorage, Beckett Street Terminal and bend widening locations indicated that existing side slopes are less than 3H:1V, and located at depths greater than 10 feet. Based on the existing channel geometry, it is concluded that the proposed dredging would not disturb side slopes to a significant extent, and would not disturb bottom habitats less than 10 feet deep. As such, it is concluded that the proposed dredging would not result in the loss of wetland or shallow water habitats in the Delaware River and Bay.

5.1.5 Dredged Material Disposal Sites with Regard to On-Site Wetlands

Five upland sites would be necessary for the disposal of material dredged during initial construction and 50-year maintenance of a five-foot, incremental deepening of the existing Philadelphia to the Sea navigation channel. Maintenance of the existing 40-foot channel would require continued use of six additional disposal sites that are currently owned and operated by the US Army Corps of Engineers for channel maintenance. The five sites selected for the deepening project are identified as 15D, Raccoon Island, 17O, Reedy Point North and Reedy Point South.

An issue relative to these sites is the presence of on-site wetlands that would be lost as a result of dredged material disposal activities. The purpose of this section is to present the past history of these sites, previous efforts leading to the identification of appropriate sites, Feasibility Study efforts to avoid wetland impact, and planned efforts for the Preconstruction Engineering and Design Study. This phase of project development encompasses all planning and engineering necessary for project construction. These studies are required to review the earlier study data, obtain current data, evaluate any changed conditions, establish the most suitable plan for accomplishment of the improvement and establish the basic design of the project features in final detail.

All five selected sites are active or formerly used dredged material disposal sites. Site 15D is a 575-acre area located adjacent to the Delaware River (Figure 5-22). The entire site is currently owned by the Sun Oil Company. The site consists of a combination of hydraulic dredged material disposal areas formerly used by Monsanto Chemical Company, American Dredging Company and the Corps of Engineers. Initial disposal began in 1955 and continued into the late 1970's. Approximately 200 acres of the Monsanto property was filled by the

Figure 5-22 Proposed Dredged Material Disposal Site 15D.

Baur Dredging Company in 1965. The Corps placed material in the area from 1955 to 1975. Sun Oil Company has used the area since then for private dredging. Approximately 10 to 15 feet of fine-grained dredged material overlies the original ground.

Much of the eastern two-thirds of the site was planted in corn and soybean in 1989. Exceptions include black willow-dominated areas in the southeastern and central portions of the site and some stands of common reed in areas not planted to crops. A small grass runway, used by ultralight aircraft, is present in the central portion of the site. The western third of this site is dominated by common reed interspersed with patches of various grasses and herbaceous vegetation. Additional forested areas, dominated by black willow, are limited to the extreme northwestern portion of the site and north-central areas.

The Raccoon Island site is an active, privately owned disposal area, approximately 480 acres in size (Figure 5-23). The site is bordered by the Delaware River to the north, State Route 130 to the south, Raccoon Creek to the west, and the American Dredging Company, White's Basin dredged material disposal area to the east. The Commodore Barry Bridge, a fixed span bridge that crosses the Delaware River, cuts across the northeast portion of the site. The owner, American Dredging Company, has used the area within the last five years for disposal of dredged material, which overlies the original ground.

All of the Raccoon Island site has been used for dredged material disposal, and is bounded by dikes. The site is predominately vegetated by common reed. Interspersed throughout the site are areas covered by oldfield vegetation, which includes a mixture of forbs and grasses. Occasional stands of black willow and sumac are also scattered throughout the areas.

Site 170 is approximately 180 acres in size (Figure 5-24). The site is bordered on the north by the Delaware River, on the east by little Mantua Creek and on the south by railroad tracks, north of, and parallel to State

Route 44. The site was formerly owned by the National Steel Company. In 1967 the Corps obtained a five-year dredged material disposal easement with National Steel. The soil is mainly silt with some layers of clay and sand. The upper 5-10 feet of soil is fine-grained dredged material.

Two overgrown fields, located in the central and south-central portions of the site, support a variety of grasses and herbaceous vegetation. A large forested area on the northern portion of the site is dominated by black willow, black cherry, and cottonwood. Other central and southern portions of the site support diverse habitat including overgrown fields dominated by common reed, shrubland dominated by black cherry, and forests of black cherry, ailanthus, sassafrass, and hickory.

Figure 5-23 Existing Raccoon Island Dredged Material Disposal Area

Figure 5-24 Proposed Dredged Material Disposal Site 170.

Reedy Point North and South are active, Federally owned, dredged material disposal sites, previously dedicated for maintenance of the Chesapeake and Delaware Canal (Figure 5-25). The sites area located on either side of the canal, immediately adjacent to the Delaware River. Reedy Point North is 122 acres in size. Reedy Point South is 133 acres in size. Reedy Point South was last used in the mid to late 1970's. Reedy Point North was last used in the early to mid 1980's. The sites have an estimated 10-15 feet of dredged material within the confines of the dikes. Site vegetation is dominated by common reed with some shrubs. Site topography is sloped as a result of dredged material disposal activities. Lower elevations are located in the vicinity of the sluices.

The selection of suitable sites for dredged material disposal activities along the Delaware River was a process that began in the early 1980's. This work was coordinated with Federal and State resource agencies at appropriate points in the analysis. In 1981, the US Fish and Wildlife Service prepared a planning aid report for the Delaware River Dredging Disposal Study (USFWS, 1981). That report provided habitat evaluations of land in the vicinity of several tributaries to the Delaware River. In an analysis of land in the vicinity of Raccoon Creek, the service identified site 15D and Raccoon Island as low habitat value sites. The Service stated:

> "This habitat type consists exclusively of old spoil disposal sites. The spoil is commonly covered by common reed, but some areas also support willows and empress tree (Paulownia tomentosa). Additionally, certain areas south of Raccoon Creek are being farmed. All of the spoil disposal sites occur downstream of Route 130 in what probably was wetland.
>
> Non-tidal common reed has little or no value as fish and wildlife habitat. The plant develops into dense, impenetrable stands which prevent more valuable plants from invading."
>
> The Service went on to state: "The Service encourages the Corps to consider using low value areas for dredged material disposal. Medium value areas may also be considered, but only if low value areas are unavailable and appropriate mitigation is provided. Use of high value areas would cause significant damage to fish and wildlife resources and, therefore, is discouraged by the Service."

In 1984, the Corps completed the Delaware River Dredging Disposal Study (USACE, 1984), which evaluated future dredging needs and existing dredged material disposal capacity. The study projected areas that would require additional dredged material disposal capacity within a 50-year study period, and identified candidate sites that could be considered for meeting the need. The study resulted in an effectual screening of potential sites for both large-scale disposal areas, to accommodate projects on the Delaware River, and smaller areas for tributary projects. The information generated by this study was reviewed and incorporated into the draft Interim Feasibility Report for the Delaware River Comprehensive Navigation Study,

Figure 5-25 Existing Reedy Point North & South Dredged Material Disposal Areas

Main Channel Deepening project (USACE, 1990). The following provides a brief description of the major steps employed during the dredged material disposal site selection process. Refer to the Plan Formulation selection of the interim Feasibility Report for a more in-depth discussion.

Plan formulation with regard to identification of suitable dredged material disposal sites involved several iterations of engineering, economic and environmental screening. The initial step employed a computerized technique called Spatial Analysis Methodology (SAM). SAM stores selected parameter information for specified locations, and displays the information in graphic or tabular form. Parameters included archaeological zones, historic sites, recreational areas, groundwater recharge zones, groundwater protection zones, areas important to fish and wildlife, wetlands, development, navigation features, elevation and distance from dredging sites. Parameters could be given weighting factors to emphasize engineering or environmental criteria. Through manipulation of weighting factors, a series of runs identified locations within the study area that were attractive for dredged material disposal.

SAM essentially generated maps that identified polygons where specified parameter criteria were met. These polygons were then transferred to U.S.G.S. quadrangle sheets for manual screening. Initial screening considered features such as roads, streams and isolated structures that the computer model was unable to define. Other considerations included minimum acreage requirements, accessibility for construction and maintenance, reasonable disposal pipeline routes and effluent water courses to the river. Sites were also visited at this stage to identify concerns that may have been missed. This analysis reduced the number of candidate areas along the Delaware River from 308 to 82.

The next step in the screening process involved the evaluation of sites with respect to institutional and environmental factors that would preclude use of a site for disposal activities. Institutional screening eliminated sites that were public park land, designated wildlife areas, or adjacent to residential areas and communities. Environmental screening eliminated sites that were not consistent with Federally approved Coastal Zone Management Plans. These plans differ between the States of Pennsylvania, New Jersey and Delaware, so different criteria were used depending on the location of the site. For example, the Pennsylvania Coastal Zone Management Plan specifically prohibits destruction of wetlands, while the New Jersey and Delaware plans do not. This screening cycle reduced the number of candidate sites from 82 to 38.

The 38 remaining sites were next subjected to a detailed cost analysis. Specific data with respect to site acquisition, initial dike construction, annual maintenance, site capacity and mitigation requirements were developed and evaluated to generate a relative ranking of the costs associated with candidate sites. Environmental reviews were also conducted to rank the significance of impacts associated with developing sites for disposal purposes.

Letters of comment were received from various Federal and State resource agencies regarding the Delaware River Dredging Disposal Study. In a letter dated November 29, 1983, the US Fish and Wildlife Service classified site 15D and existing Corps dredged material disposal sites as Resource Category IV habitat in accordance with the Fish and Wildlife Service Mitigation Policy (Federal Register Vol. 46, No. 15, January 23, 1981). Using this policy the Service defined Category IV habitat as:

> "All or portions of the disposal site contain habitat of medium to low value for fish or wildlife species. Disposal in these sites is suitable. Habitat losses may or may not require compensation, depending on the significance of the loss. These sites have the greatest potential for habitat enhancement."

In a November 18, 1983 memorandum regarding the Delaware River Dredging Disposal Study, the New Jersey Department of Environmental Protection, Division of Coastal Resources stated:

> "Sites 15D and 17G are acceptable since these sites are already connected with dredging activities serving as rehandling basins."

Region II of the US Environmental Protection Agency and the National Marine Fisheries Service also provided letters that basically stated their preference for upland sites for dredged material disposal, and urged avoidance of aquatic habitats.

In 1989, the US Fish and Wildlife Service was again contracted to provide a planning aid report for the Delaware River Comprehensive Navigation Study, Main Channel Deepening Project (USFWS, 1989). As part of that effort the Service evaluated sites 17O and 15D for habitat values and potential as dredged material disposal areas. Reedy Point North and Reedy Point South were not included in the evaluation because they were considered existing, Corps owned dredged material disposal sites. Raccoon Island was considered unavailable at the time because it is a privately owned dredged material disposal site. That site became available for the deepening project after the Service completed its review.

The following provides the Methods of Analysis section from the Service's report:

> "The information for this feasibility phase planning aid report was compiled from the Main Channel Dredged Material Disposal Investigation Summary provided by the Corps, searches of Service office files and library, review of the Service's National Wetland Inventory maps, a letter of coordination with the New Jersey Division of fish, Game and Wildlife (Appendix A), telephone conversations with various individuals, and a series of site visits (including one aerial overflight) of the proposed upland disposal sites between July 13, 1989, and October 23, 1989. Cover types were mapped on enlarged copies of U.S. Geologic Survey 7.5 minute quadrangle maps depicting sites boundaries. Cover types used are consistent with those used by Chezik (1983a).

Dominant land uses and cover types present on the proposed upland disposal sites were determined based on site visits and 1985 aerial photographs (scale 1 inch = 400 feet). An attempt was made to locate wetland areas within the boundaries of the sites based on hydrophytic vegetation, hydric soils, and wetland hydrology. This task was made difficult by the large size and inaccessibility of some sites, extensive clearing of natural vegetation for agriculture, the predominance of dense stands of common reed (Phragmites australis) (a facultative wetland species showing vigorous growth in both wetlands and non-wetlands), the presence of dredge spoil rather than evolved soils, and atypical hydrology resulting from above normal rainfall during 1989. The total area of each upland disposal site and area of wetlands present were estimated from cover maps with use of a planimeter."

On site 15D the Service identified the following wetland areas. A winding ditch, approximately 10 feet in width and 2,000 feet in length, oriented generally north and south near the western boundary of the site. Near the northernmost terminus of this ditch are a series of borrow pits, some of which held water during summer, 1989. Other smaller ditches, apparently dug to drain agricultural fields, are located in the northeastern and eastern portions of the site and drain into Raccoon Creek. The Service estimated that the wetlands in the drainage ditches and their banks comprise less than one acre. In addition, the Service identified an approximately two-acre area of wet crop fields in the west-central portion of the site, and one acre or more of emergent vegetation and open water northwest of the encircled marsh. These wetland areas are identified in Figure 5-26, which was provided by the Service.

On site 17O the Service identified about 27 acres of wetlands associated with Little Mantua Creek, an approximately eight-acre area of red maple dominated forested wetland on the southeastern portion of the site, and an approximately 28-acre area of diverse emergent and forested wetland located on the southwestern portion of the site. These wetland areas are identified in Figure 5-27, which was also provided by the Service.

Based on the wetland information provided by the US Fish and Wildlife Service, site boundaries were altered from those originally considered. The intent was to modify boundaries, which ultimately represent dike alignments, to avoid as much wetland habitat as possible, while still providing sufficient dredged material disposal capacity to meet the projected need. Figures 5-22 and 5-24 show the final dike alignments for sites 15D and 17O, respectively. These alignments meet project needs and minimize impacts to aquatic habitats.

Based on the information provided to this point, the remaining areas of dispute are drainage ditches and an approximately two-acre area of wet crop fields in the west-central portion of the site. Site 15D has been used for dredged material disposal in the past. Placement of fine grained sediments,

Figure 5-26 Cover Types Mapped By The U.S. Fish And Wildlife Service On Site 15D (USFWS, 1989).

Figure 5-27 Cover Types Mapped By The U.S. Fish And Wildlife Service On Site 170 (USFWS, 1989).

as are dredged from this portion of the Delaware River, can lower the percolation rate of precipitation at disposal sites. Many of the existing and previously used sites along the Delaware River do temporarily pond water during periods of heavy rainfall. Rainfall during the spring and early summer of 1989 was much higher than normal. Several severe storm events resulted in widespread flooding throughout southern New Jersey. It is not surprising to find wet areas or areas with standing water in disposal sites subsequent to this level of precipitation. In addition to the area of wet crop field, the Corps also does not consider the drainage ditches on site 15D as a true wetland habitat.

Regardless of the nature of these areas, dredged material disposal operations would not result in the elimination of such sites. The placement of additional quantities of fine grained dredged sediments in these sites would not increase the rate of soil drainage. Ponded water would still occur during periods of heavy precipitation. As such, any habitat value afforded by these areas would be maintained with continued use of the sites for dredged material disposal. As a result of past activities, site 15D is at a higher elevation than the surrounding landscape. This site is not hydraulically connected to any waterway or adjacent wetland habitat. Therefore, the continued use of this site would not impact the hydrology of adjacent aquatic habitats.

Based on the efforts undertaken throughout the 1980's, the Corps has concluded that use of the five upland sites selected for dredged material disposal, for construction and maintenance of the Delaware River Comprehensive Navigation Study, Main Channel Deepening Project, would not impact aquatic habitats, including wetlands. Three of the sites, Reedy Point North, Reedy Point South, and Raccoon Island, are existing, active dredged material disposal sites. Continued use of existing sites is considered to be the least environmentally damaging alternative. The remaining two sites, 15D and 170, are former dredged material disposal areas. Based on surveys conducted by the US Fish and Wildlife Service, the boundaries of these two sites were modified to avoid wetlands. All wetlands identified by the Service on site 170 have been avoided. On site 15D, the Service identified less than one acre of wetlands in drainage ditches and a two-acre area of wet crop field. Based on the past use of this site, the Corps does not consider these to be true wetland habitats. In addition, continued use of the site for dredged material disposal would maintain such areas, as is demonstrated in most of the active disposal sites along the Delaware River.

Additional work has been planned for the Preconstruction, Engineering and Design phase of the study. This work includes preparation of detailed Environmental Assessments on these sites. Based on comments received on the draft Environmental Impact Statement, these assessments will include another survey for wetland habitats.

5.1.6 Phytoplankton, Zooplankton and Planktonic Macroinvertebrates

Dredging operations result in increased turbidity to the water column, and may lead to a short-term decrease in dissolved oxygen concentrations and release of chemical constitutents contained within the sediments. Depending upon environmental factors occurring at the dredging site, the resuspension of bottom sediments can impact the planktonic community in either a positive or negative manner. Decreased light penetration caused by increased turbidity can impair the ability of phytoplankton to photosynthesize and produce oxygen. A reduction in dissolved oxygen concentrations, resulting from the combination of a lower photosynthetic rate and increased oxygen consumption due to resuspension of sediments, can adversely impact all aquatic organisms requiring oxygen. The magnitude of this impact would depend on the extent of the reduction and the period of time it was sustained. On the other hand, release of nutrients from suspended sediments can lead to phytoplankton blooms, which could increase the photosynthetic rate and increase the food supply for planktivorous organisms.

Phytoplankton are considered to be the base of the aquatic food chain. They are consumed by zooplankton and planktonic macroinvertebrates, which in turn are consumed by larger aquatic organisms. Significant adverse impacts to any lower link in the chain would result in a loss of food supplies to all organisms in the chain above that link. Impacts to phytoplankton would affect zooplankton and planktonic macroinvertebrates the most as they are positioned directly above phytoplankton in the chain.

A study of the phytoplankton community in the Delaware River, between Philadelphia and Wilmington, concluded that the phytoplankton in this portion of the river are characteristic of an enriched and turbid system (ANSP, 1981). Many of the species encountered are considered to be pollution tolerant. Zooplankton in this portion of the river are also indicative of a stressed system. The population is dominanted by a few species that are able to tolerate the existing water quality conditions. It is not anticipated that short-term water quality impacts that could result from dredging would significantly impact the planktonic community in this portion of the river.

Below Wilmington and into Delaware Bay, the river widens such that dredging impacts would affect a smaller percentage of the planktonic community. Water quality improves in this portion of the river as well. Any short-term impacts to water quality due to the resuspension of bottom sediments would not be expected to produce intolerable water quality conditions. No long-term impacts to the planktonic community within the study area are anticipated as a result of the proposed dredging.

5.1.7 Benthic Macroinvertebrates

Dredging operations do result in the destruction of bottom habitat and loss of the existing sessile benthic community. More mobile organisms, such as crabs, can escape the path of the dredge provided that dredging occurs during their active portion of the year. Sessile organisms, such as worms

and mollusks, would not be able to leave the dredging area. These organisms would be removed with the sediments and would not be expected to survive. Typically, benthic organisms from adjacent areas begin to recolonize disturbed areas soon after completion of dredging operations. Recolonization may take two growing seasons or more, and the resulting benthic community will most likely be different from the original (Hastings, 1983a; Allen and Hardy, 1980). Transitional fauna usually consist of opportunistic species, and species diversity is usually limited (Allen and Hardy, 1980). The extent of recolonization subsequent to dredging depends on several factors including the resulting substrate type, the amount of light penetration due to depth and/or turbidity, frequency of dredging, distance from similar habitat for recolonization, and long-term changes in water quality (Betz Environmental Engineers, 1975).

The Delaware River, Philadelphia to the Sea navigation channel is currently maintained to a depth of 40 feet mlw through periodic dredging of shoaling areas. Deepening of this channel to -45 feet mlw is not expected to significantly alter the substrate, amount of light penetration, long-term turbidity levels or water quality. While initial construction of a 45-foot channel would impact the benthic community in areas that are not now maintained through dredging, maintenance of the new channel is not expected to impact benthos significantly more than current disturbances.

5.1.8 Finfish

The potential impacts of a dredging operation on fishery resources include direct physical injury to organisms, and indirect injury due to factors such as water quality degradation, loss of benthic or planktonic food resources, disruption of spawning or nursery habitats and disruption of spawning activities. The most direct impact of dredging on aquatic life is the entrainment of sessile or slow moving organisms into the dredge pipe. Adult fish have the ability to leave the immediate impact area. Less motile life stages such as fish eggs, larvae and young juveniles can not escape the path of the dredge. Organisms carried through the dredge pipe would not be expected to survive. Mortality probably approaches 100 percent when dredged material is placed in upland disposal sites.

Potential water quality concerns that could indirectly impact fishery resources include increased turbidity levels, decreased dissolved oxygen concentrations and release of chemical constituents of the sediments to the water column. Increased levels of turbidity may affect finfish in several ways. Reduced visibility may impact the feeding success of sight-dependent species. Elevated levels of suspended sediments may interfere with respiration through clogging of gill filaments. Chemical constituents, previously bound to undisturbed sediment particles, may become biologically available when exposed to dissolved oxygen in the water column. These impacts would be more severe on early life stages of fish as they tend to be most sensitive.

In a study conducted by Peddicord and McFarland (1978), the tolerance limits of a variety of adult and juvenile marine, estuarine, and freshwater fish and invertebrates to contaminated and uncontaminated sediments were tested. All species tested were able to survive exposure to suspensions of uncontaminated

and contaminated sediments for much longer periods of time and at higher concentrations than are created in the water column by typical dredging operations. The only exception was the striped bass fingerling, M. saxatilis, in contaminated sediments. Mortality occurred under conditions considered in the upper range possible around dredging sites (Peddicord and McFarland, 1978).

Peddicord and McFarland (1978) cited a comprehensive literature review by Stern and Stickle (1978) which concluded that adult fish generally are more sensitive to suspended solids than most invertebrates, and that within a given fish species, juveniles are more sensitive than adults. In addition, fish show an avoidance reaction to irritating stimuli. Therefore, a fish may encounter a dredge plume for a short period of time, but would not be exposed for a period of time that would be detrimental to its health (UASCE, 1981). Fish larvae, on the other hand, have a weak avoidance potential, and thus, may be affected by suspended sediments.

In observations carried out on the Ohio River, dredging appeared to have no adverse impact on fish. No differences were detected in species composition, number of species, relative abundance, biomass, and other studied parameters (USACE, 1981). Data on larval and juvenile fish were not sufficient to permit definite conclusions on the effects on fish spawning (USACE, 1981).

The resuspension of organic matter and chemical constituents contained in the sediments can increase the rate of dissolved oxygen consumption within the water column. Decreases in dissolved oxygen concentration would only occur in the immediate vicinity of the dredging, and would not persist for a prolonged period of time after dredging ceases. Dissolved oxygen concentrations below 4 mg/L causes a block to migrating fish and 2 mg/L can be lethal (Patrick, 1988). Adult fish would be able to avoid areas of reduced dissolved oxygen levels. Egg, larval and juvenile stages would be affected to a greater degree if low concentrations persisted.

Anadromous species that make migratory runs within the Delaware estuary include the American shad (Alosa sapidissima), alewife (Alosa pseudoharengus), blueback herring (Alosa aestivalis), striped bass (Morone saxatilis) and shortnose sturgeon (Acipenser brevirostrum). These species typically migrate upstream in the spring to spawn, and downstream in the fall to reach overwintering habitat. Seasonal dredging restrictions are employed to minimize impacts to these migratory species at appropriate times of the year.

Coordination is on-going with the Delaware Basin Fish and Wildlife Management Cooperative with regard to appropriate seasonal dredging restrictions. Previous restrictions precluded bucket dredging and/or overboard disposal in the Delaware River from 1 March through 31 May and from 1 September through 30 November. These restrictions were in place to prevent disruption of anadromous fish migrations through creation of excessive turbidity and decreased dissolved oxygen concentrations. No restrictions were required for hydraulic or hopper dredging with upland disposal. New restrictions are now being employed with regard to bucket dredging, blasting and overboard disposal. Between Delaware

Bay and the Delaware Memorial Bridge, bucket dredging, blasting and overboard disposal are restricted from 1 March through 30 June. Between the Delaware Memorial Bridge and the Betsy Ross Bridge, which is above the upstream limit of the proposed project, bucket dredging, blasting and overboard disposal are restricted from 15 March through 31 May and from 1 September through 30 November. With regard to hydraulic dredging, a 3-year study will be initiated in 1992 to consider potential impacts on fishery resources in the Delaware River. The results of this study will be used to evaluate the need for hydraulic dredging restrictions. The need for such restrictions can not be determined at this time. The Corps is providing funding to the Delaware Basin Fish and Wildlife Management Cooperative in support of this work.

Another indirect impact to fisheries resulting from dredging operations is the removal of benthic invertebrate food sources from the dredging area. Species of commercial or recreational importance that utilize benthic food sources include American shad, striped bass, weakfish and summer flounder.

The American shad (Alosa sapidissima) supports a large and growing recreational fishery in the Delaware River. Adult shad are present in the Delaware estuary only during spawning migrations, and feed little if any during that time. Juvenile shad spend their first year of life in the river and/or estuary. Young-of-year (YOY) shad are largely planktivorous, but feed occasionally on bottom-living copepods and chironomids, particularly in the fall. Many more YOY shad are currently present in the estuary for longer periods of time than in the past, apparently as the result of successful spawning farther downriver and improved oxygen conditions in the Philadelphia-Camden area.

The striped bass (Morone saxatilis) is highly esteemed both as a food fish and by anglers. Striped bass less than several years old are present throughout the project area year-round, but relate to shoreline areas and do not often roam the open waters of Delaware Bay. Manooch (1973) found that the predominant food of all sizes of striped bass is fish. Others, such as Leim and Scott (1966), maintain that young striped bass feed heavily on crabs, worms, amphipods, and mysids. The 1987 year class of striped bass in the Delaware River is extremely strong (Weisberg et al. 1987).

The weakfish (Cynoscion regalis) is a highly sought after fish, both recreationally and commercially. According to Stickney, Taylor, and White (1975) young weakfish are very selective feeders that feed heavily upon epibenthic organisms such as penaeid and mysid shrimp as well as some polychaetes. In that study in the southeastern United States, Neomysis americana, a mysid and Nereis succinea, a polychaete, constituted a large portion of the diet of weakfish less than 200 mm standard length (SL). Fish did not become a significant part of the diet until weakfish were greater than 130 mm SL. There is a tendency for YOY weakfish to remain in deep water offshore during their first year of life and migrate into estuarine areas in the spring of their second year of life (McHugh 1967). Older weakfish feed heavily on fish and squid and migrate into estuaries beginning about May.

The summer flounder (Paralichthys dentatus) is another highly sought recreational species. This species is recovering from recent low population levels and is protected by a recently imposed twelve-inch legal length limit in Delaware Bay. Large numbers of fish less than this size are currently found in Delaware Bay. Although this fish feeds upon squid, shrimp, crabs, mysids, mollusks, worms, and sand dollars, its diet consists largely of fish. The summer flounder is found in Delaware Bay throughout most of the year. The summer flounder previously has been characterized as bottom-oriented and relatively immobile, however, it is now known to utilize a wide range of feeding behaviors which allow them to feed on large, quick-moving prey in the water column. Powell and Schwartz (1979) found that even small summer flounder between 100-200 mm in length consume a diet high in fish.

The removal of benthic organisms during a dredging operation does reduce the overall size of the benthic community available for consumption by fish. Proposed dredging operations would primarily take place within the limits of the existing 40-foot channel, with some additional dredging to widen channel bends. Much of this area is periodically disturbed through maintenance dredging operations. As such, the benthic community within much of the proposed project area is disturbed. In addition, there are extensive areas outside of the channel that will remain undisturbed with proposed dredging operations. No long-term adverse impacts of significance are anticipated with respect to removal of benthic organisms and finfish.

Deepening the existing channel from 40 feet at mean low water (mlw) to 45 feet at mlw through the Marcus Hook, Chester and Eddystone Ranges would require removal of an estimated 5,222,000 cubic yards (cy) of sediment and 45,100 cy of rock. Figure 5-28 provides the location of bedrock relative to the existing channel bottom. As can be seen in Figure 5-28, this rock currently lies beneath the channel and is not situated such that it provides ledges or shelves that would provide attractive cryptic habitat for fish. Removal of this rock would require detonation of explosive charges within the river. Blasting could occur between December and mid-March, which is in accordance with the Delaware Basin Fish and Wildlife Management Cooperative's proposed seasonal restrictions on construction activities in that portion of the river. Blasting at this time of the year would avoid impacts to spawning, nursery and migrational periods. Blasting techniques that would be employed to minimize impact to fish would include the use of directional charges that focus the force of the blast down into the rock, the use of appropriately sized charges, and the use of scare charges to clear fish from the impact area prior to detonation.

In May of 1988 several rock outcrops were identified in this reach of the river and were immediately removed through blasting, as they posed significant danger to shipping. Since this work was scheduled to occur during the peak spawning period for striped bass, fishery surveys were conducted during the work to evaluate the effects on striped bass spawning or nursery activity in the area (Versar, 1988). The study concluded that the rock removal had no adverse impact on striped bass. Longer-term sampling indicated that spawning had

Figure 5-28 Location of Bedrock within the Delaware River Navigation Channel in the Vicinity of Marcus Hook

(From Duran, 1986)

occurred one to two weeks prior to the blasting, and that eggs were primarily located farther downstream. Of more importance to this study are the observations made immediately after the first blast. No obvious fish kills occurred as a result of the blasting. In addition, several fish were captured in the immediate vicinity, and were found to be alive with no obvious sign of injury. Rock removal at a more appropriate time of the year is not expected to result in significant adverse impacts to fish. In addition the use of scare charges and the use of the minimium size charge necessary will further reduce the impacts of blasting on fish.

5.1.9 Wildlife

No significant adverse impacts to wildlife are anticipated with respect to the proposed dredging. Terrestrial species would not be located within the direct path of a working dredge. The only potential disturbance to terrestrial species would be noise from a dredge operating in the vicinity. Migratory shorebirds are dependent on Delaware Bay during their spring migration to the north. Eggs from horseshoe crab spawning activities provide a valuable food source for many migrating shorebirds from approximately May 1 through June 15. Horseshoe crabs spawn in shallow water along the Delaware Bay shorelines. As proposed dredging would be taking place in approximately the center of Delaware Bay, turbidity and siltation generated from dredging conducted at this time would not be expected to impact activities along the bay shorelines.

The use of the selected upland sites for dredged material disposal is not anticipated to result in any significant long-term adverse impacts to wildlife resources in the area. All of these sites have previously been used for dredged material disposal, and do not contain high quality wildlife habitat. While existing vegetation would initially be lost, these areas would revegetate in between disposal cycles. The vegetation that would develop, primarily common reed, already dominates much of these sites. Site 170 would be impacted the most, as it does contain areas of forest and shrubland.

The primary value of these sites to wildlife is that they are relatively large, undeveloped areas that provide quiet space for animals to reside. This quiet, open space will be maintained throughout the life of the project, except for periods when the sites are used for disposal. Considering the location of these sites with respect to the surrounding Philadelphia, Camden and Wilmington urban areas, it is expected that these areas with the exception of Reedy Point North and South will eventually become desirable for industrial or residential use. This is evidenced by the current interest in developing candidate site 17G, which is almost immediately adjacent to site 170, for residential use. In addition, site 170 has previously been considered for industrial development. Development pressures are expected to increase in the future as undeveloped land becomes less available. As such, the use of these sites for dredged material disposal could actually be considered a long-term benefit to wildlife, as it would maintain this open space for the life of the project.

The placement of fine grained dredged material into disposal sites has a tendency to restrict site drainage as material accumulates. It is not uncommon to find temporary ponds develop within sites during periods of heavy rainfall. These ponds can develop wetland vegetation if they exist for prolonged periods of time. Concentrations of waterfowl have been observed using such ponds in existing disposal sites for resting and feeding habitat. These ponds can provide beneficial habitat to waterfowl during migratory periods.

5.1.10 Threatened and Endangered Species

It is anticipated that no Federally listed threatened or endangered species would be significantly impacted by the proposed project. Although the project area is within the range of six species of whales and five species of sea turtles (see section 4.3.8), these species have not been impacted through dredging activities associated with the existing Philadelphia to the sea navigation project. The shortnose sturgeon is a Federally endangered species of fish in the Delaware River. Spawning and nursery habitats for this species are located well upstream of the project area. This species may migrate through the project area during the spring and fall. Migrations are protected through established seasonal dredging restrictions. The Corps will continue its efforts to coordinate the project with the National Marine Fisheries Service, with regard to these species. The endangered bald eagle and the American peregrine falcon periodically occur within the project area. Peregrine falcons are documented as nesting within one mile of the Raccoon Island site, and its territory could also encompass site 15D. On page 8 of their Section 2(b) report, the U.S. Fish and Wildlife Service provided the following information. In recent years, peregrines have nested or attempted to nest on various Delaware River bridges. These birds may travel 10 to 18 miles in search of prey. Raccoon Creek and nearby Oldman's Creek have also had numerous reports of bald eagle use in recent years. There were five active eagle nests in New Jersey in 1991. All of these nests were located within seven miles of the Delaware Estuary. One of these nests, located near Gibbstown, New Jersey, was less than 0.5 miles from the Delaware River. The NJDEPE has indicated that there has been a recent (1989-1990) documented siting of an osprey nest on Raccoon Island. The osprey is listed as a threatened species by the State of New Jersey. Although no other threatened/endangered species are known to breed or nest on the proposed disposal areas, transient use of these areas is known. Osprey have been reported along the Delaware River near Raccoon Creek. Great blue herons are reported feeding in wetlands near National Park, but no rookeries are known from this area. The great blue heron is listed as a threatened species by the State of New Jersey. Detailed Environmental Assessments of the proposed dredged material disposal sites are planned for the Preconstruction, Engineering and Design phase of project development. As part of this effort, biological assessments with regard to threatened and endangered species will be prepared. This is in accordance with Section 7 of the Endangered Species Act (16 U.S.C. 1531 et. seq.). Coordination with the U.S. Fish and Wildlife Service and the New Jersey Department of Environmental Protection and Energy will continue with regard to this issue.

5.1.11 Vegetation

The use of selected sites for dredged material disposal would result in the initial loss of all vegetation within site boundaries. All five selected upland sites have been previously used in whole or in part for dredged material disposal and are considered disturbed. Site 15D is predominantly vegetated with common reed and planted fields of corn and soybeans. The Raccoon Island and Reedy Point North and South sites are also dominated by common reed, but contain areas of oldfield, successional vegetation and stands of mature trees. Site 170 is the most diverse with shrubland, forested, oldfield and common reed areas.

Dredged material disposal sites typically revegetate naturally between disposal operations. The dominant species that invades a recently used site is common reed, however, wetland plant species can be found in poorly drained wet areas, or areas with ponded water. The degree of development that occurs on a site is a function of the frequency of disposal. Sites within the study area are typically used every two to five years, depending on the dredging requirements within the vicinity of the site and the number of sites in the area, which allows for site rotation. From an engineering perspective, it is preferable to rest a site as long as possible to obtain maximum drying and consolidation of material.

Site 15D, Raccoon Island and Reedy Point North and South would be the least impacted by dredged material disposal operations with respect to vegetation. Except for planted agricultural fields at some sites, common reed is the predominant vegetation in these areas. These areas would be expected to revegetate with common reed subsequent to a disposal operation. Site 170 is more diverse. Use of this site would result in the loss of some forest and shrubland, with common reed invading between disposal cycles.

5.1.12 Cultural Resources

While prehistoric and historic utilization of the Delaware River has been both extensive and intensive, it is anticipated that dredging the Federal navigation channel to any of the width and depth alternatives evaluated during this feasibility study has the potential to impact only two categories of cultural resources. First, there could be impacts to objects that were placed in the river either as an aid to navigation (e.g., dikes, fixed buoys) or as a hindrance to navigation (e.g., the chevaux-de-frise of the Revolutionary War). Second, channel modification could affect shipwrecks in the Delaware River.

Before examining in detail the potential for effects on these categories of resources, it is necessary to briefly consider why impacts are not expected for other categories of cultural resources. While many of the shoreline sites utilized by prehistoric peoples would have been inundated by sea level rise, there are a number of reasons why those sites would not be located in the vicinity of the navigation channel. First, the channel alignment corresponds by and large to the naturally deepest part of the river bed, which would not have been dry land during any of the time that the Delaware Estuary has been occupied by humans. Additionally, although sea level rise has submerged some

of the earlier shoreline, landfilling activities along the river banks over the past three centuries of historic settlement have extended the shoreline out into the river along large stretches of the river (Cox 1984). Thus, many previously inundated prehistoric sites may have been destroyed through these activities or may now be buried under landfill. Similarly, many historic period cultural resources along the shoreline, such as piers, wharves, and bulkheads, may also have been destroyed by, or incorporated into, landfilling activities. Other historic period resources remain, but are located either along the present waterfront, or on or alongside the islands in the river, or in the back channels between the islands and the banks of the river. None of these areas will be affected by the proposed project. Thus, there is virtually no likelihood that prehistoric sites or the remnants of any historic shoreline structures would be found in any of the areas proposed for bend widening or channel deepening.

That leaves for consideration those objects that could potentially be impacted by the proposed project, namely shipwrecks and objects placed in the river to hinder or enhance navigation. Of the several kinds of objects that might have been placed in the river to enhance navigation, none would be expected to be in the channel. Objects such as dikes, ice piers, etc. would have been constructed perpendicular to, or adjacent to, the channel, but not within the channel. Therefore, while deepening the channel would not impact any of these structures, widening the channel, especially at the bends, could conceivably impact them. Similarly, deepening and widening the channel could impact objects that had been deliberately placed in the channel to hinder navigation. In the Delaware River, the most famous examples of such obstructions are the chevaux-de-frise, wooden frames that held upright timbers tipped with iron spikes, used during the Revolutionary War to defend Delaware River forts against British attack. Although most of the chevaux-de-frise were removed in the 1780's (Cox 1988), the Corps encountered remains of several of the frames near Fort Mifflin during the 1930's while dredging the channel down to 40 feet. Although it is possible that one or more of the chevaux-de-frise still remain in the navigation channel, the very nature of the placement of these obstructions (upright in the channel) makes it more than likely that past dredging episodes have removed significant portions of them. It is highly unlikely, therefore, that any intact chevaux-de-frise remain in the navigation channel. Nevertheless, it is possible that even fragments of a chevaux-de-frise could be considered potentially significant.

As discussed above in Section 4.4, ships have traveled through the Delaware Estuary for the last three hundred years. The Institute for Conservation Archaeology's 1979 landmark study of the potential for submerged cultural resources along the Atlantic coast continental shelf gave the area encompassing the Upper Delaware Bay extending into the Delaware River a "moderately heavy" rating for both known and predicted density of submerged cultural resources. The sheer volume of shipping and the natural hazards present in the Delaware River have resulted in at least 145 documented shipwrecks between Philadelphia and the sea (Cox 1984). The National Ocean Survey's Automated Wreck and Obstruction Information System lists 83 obstructions in that same stretch of

the waterway, most of which are reputed to be shipwrecks (AWOIS listing, June 12, 1987). Many of these shipwrecks, if even partially intact, would be significant on the basis of age (rare late eighteenth and early nineteenth century vessels) and/or historical association (e.g., vessels sunk during the Revolutionary War).

In order to better assess the likelihood that implementing the proposed project would actually impact objects or shipwrecks in or adjacent to the navigation channel, it is necessary to briefly review both the sedimentology of the river bottom and the history of channel improvements in the Delaware River. Except for a few locations where there are rock outcrops, the bed of the Delaware River below Philadelphia is generally sand and gravel overlaid with mud and silt. These are predominantly Holocene sediments that are generally less than 30 feet thick; in places, bedrock is within ten feet of the channel bottom.

Rock outcroppings, generally manifested as ledge rock, are encountered near Chester and Marcus Hook, and in the upper portion of Philadelphia Harbor. Geologically, the Delaware River and Bay can be divided into an upper estuary and lower estuary, with the dividing line between the two located near Bowers Beach, Delaware and the Cohansey River in New Jersey. The upper estuary, especially that portion of it below Philadelphia, is a fairly simple tidal river, with a river bottom as described above. The stretch of the river between Marcus Hook, Pennsylvania and Artificial Island, New Jersey is a major depositional area within the estuary. The lower estuary, with its broad coastal marshes, sand beaches, deep estuarine flats of coarse bottom sediments, and numerous mid-bay shoals and channels, is more geologically diverse than the upper estuary (Kraft 1988). The coarse bottom sediments of the lower estuary are thought to have been brought in from upriver at a time of lower sea level, or to have resulted from wave erosion along the shoreline; the present river regimen very seldom moves sand or other coarse material downstream into the lower bay (Kraft 1988). The dominant topographic feature of the lower estuary is the large number of long shoals that point finger-like to the north and west. Tidal forces have created these shoals, many of which have deep troughs between them. While the location of these shoals and troughs was largely determined by stream erosion patterns of the late Pleistocene, the changes in tidal currents that have occurred as a result of sea level rise have led to changes in the shape of many of the shoals, a process that continues today (Kraft 1988). Both the presence of the shoals and their tendency to undergo modification have long affected navigation in the lower estuary.

The presence of shoals is also a problem in the upper estuary. In its original condition, the Delaware River below Philadelphia was obstructed by numerous bars and shoals which reduced the minimum usable depth to 17 feet at mean low water (House Document No. 733, 1910). Prior to the start of systematic improvement of the river in the 1880's, a ship sailing upriver to Philadelphia needed as much as four days to complete the trip if it had to wait for high tides to pass over the shoals (Boggs 1929). Many of the original shoals have been removed or at least reduced by channel dredging over the last century. Since the start of systematic improvements to the Delaware estuary, over one billion cubic yards of material have been removed. The dredging, combined with the construction of dikes and jetties, has altered the natural regimen of the

river with respect to currents, depths, and tidal conditions. Present-day shoaling in the navigation channel is still partly a result of the net transport of sediment downstream, but it is also largely the result of the build up of areas where the ebb and flood flows of material do not take the same course, and a result of sediments sliding from the sides of the channel into the channel, which is causing a gradual lowering of the river bed for some distance on either side of the channel. To maintain the present 40-foot navigation channel, up to 5 million cubic yards are dredged annually.

Systematic improvements to the river began in 1885. These improvements are summarized in Table 5-26. It is clear from this table that there has been considerable disturbance to the river bottom over the last century, and in many areas, historic resources that might once have been present would long since have been removed or destroyed. Nevertheless, there are still portions of the river bed that have not been substantially altered and within which the potential for historic resources must be carefully evaluated. These areas include (1) the proposed bend widening areas at the intersections of ranges, which, although adjacent to the present channel, quite likely have not been dredged before, and (2) naturally deep areas within the main channel that may have never been dredged or may have only been minimally dredged. It would not be surprising to find shipwrecks in undredged areas adjacent to the channel, such as the locations proposed for bend widening. Typically, a vessel that encounters disaster while navigating the river would be deposited just off the channel, either because a navigational error led the ship off course where it ran aground and was abandoned or because the stricken vessel was able to maneuver to the closest shallow water in an effort to save the crew and the boat (Cox 1986). In order to ascertain the presence/absence of potentially significant historic resources at the areas proposed for bend widening, a remote sensing investigation, using a magnetometer and side scan sonar, was conducted at fourteen range intersections in the northern portion of the project area (Cox 1988). Of the more than sixty targets identified during the investigation, six are considered to be high probability targets. That is, each one has a magnetic and/or acoustic signature that is characteristic of a significant submerged cultural resource (See Table 5-27). The results of this investigation were coordinated with the Delaware, New Jersey, and Pennsylvania State historic preservation officers (SHPO). Their comments are included in the Pertinent Correspondence section of the Main Report. In the next phase of study, the Corps will conduct remote sensing investigations at the remaining bend widening areas. All high probability targets identified in areas that are still proposed for bend widening will then be subjected to underwater examination by divers, and the results coordinated with the appropriate State Historic Preservation Officer. Every effort will be made to avoid adverse impacts to any significant shipwrecks, and to minimize and appropriately mitigate any impacts that cannot be avoided.

Despite the significant amount of dredging that has taken place over the last century, there are still areas of the river and bay which are naturally deep, and which therefore may never have been dredged or may have been only minimally dredged. While surveys of the Delaware River has been conducted since the mid-nineteenth century, many of these early surveys contain insufficient data

Table 5-26 Previous Work in Delaware River, Philadelphia to the Sea

Year Authorized	Year Completed	Depth	Width	Quantity Dredged (C.Y.)*	Work Completed	Congressional Documents House/Senate	Number	Congress	Session	Year
Natural	- - -	at least 17'	175-600'	- - -	- - - - - - - -	House	2	59th	First	1906
- - - -	1874-1885	22'		3,467,000	Dredging at Mifflin bar, Cherry Island flats, Bulkhead shoal, Duck Creek flats, Schooner Ledge	House	64	45th	Third	1879
1885	1898	26'	600'	unknown	Channel from Christian Street, Philadelphia to deep water in Delaware Bay	Senate	59	48th	First	1885
1890	1898	12-26'	1000'	51,470,000	Philadelphia/Camden harbor improvements, including removal of Smith and Windmill Islands and a part of Petty Island and dredging of shoals	Senate House House	59 260 733	48th 50th 61st	First First Second	1885 1888 1910
1899	1909	30'	600'		Channel from Christian Street, Phila to deepwater in Delaware Bay; removal of material at Duck Creek flats, Baker shoal, Salem Cove, Deep Water Point, Cherry Island flats, Schooner Ledge, Mifflin bar shoal; bulkheads at Baker shoal and Edgemoor.	House House House	219 91 733	55th 56th 61st	Second First Second	1899 1900 1910
1910	1930	35'	800'	49,424,000	Channel from Allegheny Ave to deep water in Delaware Bay (63 miles long), with 1200' width at Bulkhead bar, 1,000 feet at other bends, 1,000 feet in Phila Harbor; also provided for construction of dikes	House	733	61st	Second	1910
1930	1934	30'-35'	variable	8,645,000	Anchorages 35 feet deep at Port Richmond and Mantua Creek, 30 foot anchorage at Gloucester, NJ and extend 1,000 foot channel in Phila Harbor to Horseshoe Bend	House	304	71st	Second	1930

Table 5-26 Previous Work in Delaware River, Philadelphia to the Sea (continued)

Year Authorized	Year Completed	Depth	Width	Quantity Dredged (C.Y.)*	Work Completed	House/Senate	Number	Congress	Session	Year
1935	1935	35'	- - -	2,878,000	35 foot deep anchorage area at Marcus Hook, PA	House	5	73rd	First	1934
1938	1942	40'	800'	53,380,000	37 foot channel from Phila-Camden Bridge to Phila Navy Yard, thence 40 feet deep to deepwater in Delaware Bay	Senate	159	75th	Third	1938
1945	1947-1957	37'	- - -	9,850,000	Enlargement of Mantua Creek and Marcus Hook anchorages to 37 feet deep	House	340	77th	First	1942
1945	1960	37'	- - -	1,102,000	A 37-foot channel, Allegheny Ave to Ben Franklin Bridge; deepen Port Richmond anchorage	House	580	76th	First	1940
1954	1962	40'	400-500'	4,451,000	A 40-foot channel from Allegheny Ave to Naval Base, 400 feet wide along west side of channel through Phila Harbor	House	358	83rd	Second	1954
1958	1964	40'	various	16,686,000	Deepen and widen anchorage at Marcus Hook	House	185	85th	First	1958

* U. S. Army Corps of Engineers, 1969.

Table 5-27 Potentially Significant Remote Sensing Targets Identified at Proposed Bend Widening Areas (Data from Cox 1988).

Target Number	Reference Number	Range Intersection Location	Water Depth	Magnetic/Acoustic Signature	Remarks
1	a4:4	Horseshoe Range and Eagle Point Range (near League Island, Philadelphia)	35'	Acoustic only	At the northern end of the bend, on the channel shoulder; may be a former bulkhead or the stern portion of a wooden-hulled vessel; location is site of Revolutionary War battle
2	e-1, 1:5	Tinicum Range and Eddystone Range (north of Chester, PA)	25'	Both	In the middle of the bend, near channel shoulder; three equally spaced objects, with an associated buoy and sinker; object appears to be over 200 ft long and may be a shipwreck
3	e-2, 4:16	Eddystone Range and Chester Range (near Chester, PA)		Both	Large scour, with widespread magnetic signature, indicating a large amount of metal. Object is probably not historic, but unusual nature warrants further investigation
4	i4:9	Cherry Island Range and Deepwater Point Range (near New Castle, DE)	35'	Both	Two large components, with associated scours; identity unknown. Located near channel buoy "IC"
5	11:15	Reedy Island Range and Baker Range (near Artificial Island)	15'	Magnetic only	Material buried; generated magnetic signature over an area approximately 100 feet long, with gradual build-up in intensity, a characteristic of submerged cultural resources
6	13:10	Reedy Island Range and Baker Range (near Artificial Island)	25'	Magnetic only	Target is buried; magnetic signature recorded over an area approximately 325 ft x 65 ft

to accurately determine the depth at any particular location. Systematic dredging of the river began in 1885 (refer to Table 5-26), with a navigation channel 26 feet deep by 600 feet wide completed in 1898. By 1909 the channel had been deepened to 30 feet, and subsequent deepenings through the 1960's have created the present 40 foot deep channel. Current maintenance dredging practices for the Delaware River, known as advance maintenance dredging, require dredging deeper than 40 feet (in some cases as deep as 44 or 45 feet), to ensure a minimum 40 foot channel throughout the year. Since the entire channel is now at least 40 feet deep, that was used as the starting depth for researching naturally deep areas; any historic resource that sank in an area of less than 40 feet of water, even though it might have settled some into the river bottom deposits, would most likely not have settled more than a couple of feet, and therefore would have already been impacted, if not destroyed, by previous channel dredging. Dredging operations in 1948 cut through what is believed to have been two shipwrecks during deepening of the Mantua Creek anchorage to 37 feet (Cox 1988). Hydrographic surveys of the Delaware River conducted by the Corps in 1909, just after completion of dredging the 30 foot channel, show seven locations along the channel with depths of 40 feet or greater between Philadelphia Harbor and Bombay Hook Point (U.S. Congress, 1910). By 1937, after completion of the 35 foot channel and the creation of four anchorage areas, hydrographic surveys show twenty-three areas with depths of at least 40 feet, including the original seven, between Philadelphia and Bombay Hook Point, plus additional deep areas from Bombay Hook point to the mouth of the bay (U.S. Congress 1938) (see Table 5-28). Of the twenty-three deep areas north of Bombay Hook identified in the 1937 survey, only the original seven from the 1909 survey are of concern. Since the remaining deep areas did not show up in the 1909 detailed survey, they are most likely the result of the dredging work in the channel that took place between 1909 and 1937. It is also possible that some of these "new" areas were used as sources of borrow for the creation of disposal areas such as Artificial Island and Killcohook. Any resource that may have been present in these areas prior to their deepening would have been disturbed, if not completely destroyed, by dredging activities.

Therefore, that leaves for consideration the original seven locations with depth of at least 40 feet, plus those areas within the channel in Delaware Bay that were identified as having a depth of 40 feet or greater in the 1937 survey but which were beyond project limits, and therefore not covered, in the 1909 survey. Above Bombay Hook, the deep areas total a little less than nine miles, while in the bay deep areas may cover more than thirty seven miles in length. At present the Corps is researching additional hydrographic surveys and old dredging records to determine whether any of these areas are deep as a result of pre-1909 work in the channel, and whether any area has been deepened through dredging work. It is known that considerable quantities of material have been removed from areas in the Delaware River channel and used as fill for the construction of landfill along the shore, and in major highway projects. For the deep areas in the bay, a more detailed examination of hydrographic charts is being undertaken to pinpoint those areas that are deeper than 50-55 feet and which therefore are below any possible impact as a result of deepening the channel to 45 feet. For those channel areas within the river and bay which do

Table 5-28 Channel Areas with Depths of at Least 40 Feet MLW (1909 and 1937 surveys).

Area No.	General Vicinity	River Miles	Length	Remarks
1	Horseshoe Shoal	6.7 to 8.1	1.4 miles	channel underlain by sand (1909: Sheets 10 & 11; 1937: Sheet 1)
2	Philadelphia Airport	14.1 to 15.5	1.4 miles	interbedded silt and sand (1909: Sheet 9; 1937: Sheet 1)
3	Chester Island	18.9 to 20.1	1.2 miles	bedrock, overlain by sand and silt, within 10 feet of channel bottom (1909: Sheet 7; 1937: Sheet 1)
4	Delaware Memorial Bridge	33.1 to 34.4	1.3 miles	more than 20 feet of silt below channel bottom sand (1909: Sheet 5; 1937: Sheet 2)
5	Pea Patch Island	41.5 to 42.6	1.1 miles	mainly silt with some fine sands areas (1909: Sheet 3; 1937: Sheet 2)
6	Reedy Point Anchorage	45.7 to 47.7	2.0 miles	mainly silt with some fine sands areas (1909: Sheet 2; 1937: Sheet 2)
7	Bombay Hook Point	63.4 to 63.8	0.4 miles	mainly silt with some fine sands areas (1909: Sheet 1; 1937: Sheet 3)
		SUBTOTAL	8.8 miles	
8	Bombay Hook Point to Fourteen Foot Bank Light	63.8 to 87.0	23.2 miles	fine to coarse sand (1937 survey only; Sheet 3)
9	Brandywine Shoal to Cape Henlopen	90.7 to 105.0	14.3 miles	fine to coarse sand (1937 survey only; Sheet 3)
		TOTAL	46.3 miles	

lie within the zone of potential impact, and which do appear to be naturally deep, the Corps will conduct a remote sensing survey for cultural resources in the next phase of study. The results of the survey will then be coordinated with the staff of the appropriate State historic preservation officer, and, in consultation with that staff, the Corps will devise appropriate means to avoid or minimize adverse impacts to any significant historic resource.

Each of the three proposed new dredged material disposal sites is located along the New Jersey shore of the Delaware River at the confluence of the river with one of its tributaries. It is not surprising, therefore, that each site is found in an area rich in prehistoric and historic resources. However, two of the sites are previously used dredged material disposal sites. The use of site 15D for the disposal of dredged material will have no effect on significant prehistoric or historic resources, since previous use of this site for disposal of dredged material has buried whatever resources might have been here, as well. There is a National Register property, the Salisbury Farm site, located nearby, but it is well outside of the boundaries of site 15D and will not be adversely impacted by the proposed use of site 15D. The second previously used disposal site is Raccoon Island, which is now covered by at least 20 feet of fill. Use of this site for additional disposal of dredged material will have no effect on significant cultural resources.

The third, and last, proposed dredge material disposal site is site 170, the GATX site. Of the fifteen cultural resources sites identified during studies for the once-proposed GATX terminal facility (Wilson 1976), eight lie within the boundaries of the proposed disposal area. These eight sites include four house sites, two Revolutionary War facilities, and two prehistoric sites. Several of these sites were destroyed in the 1940's when lands adjacent to Little Mantua Creek were bulldozed into dikes, and fill was placed in the enclosed area (Sites 6, 9, 11 and D). However, at least one of the prehistoric sites (Site B) and three of the historic house sites (Sites 2, 3, and 4) have the potential to be adversely impacted by the use of Site 170 as a dredged material disposal site. The Corps is continuing coordination with the Office of New Jersey Heritage (the New Jersey State Historic Preservation Officer, or SHPO) to determine the present condition and significance of these prehistoric and historic resources. Should any of these sites prove to be eligible for the National Register of Historic Places, the Corps and the New Jersey SHPO will develop plans to avoid or mitigate adverse impacts to the site, according to the procedures of the Advisory Council on Historic Preservation, as set forth in 36 CFR Part 800. The Corps has attempted to coordinate the project with the New Jersey SHPO over the last 20 months. Despite repeated attempts including meetings, a letter of coordination has not been received. Should it be necessary the Corps will work with the Advisory Council on Historic Preservation to complete the Section 106 process.

Thus, of the three proposed dredged material disposal sites, adverse impacts to cultural resources are not expected at two of the sites. If adverse impacts are determined to be the possible at the third site, the Corps in consultation with the New Jersey SHPO, will endeavor to avoid or mitigate these impacts.

The continued use of the existing Reedy Point North and South Disposal Areas will have no effect on prehistoric or historic resources since previous use of the site for disposal of dredged material has buried whatever resources might have been there.

5.2 Socio-economic Effects

The social impacts of implementing the proposed plan are not significantly adverse. Slight increases in noise, resulting from dredging activities, and air pollution, resulting from engine exhaust of dredges and earth moving equipment, would be short-term impacts and minor. Aesthetics would be slightly impacted due to the temporary increase in turbidity at the dredging site, and the change in elevation at the disposal areas.

One of the selected upland dredged material disposal sites, site 15D, was planted in corn and soybeans in 1989. The use of this site for dredged material disposal purposes would remove the land from agricultural production. Site 15D has been used for dredged material disposal in the past. The existing farming occurs on dredged sediments. As such, this land is not considered prime or unique farmland. Due to the disturbed nature of the site, removal of the area from agriculture is not considered significant with respect to agricultural activities in Gloucester County New Jersey.

The economic analysis quantified savings in transportation costs resulting from the proposed channel deepening for vessel movements through the Delaware River port system. Transportation savings were computed by combining the costs of vessel operations, projections of future growth in commodity tonnage, and the impact of changes in the distribution of vessels using the channel. The commodities to benefit include crude oil, coal, iron ore, containers and scrap. Benefitting crude oil import movements originate from West Africa, North Africa, the Middle East, the North Sea, Norway the Bahamas, Indonesia, China, Mexico, Venezuela, and Australia. Benefitting coal export movements are destined to Continental Europe, England, Turkey, and North Africa. Benefiting iron ore import movements originate from Atlantic Canada, Brazil, Sweden, and West Africa; and benefitting scrap exports are destined for Turkey.

An econometric framework using a two-stage least squares multiple regression model was applied to predict cargo tonnage carried by vessels if the channel were deepened. The econometric framework estimated production functions of vessel operations using detailed actual vessel movement data for the last five available years. The individual ship's production process represent the technical constraints faced by ship operators as well as their market constraints since the demand for ocean transportation services is a derived demand, meaning that the demand for other goods and services determines the demand for ocean transportation.

The amount of tonnage which can be carried by a ship leaving or entering a harbor should be positively correlated to its size. The larger the ship, the greater its capacity for transporting tonnage will also be. Since ship operating firms are assumed to be profit maximizers faced with a demand for

their services derived by other markets, their optimal behavior should be characterized by providing a supply of transportation services at a minimum cost. In other words, ship operators should be using the most economically efficient ship available to transport cargo. However, channel dimensions generally constrain ship operators by limiting the amount of cargo which can be loaded upon their vessels. This constraint results in operators using the most efficient ships at less than their optimal load or using less efficient ships. Either way, ship operators are confronted by higher costs directly caused by a constructed channel. The objective of the regression analysis was to produce a model to be used as a tool to predict cargo tonnage carried by vessels, and thus, simulate actual operating practices under different channel depths.

Predicted tonnage was estimated for three data bases: crude oil vessels with operating drafts less than or equal to 40 feet (which is the maximum draft possible under the existing channel condition), coal vessels, and iron ore vessels. The class of crude oil vessels with operating drafts greater than 40 feet will not carry additional tonnage into Big Stone Beach Anchorage in the lower bay, due to channel deepening. The operators of these vessels have made a decision currently to lighter at the anchorage until the vessel operating draft is sufficiently reduced to allow for navigation up river to the pertinent facility. Benefits, therefore were solely based on savings from reduced lightering requirements. Other vessel types which do not lighter are expected to continue to behave optimally by chartering the most cost efficient vessel for the available channel depth. The data bases were disaggregated by trade route and vessel design draft class. Average operating draft, average design deadweight tonnage, and average carried tonnage were calculated for each vessel class by trade route.

Individual transportation cost models were developed for each design draft vessel class and for each trade route. Estimates of the total transportation cost for each design draft class by trade route by commodity over the project life were accomplished by combining projections with fleet distributions. Where appropriate, the impact of a fleet shift due to operational efficiencies as the channel is deepened was also incorporated into the analysis. These shifts were estimated based on the relative change in marginal cost for each vessel design draft class. Subtracting the total transportation cost of each channel depth improvement from the total transportation cost for the existing 40 foot (MLW) channel depth results in estimates of cost savings from the more efficient movement of tonnage. Finally, the transportation savings for all benefitting commodities and trade routes were summed and annualized.

5.3 Mitigation

The appropriate application of mitigation is to formulate a project that avoids or minimizes adverse impacts first, and compensates for impacts only as a final alternative. This concept has been incorporated into formulation of the recommended plan of improvement. The most important step in the mitigation process is avoidance of impacts. The dredged material disposal area screening analysis was effectively used to select disposal sites that do not contain valuable or sensitive ecological habitats. The analysis resulted in the

selection of three additional disturbed areas that have previously been used for dredged material disposal. These areas are predominantly vegetated with common reed and cultivated agricultural species. Site 170 is the only site with habitat diversity. This site contains areas dominated by oldfield herbaceous vegetation, shrubs and mature trees. Wetland habitats in the vicinity of disposal sites will be preserved by aligning dikes to exclude these areas. As such, the proposed upland disposal sites do not contain wetland or other aquatic habitat types. The continued use of these sites for dredged material disposal operations would have no long-term adverse impacts on the quality of the natural or social environment within the study area.

Avoidance would also be employed to lessen the impact of dredging on the aquatic environment. Coordination is on-going with the Delaware Basin Fish and Wildlife Management Cooperative with regard to appropriate seasonal dredging restrictions. Previous restrictions precluded bucket dredging and/or overboard disposal in the Delaware River from 1 March through 31 May and from 1 September through 30 November. These restrictions were in place to prevent disruption of anadromous fish migrations through creation of excessive turbidity and decreased dissolved oxygen concentrations. No restrictions were required for hydraulic or hopper dredging with upland disposal. New restrictions are now being employed with regard to bucket dredging, blasting and overboard disposal. Between Delaware Bay and the Delaware Memorial Bridge, bucket dredging, blasting and overboard disposal are restricted from 1 March through 30 June. Between the Delaware Memorial Bridge and the Betsy Ross Bridge, which is above the upstream limit of the proposed project, bucket dredging, blasting and overboard disposal are restricted from 15 March through 31 May and from 1 September through 30 November. With regard to hydraulic dredging, a 3-year study will be initiated in 1992 to consider potential impacts on fishery resources in the Delaware River. The results of this study will be used to evaluate the need for hydraulic dredging restrictions. The need for such restrictions can not be determined at this time. The Corps is providing funding to the Delaware Basin Fish and Wildlife Management Cooperative in support of this work. Chemical testing of channel sediments and groundwater in the vicinity of disposal sites would assist in avoiding water quality impacts by facilitating the identification of problems before they become significant. The monitoring and control of effluent leaving an upland disposal site would also minimize potential water quality impacts by limiting the concentration of suspended sediments in the effluent.

Through appropriate consideration of the environment during plan formulation, and the use of established procedures during construction and maintenance of the proposed project, significant adverse environmental impacts would be avoided and/or minimized. Construction of replacement habitats is not required to mitigate with-project losses.

Throughout the course of this study the Corps has endeavored to avoid or minimize adverse impacts to cultural resources. With regard to the proposed disposal sites, only Site 170 has the potential to contain significant cultural resources. In the next phase of study a cultural resources investigation of the identified prehistoric and historic sites at 170 will be undertaken, and the results coordinated with the New Jersey State Historic Preservation Officer (SHPO). With regard to the proposed channel deepening and bend widening, all bend widening areas, and all areas within the channel with natural depths of 40 feet or greater, will be subjected to a remote sensing survey in the next phase of study. In consultation with the appropriate state historic preservation officer, the Corps will conduct an underwater examination of each remote sensing target that has the potential to be a significant historic resource.

If significant cultural resources are identified at proposed disposal site 170 or found within proposed project areas in the Delaware River, the Corps will follow the procedures outlined in the Advisory Council's regulations, 36 CFR Part 800, to avoid or minimize adverse impacts to significant cultural resources.

5.4 Unavoidable Adverse Environmental Impacts

Unavoidable adverse environmental impacts associated with the proposed dredging include loss of benthic organisms in the areas to be dredged, and water quality impacts that result from the suspension of bottom sediments during the dredging process. These impacts would also occur with the no action alternative and alternative channel plans that are shallower or one-way, but to a lesser degree due to the smaller amount of dredging required. The removal of approximately 45,100 cubic yards of rock from the channel would also adversely impact the aquatic environment, as the use of explosive charges would be required. This work would be appropriately timed to minimize impacts to finfish. A five-foot deepening of the existing channel is also likely to promote a measurable upstream movement of saline water. However, based on a conservative modelling effort, the projected increases would be well within the existing standards, under conditions that occurred during the 1960's drought of record. Disposal of dredged material at the upland sites would result in the loss of existing vegetation. These sites have all been used for disposal of dredged material in the past and are disturbed. While these areas do provide some wildlife habitat, the environmental impacts associated with additional disposal are considerably less than the use of previously undisturbed upland areas. In Delaware Bay, dredged material would be used for beneficial purposes. Proposed options include wetland creation in areas where wetlands have been lost to erosion, sand stockpiling for future beach nourishment efforts and island creation for habitat development. While these options would change exsiting habitats, the resulting habitats are considered more productive and beneficial. Final site section will occur during the next phase of planning, so that additional environmental testing can be accomplished to locate areas that would have minimal impact on the acquatic environment.

5.5 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. In 1986, the ports in the vicinity of Philadelphia were responsible for 100,000 jobs in the Delaware Valley, which generated one billion dollars of income. State and local taxes, including income, profit and sales taxes, amounted to over 92 million dollars. The proposed deepening of the existing navigation channel to these ports is considered a significant part of keeping the ports competitive with others in the United States. Other efforts are underway to improve port facilities, in order to maintain the existing level of commerce and attract additional users. These efforts play a significant role in the maintenance of a healthy regional economy that would benefit all.

Short-term use of the natural environment would be necessary to achieve long-term productivity of the Delaware River ports. Dredging does place 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. In addition, a higher level of dredging would require more dredged material disposal capacity. This translates into a need for more land than is necessary to maintain the existing channel, or the no action alternative. The sites selected for the proposed project have all been used for dredged material disposal in the past. Use of these already disturbed sites does minimize the impact on the natural environment.

5.6 Irreversible and Irretrievable Commitments of Resources

There are no irreversible or irretrievable commitments of resources required for implementation of the proposed plan. 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 if maintenance dredging is not continued. The use of selected dredged material disposal areas does not represent any irreversible or irretrievable commitments of resources. These areas have all been used for dredged material disposal in the past. While initial use would result in the loss of existing vegetation, a similar type of vegetation would be expected to return if disposal activities were stopped. As such, similar wildlife habitat would develop subsequent to disposal.

5.7 Cumulative Effect

The cumulative effect of alternative dredging schemes increases as the volume of material to be dredged increases. The greater the volume of material, the longer the duration of disturbance. Dredging activities temporarily increase turbidity in the water column, which may result in short-term degradation of water quality. The potential for adverse effects on aquatic resources can increase with the duration of the disturbance, depending on the degree of water

quality degradation. Based on a comparison of the economic costs and benefits of the alternatives, a two-way, full-width channel with a depth of 45 feet at mean low water (mlw) was selected as the proposed plan of improvement. Channel depths in one-foot increments between 41 and 46 feet mlw were considered during the evaluation. Channel schemes included the full-width option and two asymmetric designs that would deepen the inbound lane, but not the outbound lane. As such, the only dredging alternative considered with a potentially greater cumulative effect would be the two-way, full-width channel with a depth of 46 feet at mlw. Other dredging alternatives with potentially greater cumulative effects that were previously eliminated from the study include deepening the channel to 50 feet at mlw, deepening the channel between Philadelphia and Trenton, NJ, channel realignment at the Benjamin Franklin Bridge, channel realignment at Marcus Hook, PA and additional anchorage modifications. Sediment quality data collected to date has not indicated significant concerns relative to water quality degradation during dredging operations. Adverse effects will be minimized by using seasonal dredging restrictions to avoid disturbances during appropriate times of the year.

An attempt has been made to minimize the cumulative effect of dredged material disposal operations by maximizing the efficiency of required disposal sites. Selected upland sites for initial construction include active and previously used dredged material disposal sites, so undisturbed tracts of land will not be required. Subsequent maintenance activities will utilize these same sites, along with the active areas currently used for maintenance of the existing 40-foot navigation project. The proposed plan includes periodic dike raising to make maximum use of all sites. In Delaware Bay, beneficial use options will be employed to productively dispose of dredged material. These options include sand stockpiling for future beach nourishment projects, wetland creation to restore areas lost to erosion and island development for habitat creation. Proper management of upland and beneficial use sites will minimize the cumulative effect of dredged material disposal operations associated with the proposed plan of improvement.

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The following individuals were primarily responsible for the preparation of this Environmental Impact Statement.

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7.0 Public Involvement

The Delaware River Comprehensive Navigation Study was initiated in 1982 to address the navigation problems of all the tributaries and waterways that support commercial navigation along the tidal estuary. In 1983 a reconnaissance report identified problems with both existing Corps projects and other areas identified by the public. Due to the study scope and complexity, a decision was made to divide future efforts into separate studies. This has resulted in the preparation of several interim reports that address the navigation needs of component water ways of the Delaware River system.

A notice of intent to prepare a Draft Environmental Impact Statement (DEIS) for the main channel deepening project was published in the Federal Register on May 4, 1989. A notice of availability for that DEIS was published in the Federal Register on July 13, 1990. Based on comments received on the DEIS it was determined that an amendment would be necessary to provide additional information regarding the environmental impacts of the proposed project. A notice of intent to prepare the DEIS amendment was published in the Federal Register on June 12, 1991. A notice of availability for the DEIS amendment was published in the Federal Register on December 6, 1991.

The Delaware River Comprehensive Navigation Study has evolved through several phases of planning. Prior to initiation of this study, an extensive analysis was conducted to identify and screen potential dredged material disposal sites to meet future disposal capacity needs. This study was conducted in conjunction with a Plan Formulation Committee that was comprised of appropriate Federal, State and local agencies. This committee met several times between 1980 and 1983, and assisted in the formulation of screening criteria and site identification.

A study initiation letter for the current study was issued to the public on April 29, 1982. Since then, several interim reports have been prepared and released to the public for their review and comment. In addition, public newsletters have been issued in March 1984, August 1985, and September 1989, which provided project information and requested comments. An interagency scoping meeting for preparation of the DEIS for the main channel deepening project was held on June 22, 1989. That meeting was attended by personnel representing the U.S. Fish and Wildlife Service, the U.S. Environmental Protection Agency, the National Marine Fisheries Service, the Delaware River Basin Commission, the State environmental agencies of Pennsylvania, New Jersey and Delaware, and the State Historic Preservation Officers of these States. Scoping for the preparation of the DEIS amendment included a series of meetings with Regions II and III of the U.S. Environmental Protection Agency, the New Jersey Department of Environmental Protection, the Delaware Department of Natural Resources and Environmental Control and the Delaware Estuary Program. Letters of comment on the DEIS were also instrumental in developing the scope of issues for the amendment. All of the information gathered during preparation and coordination of the DEIS and the DEIS amendment has been used to develop the content of this Final Environmental Impact Statement.

The U.S. Fish and Wildlife Service provided a Section 2(b) report, pursuant to the Fish and Wildlife Coordination Act, in February 1992. That report is reprinted in its entirety in the comment/response section of the main report. The summary of recommendations section of the report, which is found on pages 24 and 25, is provided here, along with responses to the recommendations.

VII. SUMMARY OF RECOMMENDATIONS

For the Final EIS to adequately assess potential project-related adverse impacts to fish and wildlife resources, and identify appropriate mitigative measures, the Service recommends that the Corps include the following measures:

1. Incorporate seasonal dredging, blasting, and aquatic disposal restrictions adopted by the Technical Committee of the Delaware Basin Fish and Wildlife Management Cooperative into all project plans.

2. Quantify the actual extent of benthic community disruption from the proposed project in excess of that caused by current maintenance dredging.

3. Provide a thorough discussion of sample size determination and site selection for contaminants testing.

4. Provide results and discussion of grain size analysis conducted in conjunction with contaminants testing, and clarify the number of sediment samples that exceeded the NJDEPE ISAL level for arsenic.

5. Conduct additional contaminant testing of sediments to be dredged, including bulk sediment or elutriate toxicity testing to determine the potential magnitude of impacts from resuspension of contaminants on living resources, and avoid any effluent discharge into tributaries, including racoon creek.

6. Prepare a Biological Assessment to address potential project-related adverse impacts to the endangered bald eagle and peregrine falcon that are known to occur in the project area.

7. Coordinate with the National Marine Fisheries Service regarding potential adverse project impacts to threatened and endangered species under that agencies jurisdiction.

8. Coordinate with the States of Delaware and New Jersey, and the Commonwealth of Pennsylvania regarding potential occurrence of State listed threatened and endangered species in the project area.

9. Document the applicability of any 404(r) exemption to State water quality certification and compliance with State Coastal Zone Management Plans.

10. Document the assumptions of the salinity model used to demonstrate its applicability to the lower bay.

11. Assess the potential impact of proposed channel deepening on circulation patterns in Delaware Bay, and analyze the possible effects of any changes on oyster seed beds and blue crab recruitment.

12. Investigate the current availability of site 17G as a preferred alternative to site 17O.

13. Retain vegetated buffer zones between any disposal areas on site 17O and the adjacent tidal wetlands.

14. Plan activities on upland disposal sites, including tree felling, vegetation clearing, other site preparation, and inundation of wildlife habitat with dredged material to occur outside the April 1 to July 15 migratory bird nesting season.

15. Develop plans to fully mitigate for all habitats adversely impacted by dredged material disposal. Mitigation should be in compliance and pursuant to the Fish and Wildlife Service's Mitigation Policy.

16. Coordinate closely with the Service and the States of New Jersey and Delaware regarding opportunities for creation and maintenance of habitat for waterfowl and other wildlife on active disposal sites. Planning and design should be consistent with the goals of the North American Waterfowl Management Plan.

17. Conduct an investigation of management strategies to limit the potential for botulism poisoning of wildlife using wetlands on disposal sites.

18. Provide a more detailed description of potential adverse impacts to living resources as a result of expanded use of the Buoy 10 disposal site.

19. Present a more detailed description of alternatives to aquatic disposal at the Buoy 10 site to include wetland restoration, wetland island creation, and beach nourishment options. Biological as well as engineering studies of the sites will be necessary prior to final assessment of the suitability of these alternatives.

Recommendation number 1 pertains to seasonal dredging restrictions. Coordination is on-going with the Delaware Basin Fish and Wildlife Management Cooperative with regard to appropriate seasonal dredging restrictions. Previous restrictions precluded bucket dredging and/or overboard disposal in the Delaware River from 1 March through 31 May and from 1 September through 30 November. These restrictions were in place to prevent disruption of anadromous fish migrations through creation of excessive turbidity and decreased dissolved oxygen concentrations. No restrictions were required for hydraulic or hopper dredging with upland disposal. New restrictions are now being employed with regard to bucket dredging, blasting and overboard disposal. Between Delaware Bay and the Delaware Memorial Bridge, bucket dredging, blasting and overboard disposal are restricted from 1 March through 30 June. Between the Delaware Memorial Bridge and the Betsy Ross Bridge, which is above the upstream limit of the proposed project, bucket dredging, blasting and overboard disposal are

restricted from 15 March through 31 May and from 1 September through 30 November. With regard to hydraulic dredging, a 3-year study will be initiated in 1992 to consider potential impacts on fishery resources in the Delaware River. The results of this study will be used to evaluate the need for hydraulic dredging restrictions. The need for such restrictions can not be determined at this time. The Corps is providing funding to the Delaware Basin Fish and Wildlife Management Cooperative in support of this work.

Recommendation number 2 pertains to the extent of benthic community disruption in areas not currently maintained through dredging. The acreage of required dredging in areas not currently dredged will be provided during the Preconstruction, Engineering and Design (PED) phase of project planning, when detailed channel surveys are prepared. A review of existing survey data for the channel, the Marcus Hook Anchorage, Beckett Street Terminal and bend widening locations indicated that existing side slopes are less than 3H:1V, and located at depths greater than 10 feet. Based on the existing geometry, it is concluded that the proposed dredging would not disturb side slopes to a significant extent. This will be verified during the PED study.

Recommendations 3 through 5 pertain to sediment quality testing, and potential contaminant impacts on living resources. The 1991 sediment testing program was designed by Regions II and III of the U.S. Environmental Protection Agency. The number of samples collected and the analyses conducted was accomplished at their request. The USEPA did consider areas with a high probability of contamination when selecting sampling sites. The results of the grain size analyses are provided in Tables 5-22 and 5-23 of the FEIS. The confusion with regard to arsenic concentrations in sediment has been clarified in the FEIS. With regard to toxicity testing, additional sediment quality analyses are planned for the PED phase of project development. These analyses will include the application of the tiered testing approach as outlined in the "Green Book". The bulk and elutriate data collected to date adequately characterizes the sediment quality within the project area. Bioassays, bioaccumulation testing and modelling of disposal operations, including calculations of mixing zones will be used to evaluate selected options with regard to impacts on aquatic life. The discharge of water from upland disposal sites will be to the Delaware River, not tributaries such as Raccoon Creek.

Recommendations 6 through 8 pertain to threatened and endangered species. In the Service's November 1989 planning aid report, the Service indicated that the peregrine falcon nests or has attempted to nest on Delaware River bridges within the project area. The Service also indicated that aside from occasional transient individuals, no other federally listed or proposed threatened or endangered species under their jurisdiction were known to occur within the project area. There was no indication that a Biological Assessment would be required to address adverse impacts to threatened or endangered species. Detailed Environmental Assessments on the selected upland disposal sites are scheduled to be prepared during the PED phase of planning. This issue will be addressed as part of these assessments. The Corps has been attempting to coordinate with the National Marine Fisheries Service with respect to species under their jurisdiction. To date, no coordination letter has been received. The NMFS has not had endangered species concerns with regard to the existing Philadelphia to the Sea navigation project. The Corps will continue its coordination efforts with the NMFS and State agencies with respect to these concerns.

Recommendation number 9 concerns the Section 404(r) exemption from State Water Quality Certification and compliance with State Coastal Zone Management Plans. The Section 404(r) exemption is applicable provided that an Environmental Impact Statement is prepared, that the assessment of effects includes the application of the 404(b)(1) guidelines, and that the EIS is submitted to Congress before the discharge takes place, and prior to either authorization or appropriation of funds for project construction. These conditions are met for the proposed project. The Section 404(r) exemption is part of Corps' regulation, and has been used in many projects around the country. With regard to compliance with State Coastal Zone Management plans, consistency letters have been provided by the States of Pennsylvania, New Jersey and Delaware. These letters can be found in the comment/response section of the main report.

Recommendations 10 and 11 pertain to potential salinity and circulation impacts in Delaware Bay. To date, potential salinity impacts associated with channel deepening have been addressed through application of the DRBC's Transient Salinity Intrusion Model (see section 5.1.2 of the FEIS). A more sophisticated 3-D hydrodynamic model will be employed during the PED phase of planning to further evaluate salinity concerns. This model also has the capability of addressing the effect of channel deepening on other physical features of the Delaware Estuary, such as circulation patterns. The first step in this modelling effort will be a scoping/coordination phase to identify all agency concerns to be addressed through model runs. The Corps will consult with the U.S. Fish and Wildlife Service to insure that their concerns are sufficiently addressed.

Recommendation number 12 requests a reevaluation of the availability of candidate dredged material disposal site 17G as a preferred alternative to Site 17O. Site 17G will be reevaluated during the PED phase of planning.

Recommendation number 13 requests the retention of vegetated buffer zones between the 17O disposal area and adjacent tidal wetlands. The detailed Environmental Assessments for the upland disposal sites will include a second wetland delineation determination. This delineation will lead to a precise determination of dike alignments to avoid wetland habitats. The inclusion of vegetated buffer zones between disposal sites and adjacent wetlands will be part of this dike alignment determination.

Recommendation number 14 requests that construction activities pertaining to preparation of upland dredged material disposal areas be restricted between April 1 and July 15 to protect the migratory bird nesting season. During the next study phase disposal area preparation activities will be investigated, and measures identified to avoid unnecessary adverse impact to nesting birds.

Recommendations 15 through 17 request mitigation for the use of upland dredged material disposal sites, pursuant to the Fish and Wildlife Service's Mitigation Policy and the North American Waterfowl Management Plan. Selected upland dredged material disposal sites have all been previously used for dredged material disposal purposes and are disturbed areas. Based on the wetland delineations conducted by the U.S. Fish and Wildlife Service, boundaries of the proposed sites have been aligned to avoid wetland impacts. In addition the proposed project does include wetland creation as a beneficial use of material

dredged in Delaware Bay. Another beneficial use option in Delaware Bay is island creation, also for habitat development. As such, additional habitat compensation at these previously used dredged material disposal sites is not warranted. The Corps will continue to coordinate with the Service with regard to developing disposal site management plans that will provide some habitat benefits that are consistent with the goals of the North American Waterfowl Management Plan. These plans may include such activities as maintaining ponded water on sites and promoting the growth of beneficial wetland vegetation between disposal operations. The potential for botulism poisoning of wildlife using this habitat would be a concern of the investigations.

Recommendations 18 and 19 request more detailed information pertaining to open water disposal in Delaware Bay. Recommendation 18 cites expanded use of the Buoy 10 disposal site. This is in error as beneficial use options have been selected instead of the Buoy 10 site for project construction. With regard to beneficial use options, more detailed studies are required during the PED phase of planning. These studies will include a benthic invertebrate sampling program to assess habitat quality at selected sites. Bioassays and bioaccumulation studies will also be necessary to determine the impact of open water disposal on aquatic life. Along with biological studies, detailed engineering studies will be conducted to develop feasible designs for all options.

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9.0 Index

Subject	Page
Alternatives Analysis	3-1-75
Anadromous Fish	4-29; 5-96
Anchorages	2-4; 3-7
Aquatic Disposal	3-28
Artificial Island D/A	3-21; 3-25
Asymmetric Channel Design	3-12
Benthic Invertebrates	4-24; 5-94
Benthic Recolonization	5-95
Blue Crab	4-29
Buoy 10 D/A	3-25; 3-22
Climate	4-5
Comparative Impacts	3-83
Cultural Resources	4-41; 4-49; 5-102
Drought	4-9; 5-21
Effluent Discharge	5-78
Elutriate Test	4-16; 5-44
Environmental Statutes	1-3-6
Finfish	4-29; 5-95
Geology	4-5-6
Groundwater	4-6-8; 5-1-14
Hydraulic Dredging	5-77
Hydrology	4-8; 5-15
Ichthyoplankton	4-38
Irreversible and Irretrievable Commitments	5-116
Killcohook D/A	3-19; 3-24
Lightering	2-9
Mitigation	3-81; 5-113
MSX	4-28; 5-25
National Park D/A	3-16; 3-24
Need for Action	2-1-9
No Action	3-10; 3-14

Subject	Page

Objective of Action 2-1
Oldmans D/A 3-18; 3-24
Oyster 4-26; 5-24

Pedricktown North D/A 3-18; 3-24
Pedricktown South D/A 3-18; 3-24
Penns Neck D/A 3-19; 3-24
Phytoplankton 4-22; 5-94
Planktonic Invertebrates 4-24; 5-94
Population 4-4
Public Concerns 2-9
Public Involvement 7-1

Recreation 4-5
Reedy Point North D/A 3-20; 3-77; 5-86
Reedy Point South D/A 3-20; 3-77; 5-86
References 8-1
Rock Removal 3-2; 5-98

Salinity 4-9; 5-15
Section 404(b)(1) Evaluation 1-4
Sediment Distribution 5-48; 5-63
Sediment Quality 4-16; 5-36
Selected Plan 3-76
Shallows 5-81
Socio-economics 4-4; 5-112
Spatial Analysis 3-13
Study Area 4-1
Study Authority 2-1

Thin Layering 3-26
Threatened and Endangered Species 4-40; 5-101
Transient Salinity Intrusion Model 5-20
Two-Way Channel 3-11

Unavoidable Adverse Impacts 5-115
Upland Disposal 3-25

Vegetation 5-102

Water Quality 4-10-15; 5-36
Wetlands 4-17; 5-81
Wildlife 4-38; 5-100

Zooplankton 4-23; 5-94

SECTION 404(b)(1) EVALUATION
FOR
DELAWARE RIVER COMPREHENSIVE NAVIGATION STUDY MAIN CHANNEL DEEPENING

I. PROJECT DESCRIPTION

a. Location	a. Delaware River and Bay from Philadelphia to the Sea with dredging, rehandling and confined disposal at disposal sites in Delaware and New Jersey and various locations in Delaware Bay for beneficial uses.
b. General Description	b. Deepening of existing commercial navigation channel in Delaware River and Bay from -40 feet mlw to -45 feet mlw
c. Authority and Purpose	c. Authorized by a resolution adopted by U. S. House of Representatives, Committee on Public Works dated December 1, 1970 and resolutions adopted by the U. S. Senate, Committee on Public Works, dated March 1, 1954 and September 2, 1974
d. General Description of Dredged or Fill Material	
(1) General characteristics of Material (grain size, soil type)	(1) Gravel, sand and silt; See Tables 5-22 and 5-23 of the FEIS.
(2) Quantity of Material (cu. yds.)	(2) Approximately 50 million cubic yards (mcy) initial; Approximately 6.25 mcy annually - maintenance;
(3) Source of Material	(3) Delaware River Navigation Channel from Beckett Street Camden, N.J. to the Mouth of Delaware Bay.

C-1

e. Description of the Proposed Discharge Site(s)

(1) Location (map)	(1) Site 170 - Fig. 3-4; Sites 15D and Raccoon Island - Fig. 3-5; Reedy Pt. - Fig. 3-8 and Beneficial use sites -Fig. 3-15 -all in FEIS
(2) Size (acres)	(2) 170 - 180 ac.; 15D - 575 ac.; Raccoon Island - 600 ac.; Reedy Pt. - 255 ac. (2 sites); Beneficial use sites - unconfined open water.
(3) Type of Site	(3) Proposed and existing upland disposal sites adjacent to the Delaware River and open water sites in Delaware Bay
(4) Type(s) of Habitat	(4) Sites 15D, Raccoon Island, Reedy Point and a portion of 170 have previously been used for disposal of dredged material. These areas are predominantly vegetated with common reed grass with areas of oldfield vegetation, and secondary growth. Some areas are planted with seasonal crops. Beneficial use sites are estuarine subtidal habitats in Del. Bay.
(5) Timing and Duration of Discharge	(5) 7 year initial dredging duration; maintenance dredging will occur annually in selected reaches

f. Description of Disposal Method — f. Hydraulic pipeline dredge or hopper dredge with direct discharge to upland diked disposal area or beneficial use sites in Bay

II. FACTUAL DETERMINATIONS (Section 230.11)

a. Physical Substrate Determinations (consider items in sections 230.11(a) and 230-20 Substrate

(1) Substrate Elevation and Slope	(1) Change in bottom elevation at overboard site.
(2) Sediment Type	(2) Dredged material and disposal area sediment types similar
(3) Dredged/Fill Material Movement	(3) Not significant
(4) Physical Effects on Benthos	(4) Burial at overboard sites. Areas will be selected to minimize benthic impacts.
(5) Action Taken to Minimize Impact (Subpart H)	(5) Effluent from diked upland disposal area will be controlled by an adjustable weir

b. Water, Circulation, Fluctuations and Salinity Determinations

(1) Water (refer to section 230.11(b), 230.22 Water and 230.25 Salinity Gradients; test specified in Subpart G may be required). Consider effects on:	
(a) Salinity	(a) No significant effect
(b) Water Chemistry (pH, etc.)	(b) Minor and short term area
(c) Clarity	(c) Minor turbidity at diked disposal area sluice; short-term turbidity during overboard disposal
(d) Color	(d) No significant effect
(e) Odor	(e) No change
(f) Taste	(f) N/A
(g) Dissolved Gas Levels	(g) Minor reduced DO during dredging and disposal
(h) Nutrients	(h) Some redistribution during dredging; release into water column during overboard disposal
(i) Eutrophication	(i) N/A
(2) Current Patterns and Circulation (consider items in sections 230.11(b), and 230.23). Current Flow and Water Circulation	(2) Minor impact
(3) Normal Water Level Fluctuations (tides, river stage, etc.) (consider items in sections 230.11(b) and 230.24)	(3) No effect
(4) Salinity Gradients (consider items in sections 230.11(b) and 230.25)	(4) No significant effect; see section 5.1.2 of FEIS
(5) Actions That Will be Taken to Minimize Impacts (refer to Subpart H)	(5) Use and monitoring of existing site discharge to well mixed estuary

c. <u>Suspended Particulate/Turbidity Determinations</u>

(1) Expected Changes in Suspended Particulates and Turbidity Levels in the Vicinity of Disposal Site (consider items in section 230.11(c) and 230.21)

(1) Minimal increase in suspended particulates and turbidity from upland sites due to use of an adjustable weir. Short-term increase in suspended sediments and turbidity during overboard disposal of coarse grained material

(2) Effects (degree and duration) on Chemical and Physical Properties of the Water Column (consider environmental values in section 230.21, as appropriate)

(a) Light Penetration	(a) No measurable change
(b) Dissolved Oxygen	(b) Minor short-term decrease in DO levels
(c) Toxic Metals and Organics	(c) No significant effect on water column
(d) Pathogens	(d) No significant effect
(e) Aesthetics	(e) No significant effect

(3) Effects on Biota (consider environmental values in section 230.21, as appropriate

(a) Primary Production, Photosysthesis	(a) No measurable change
(b) Suspension/Filter Feeders	(b) No measurable change
(c) Sight Feeders	(c) No measurable change

(4) Actions taken to Minimize Impacts (Subpart H)

(4) Use of confined upland disposal areas will minimize release of suspended solids into receiving waters which are well mixed. Apprropriate siting of beneficial use sites will minimize impacts to benthic resources.

d. <u>Contaminant Determinations (consider requirements in section 230.11(d)</u>

d. This following information has been considered in evaluating the ecological significance of possible contaminants in dredged of fill material.

(1) Physical characteristics of sediments
(2) Hydrography in relation to known or anticipated source of contaminants.
(3) Results from previous testing of similar material in the vicinity of the project

d. Contaminant Determinations (consider requirements in section 230.11(d) (Cont'd)

(4) Existing water quality conditions in the vicinity of the site.
(5) Mixing and dilution afforded by Delaware River.

The dredging of sediments and subsequent upland disposal will not pose an adverse impact on surface water quality or groundwater.

e. Aquatic Ecosystem and Organism Determinations (use evaluation and testing procedures in Subpart G, as appropriate).

(1) Effects on Plankton	(1) No significant effect
(2) Effects on Benthos	(2) Existing benthic organisms will be buried at overboard sites. No impact from effluent from diked upland disposal area.
(3) Effects on Nekton	(3) No significant effect
(4) Effects on Aquatic Food Web (refer to section 230.31)	(4) No significant effect
(5) Effects on Special Aquatic Sites (discuss only those found in project area or disposal site)	(5) No special aquatic sites are impacted by proposed disposal activities.
(6) Threatened and Endangered Species (refer to section 230.30)	(6) None anticipated
(7) Other Wildlife (refer to section 230.32)	(7) Limited in constant use disposal areas.
(8) Actions to Minimize Impacts (refer to Subpart H)	(8) Use of confined disposal areas will minimize impacts to aquatic organisms. Disposal at Delaware Bay overboard sites will be seasonally scheduled to avoid impacts to aquatic resources.

f. Proposed Disposal Site Determination

(1) Mixing Zone Determination (consider factors in section 230.11(f)(2)

(1) The following factors have been considered in evaluating the disposal site:

f. Proposed Disposal Site Determination (Cont'd)

(a) Depth of water at disposal site
(b) Current velocity, direction, and variability at disposal site
(c) Dredged material characteristics constituents, amount, and type of material, settling velocities
(d) Number of discharges per unit of time
(e) Use of confined upland disposal with a controlled weir.

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

(2) Determination of Compliance with Applicable Water Quality Standards (present the standards and rationale for compliance and non-compliance with each standard)

(2) It is anticipated that the discharges will be in compliance with State water quality standards.

(3) Potential Effects on Human Use Characteristics

(3) No impacts are anticipated

g. Determination of Cumulative Effects on the Aquatic Ecosystem (consider requirements in section 230.11(g)

(g) No significant effects

h. Determination of Secondary Effects on the Aquatic Ecosystem (consider requirements in section 230.11(h)

(h) No significant effects

III. FINDINGS OF COMPLIANCE

a. No significant adaptations of the guidelines were made relative to this evaluation.

b. The selected dredged material disposal sites are presently active diked, upland Federal areas at Reedy Point North and South, previously used upland disposal areas or open water sites in Delaware Bay for beneficial use of material. The proposed new disposal areas were selected from over 300 potential sites many of which would have had significant adverse impacts on shallow water habitat, wetlands, oyster beds and other benthic and fishery resources.

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.

d. Use of the selected disposal sites is not expected to harm any endangered species or their critical habitat (see Threatened/Endangered Species section of the Environmental Impact Statement). 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.

f. Appropriate steps to minimize potential adverse impacts of the discharge on aquatic systems includes limiting the suspended solids in the diked upland disposal area effluent to no more than 8 grams per liter above background concentration. Disposal at the Delaware Bay site will be scheduled to avoid seasonal impacts to aquatic resources.

g. On the basis of the guidelines the proposed disposal sites for the discharge of dredged material is specified as complying with the inclusion of appropriate and practical conditions to minimize pollution or adverse effects to the aquatic ecosystem.

SELECTED PLAN
TYPICAL CHANNEL SECTION
NOT TO SCALE

DETAIL B
SCALE IN FEET

PLAN
NOT TO SCALE

DELAWARE RIVER COMPREHENSIVE NAVIGATION STUDY

MAIN CHANNEL DEEPENING SELECTED PLAN

PHILADELPHIA DISTRICT
CORPS OF ENGINEERS

PLATE 1

CHANNEL DIMENSIONS		
LOCATION	DEPTH	WIDTH
A-B WEST SIDE	40 FT	400'-500'
A-B EAST SIDE	37 FT	500'-600'
B-C	40 FT	800'
C-D	40 FT	1000'

PLATE 2

CORPS OF ENGINEERS U.S. ARMY

PLATE 3

APPENDIX A CORRESPONDENCE

Appendix A
Correspondence

Table of Contents

Item	Page
Delaware River Port Authority letter dated August 17, 1983 indicating intent to act as study sponsor.	A-1
Delaware River and Bay Authority letter dated August 18, 1983	A-2
Update Newsletter Published in March 1984	A-3
Corps of Engineers letter dated June 7, 1985 to U.S. Coast Guard requesting input on safety and traffic management requirements for one-way and asymmetric channels	A-10
Update Newsletter published in August 1985	A-12
Corps of Engineers letter dated September 25, 1985 providing memorandum to U.S.C.G. for comment, summarizing September 10, 1985 meeting on one-way and asymmetric channels.	A-18
Coordination Meeting with port interest on September 30, 1985 regarding support for studies of main channel deepening	A-21
U.S. Fish and Wildlife Service Planning Aid Report dated October 7, 1985	A-22
Delaware River Port Authority letter dated November 26, 1985 (endorsed by other port interests) supporting further study of main channel deepening	A-23
Corps of Engineers letter dated December 4, 1985 requesting input from Mariners' Advisory Committee on design criteria and plans	A-24
Delaware River Port Authority letter dated January 13, 1986 providing a Sun Transport letter supporting study of main channel deepening	A-25
Coordination Meeting with Mariners' Advisory Committee on January 17, 1986 regarding design criteria	A-26

Table of Contents (Cont'd)

Item	Page
Coordination Meeting with Mariners' Advisory Committee on March 26, 1986 regarding design criteria	A-29
Final Coordination Meeting with Mariners' Advisory Committee on May 28, 1986 regarding design criteria	A-31
Delaware River Port Authority letter dated April 12, 1988 indicating support for the Delaware River Comprehensive Navigation Study.	A-33
Delaware River Port Authority letter dated May 19, 1988 outlining goals for the Delaware River Comprehensive Navigation Study.	A-34
Corps of Engineers letter to Delaware River Port Authority dated November 10, 1988 describing the advantages of cost sharing as a funding option.	A-35
State of New Jersey, Department of Environmental Protection letter dated November 29, 1988 regarding submerged cultural resources investigations.	A-37
Commonwealth of Pennsylvania, Pennsylvania Historical and Museum Commission, Bureau for Historic Preservation letter dated December 13, 1988 regarding submerged cultural resources investigations.	A-39
The Pilot's Association for the Bay & River Delaware letter dated December 2.., 1988 announcing the names of the individuals who agreed to serve on the Ad-Hoc Committee for Channel Deepening.	A-40
State of Delaware (Division of Historical and Cultural Affairs) letter dated January 12, 1989 regarding investigations of submerged cultural resources.	A-41
Corps of Engineers letter to Mariners' Advisory Committee dated January 17, 1989 requesting review comments on channel design criteria.	A-43
Pilot Coordination Meeting on February 16, 1989 regarding Delaware River Main Channel Deepening.	A-58
Summary of February 21, 1989 meeting with Delaware River Port Authority Dredging.	A-61

Table of Contents (Cont'd)

Item	Page
Corps of Engineers letter to U.S. Coast Guard dated June 5, 1989 requesting information on Navigation Aids.	A-63
Corps of Engineers Notice of Scoping Meeting dated June 15, 1989.	A-64
New Jersey State Department of Environmental Protection memo to Corps of Engineers dated June 23, 1989 regarding comments from June 22, 1989 Environmental Scoping Meeting.	A-65
Minutes for August 2, 1989 Dredging Committee Meeting	A-66
Corps of Engineers Update newsletter for Comprehensive Navigation Study dated September 1989.	A-67
Corps of Engineers letter to Delaware River Port Authority dated October 6, 1989 regarding requirements for Local Cooperation Agreement.	A-73
State of Delaware (Department of Natural Resources & Environmental Control) letter dated October 6, 1989 regarding beneficial uses of dredged material.	A-74
Delaware River Port Authority letter dated October 27, 1989 regarding upland disposal site options.	A-76
U.S Fish and Wildlife Planning Aid Report dated November 16, 1989	A-79
Telephone Conversation with U.S. Coast Guard dated November 16, 1989.	A-143
Delaware River Port Authority letter dated November 29, 1989 regarding requirements for Local Cooperation Agreement.	A-144

Table of Contents (Cont'd)

ITEM	PAGE
Delaware River Port Authority letter dated November 1, 1991 intent to act as local sponsor.	A-145
Delaware River Port Authority letter dated December 5, 1991 regarding the local sponsor financing.	A-146
Delaware River Port Authority consulated financial statements and supplemental schedules.	A-147
Corps of Engineers letter to U.S. Fish and Wildlife Service dated November 27, 1991. Requesting the review of the EIS Amendment and to provide the final FWCA 2(b) Report.	A-177
Corps of Engineers letter to the U.S. Environmental Protection Agency noting a change delay in the public comment period.	A-178
Corps of Engineers letter to the U.S. Environmental Protection Agency noting a change delay in the public comment period.	A-179
Corps of Engineers letter to U.S. Environmental Protection Agency dated November 21, 1991 filing notice of availability.	A-180
Corps of Engineers letter to the National Marine Fisheries Service dated December 5, 1991. Requesting review and comment of the amendment to the Draft Environmental Impact Statement.	A-181
Corps of Engineers letter to the National Marine Fisheries Service Habitat Conservation Branch, dated December 5, 1991. Requesting review and comment of the amendment to the Draft Environmental Impact Statement.	A-182
Corps of Engineers letter to the Delaware Department of Natural Resources and Environmental Control, dated December 3, 1991. Requesting review and comment of the amendment to the Draft Environmental Impact Statement.	A-183
Corps of Engineers letter to the New Jersey Department of Environmental Protection, dated December 3, 1991. Requesting review and comment of the amendment to the Draft Environmental Impact Statement.	A-185

Table of Contents (Cont'd)

Item	Page
Corps of Engineers letter to the Delaware Department of Natural Resources and Environmental Control Division of Water Resources, dated December 3, 1991. Requesting review and comment of the amendment to the Draft Environmental Impact Statement.	A-186
Corps of Engineers letter to the New Jersey Department Office of Program Coordination, dated December 3, 1991. Requesting review and comment of the amendment to the Draft Environmental Impact Statement.	A-188
Corps of Engineers letter to all interested parties for review and comment of the amendment to the Draft Environmental Impact Statement, dated November 27, 1991.	A-189

DELAWARE RIVER PORT AUTHORITY
OF
PENNSYLVANIA AND NEW JERSEY
BRIDGE PLAZA
CAMDEN, NEW JERSEY 08101

(609) 963-6420
(215) 629-6700

August 17, 1983

JAMES R. KELLY
PRESIDENT

Lt. Col. Roger L. Baldwin
District Engineer
U. S. Army Corps of Engineers
Custom House, 2nd & Chestnut Streets
Philadelphia, Pa. 19106

RE: Delaware River Comprehensive Navigation Study

Dear Colonel Baldwin:

We have met with members of your staff to review and discuss results of the reconnaissance report and the requirements of local sponsorship for continuation of the study. We concur with the study results, and assure you that the Delaware River Port Authority continues to fully support the study and will support the items of local cooperation summarized on the attached sheet, if further studies determine that the projects are feasible.

We have provided the Delaware River & Bay Authority with a copy of the report and have asked them to also support the study findings and the items of local cooperation. As soon as we hear from their Executive Director, William J. Miller, we will forward their response to you.

We look forward to working with you for the betterment of the Philadelphia Port area.

Sincerely,

James R. Kelly
President

JRK:RGH:JE

attachment

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THE DELAWARE RIVER AND BAY AUTHORITY

DELAWARE MEMORIAL BRIDGE
POST OFFICE BOX 71
NEW CASTLE, DELAWARE 19720
302-571-6303

CAPE MAY - LEWES FERRY
POST OFFICE BOX 827
CAPE MAY, NEW JERSEY 08204
609-886-9699

August 18, 1983

Lt. Col. Roger L. Baldwin
District Engineer
U. S. Army Corps of Engineers
Custom House, 2nd & Chestnut Streets
Philadelphia, Pennsylvania 19106

Re: Delaware River Comprehensive Navigation Study

Dear Colonel Baldwin:

Mr. James R. Kelly, President of the Delaware River Port Authority, has provided this office with a copy of the Corps of Engineers Stage 1 Report of the Delaware River Comprehensive Navigation Study. This report has been reviewed and the Delaware River and Bay Authority concurs with the study results and supports the study and the items of local cooperation which are attached.

The Delaware River and Bay Authority will be happy to assist you in any way possible, particularly if further studies determine that the projects are feasible.

Very truly yours,

William J. Miller, Jr.
Executive Director

WJM:es

attachment

DELAWARE RIVER COMPREHENSIVE
NAVIGATION STUDY

UPDATE

NUMBER 1 MARCH 1984

US Army Corps
of Engineers

Philadelphia District

TO KEEP YOU INFORMED...

This is the first in a planned series of newsletters to keep you informed about the Delaware River Comprehensive Navigation Study being conducted by the U.S. Army Corps of Engineers, Philadelphia District Office. These newsletters will give information about the study and provide us with an opportunity to obtain your input and to exchange ideas as the study progresses.

The purposes of this initial issue are to:

- introduce you to the study of current and future navigation problems along the waterways of the Delaware River and the alternative solutions we are analyzing
- explain the nature of study tasks which are ongoing
- inform you of the progress and findings to date
- and give you the opportunity to be placed on the study mailing list

STUDY AREA

The Delaware River Comprehensive Navigation Study is addressing the navigation related problems of all waterways which support commercial activities along the Delaware River from Trenton, New Jersey to the sea, including the Chesapeake and Delaware Canal. The waterways within the study area are shown on Figure 1.

SCOPE OF STUDY

The objective of this study is to define the federal interest in navigation development, especially with respect to the future port needs for improvements, in the study area.

Federal interest in navigation is limited to general navigation features including channels, harbor areas, turning basins, and harbors of refuge. It does not involve facilities such as docks, berths, and access channels. However, these latter facilities must be analyzed as integral features of waterway improvement plans.

For a navigation feature to be in the Federal interest, it must provide benefits to the general public as demonstrated by multiple users, or a public terminal which is available to all on equal terms. The feature must also be economically justified; the project costs are exceeded by the benefits it provides by reducing waterborne transportation costs.

PLAN OF STUDY

There were four principal activities accomplished in the initial stage of study:

- to identify navigation problems which warrant further study

PENNSYLVANIA
NEW JERSEY
MARYLAND
DELAWARE
DELAWARE BAY
ATLANTIC OCEAN
PHILADELPHIA
TRENTON
CAMDEN
WILMINGTON
Reading
Pottstown
Princeton
Lancaster
West Chester
Kennett Square
Chester
Marcus Hook
Paulsboro
Woodbury
Westville
Penns Grove
Glassboro
Williamstown
Hammonton
Newark
New Castle
Delaware City
Salem
Chesapeake City
C&D Canal
Odessa
Bridgeton
Millville
Vineland
Smyrna
Port Mahon
Dover
Bowers
Frederica
Big Stone Beach
Milford
Greensboro
Wye Mills
Denton
Easton
Cambridge
Seaford
Milton
Lewes
Rehoboth Bay
Millsboro
Cape May Canal
Cape May
Stone Harbor
Cape Henlopen
Lewes Rehoboth Canal
Assawoman Canal
SCALE IN MILES
10 0 10
DELAWARE RIVER
COMPREHENSIVE NAVIGATION
STUDY
US Army Corps of Engineers
Philadelphia District

FIGURE 1

Table 1

Summary of
Preliminary Waterways Evaluations

	Project	Significant Problems of Federal Interest
1.	Big Timber Creek, NJ	None
2.	Broadkill River, DE	None - No commercial activity
3.	Chesapeake & Delaware Canal	Interest in deepening/widening
4.	Cohansey River, NJ	None
5.	Cooper River, NJ	None
6.	Petty Island Back Channel	Pursued under small projects program
7.	Delaware City Branch Channel, DE	Channel deepening - Benefit/cost analyses did not justify further study
8.	Del. Power & Light/Edgemoor, DE	None - Sole beneficiary
9.	Delaware River, Camden, NJ	Deepening at Broadway & Beckett St. Terminals
10.	Delaware River - Phila. to Sea	
	Anchorages	Deepening & dimension changes to be reevaluated
	Channel	Realignment and deepening,
11.	Deepwater Port - Delaware Bay	Deeper access channels and anchorages
12.	Hog Island, Philadelphia	Channel deepening
13.	Del. River - Phila. to Trenton	Channel deepening if Phila. to the Sea were deepened
14.	Tioga Marine Terminal, Philadelphia	Channel deepening, turning area
15.	Harbor of Refuge, DE	Deepening & larger turning basin
16.	Little River, DE	None - Benefit/cost analysis did not justify further study
17.	Mantua Creek, NJ	None
18.	Maurice River, NJ	Authorized dimensions adequate
19.	Mispillion/Cedar Creek, DE	None - Authorized dimensions adequate
20.	Murderkill & St. Jones Rivers, DE	None - Authorized dimensions adequate
21.	Phoenix Steel, Claymont, DE	None
22.	Port Mahon, DE	None - Benefit/cost analysis did not justify further study
23.	Port Penn/Augustine Beach, DE	None - No study-related problems identified
24.	Raccoon Creek DE	None - Benefit/cost analysis did not warrant further study
25.	Roosevelt Inlet, DE	Authorized dimensions adequate
26.	Salem River. NJ	Authorized dimensions adequate
27.	Schuylkill River, PA	Channel deepening
28.	Smyrna River, DE	None - No navigation problems identified
29.	Wilmington Harbor/Christina River, DE	Channel deepening, larger turning basin

- to perform a cursory formulation of alternatives to ensure that potential projects are likely to be economically justified

- to identify potential local project sponsors, and

- to accurately estimate study schedules and costs.

The current authorized channel dimensions on both the main stem and various tributary projects of the Delaware River present a constraint to efficient vessel movement. Inadequate authorized depths in these channels are causing the use of costly alternatives such as lightering, lightloading and waiting for tides. Due to the continuing increases in ship sizes this problem is projected to get worse.

The conclusions of the initial problem identification activities for each waterway are presented in Table 1. Our Plan of Study established two separate feasibility studies to address the problems at waterways of Federal interest. The interim study entitled "Delaware River from Philadelphia to Wilmington" is addressing the problems at waterways tributary to the Delaware River which are expected to have straight-forward solutions, well suited to a "fast track" approach.

The major waterways, including the main Delaware River channel and C&D Canal, require more complex analyses due to their impacts within the Delaware River port system and the interaction with neighboring ports. Therefore, they are being considered by the "parent study". The interim and parent studies are described further below.

INTERIM STUDY

The interim or "fast track" study is analyzing navigation problems at the lower Schuylkill River and Tioga Marine Terminal in Philadelphia; Broadway and Beckett Street Terminals in Camden, and Wilmington Harbor. The problems at the interim study project areas result primarily from existing channel depths being less than the 40 foot main channel depth. The interim study therefore is evaluating the justification for deepening the project areas up to 40 feet. The waterways under study, alternatives to be considered, and identified sponsors are shown in Table 2.

Provisions of a Federal access channel to the proposed Hog Island facility was recommended for inclusion by the Plan of Study. However, it did not receive local support and was subsequently dropped.

The data collection and problem identification phases of the interim study have been completed using consulting firms and the staff of the Corps' Baltimore District to assist Philadelphia staff. Current activities include the comparison of project benefits and costs and assessment of project-related impacts. A public meeting will be held to present and discuss the tentative findings in the fall of 1984. The final report will be completed in January 1985.

PARENT STUDY

The parent study is evaluating solutions to the problems along the major regional waterways as well as tributary waterways. Currently, the study is concentrating on formulation of all potential measures to solve the problems identified, and will narrow the range of viable solutions to be considered in further detail. Subsequently, we will concentrate more heavily on analysis and evaluation of the leading alternative solutions. Table 3 lists the waterways and alternatives to be considered by the parent study. In addition, the parent study will reconsider the interim study waterways if main channel deepening appears feasible. The Delaware River and Bay Authority and Delaware River Port Authority have indicated their support and sponsorship for the parent study.

Ongoing "parent" analyses include initial economic evaluations for modifications of the main channel and the C&D Canal, as

well as construction of a deepwater port. These are the major projects which would impact the remaining waterways in the Delaware River system. The results of this economic screening will also shape the remainder of the study efforts. Maximum use is being made of the results of previous studies such as the Delaware River Regional Port Study by Booz, Allen & Hamilton, Inc. However, a significant amount of data collection has taken place to update and supplement available information.

Inventories of landside transportation systems and port facilities have been developed for the region. These data are being used as part of the analyses of commodity flows, facility throughput capacity, vessel usage, and transportation costs for the Delaware River ports. A similar analysis will also be conducted for commodities passing through competitive ports in the region, including Norfolk, Baltimore, and New York. With this information we will be able to determine the navigation related problems of the region and estimate the project benefits resulting from overall transportation savings.

QUESTIONS AND COMMENTS

Some readers may have been contacted already by the study team or our consultants in regard to the interim or parent studies. If so, we would like to thank you for your assistance and cooperation.

For additional copies of this update or if you have any questions regarding the study, you can write to Dr. John A. Burnes, Chief of Planning Branch, at the address shown on the last page or call (215) 597-5951. If you have any comments or wish to be placed on our mailing list so you will continue to receive study publications, please fill out and return the back page of this UPDATE.

TABLE 2

INTERIM STUDY ALTERNATIVES

Waterway	Alternatives Depths Considered (feet)	Sponsor
Schuylkill River - Mouth to Penrose Avenue	34 to 40	City of Philadelphia
Tioga Marine Terminal, Philadelphia	37 to 40	City of Philadelphia
Beckett Street Terminal, Camden	38 to 40	South Jersey Port Corp.
Broadway Terminal, Camden	31 to 40	South Jersey Port Corp.
Wilmington Harbor, Delaware	36 to 40	City of Wilmington

TABLE 3

PARENT STUDY ALTERNATIVES

Waterway	Alternatives to be Considered
Deepwater Port	depths of 55, 60, 65 and 72 feet, mid-stream operations and facility development
Chesapeake & Delaware Canal	depths from 35 to 40 feet
Harbor of Refuge, Delaware	depths from 15 to 20 feet
Delaware River, Trenton to the Sea	depths of 42, 45 and 50 feet, anchorage modifications and channel realignments as required.

If you wish to be on our study mailing list
please fill out the following

Name: _____

Street Address: _____

City & State: _____

Zip Code: _____

This space is provided for your comments or suggestions
AND/OR
the names and addresses of other persons to be added to the mailing list

_____

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07 JUN 1985

NAPEN-P

SUBJECT: Safety and Traffic Management Requirements for One-Way and Asymmetric Channels

Commander
U. S. Coast Guard Base
ATTN: Captain of the Port
King and Cumberland Streets
Gloucester, New Jersey 08030

1. The purpose of this letter is to request input on the safety and viability of one-way and asymmetric channels as alternatives for channel improvement projects under the Delaware River Comprehensive Navigation Study.

2. In keeping with the policies of the Administration, our current guidance for the planning and design of Corps of Engineers waterway projects or modifications requires that we identify and recommend channel plans which maximize net project benefits; i.e., we are charged to formulate the least cost plan for any given channel depth and its associated benefits. We have found that in situations where traffic volumes are relatively light or the needs for channel improvements are driven primarily by movements in one direction, one-way or asymmetric channels may be the optimum alternative. However, we need assistance in defining the applicability of these concepts along with appropriate traffic management systems to provide for safe navigation. Perhaps a computerized system such as the one in use at the Chesapeake and Delaware Canal would be appropriate at other locations with these concepts. The projects of primary concern at present are the Philadelphia to the Sea project, deepened access to and from Big Stone Beach Anchorage, and the Chesapeake and Delaware Canal.

3. Our informal coordination to date has involved conversations with representatives of the U. S. Coast Guard, Maryland Pilots, and the Pilots Association for the River and Bay Delaware and these concepts have met with mixed reactions, ranging from acceptance to rejection. Since we must rely on the U. S. Coast Guard with input from the pilots to determine what conditions are safe for navigation, it is difficult to plan alternative waterway improvements without a consensus of opinions on navigation safety and traffic management requirements.

NAPEN-F
SUBJECT: Safety and Traffic Management Requirements for One-Way and Asymmetric Channels

4. All of the parties we have contacted were amenable to meeting further to discuss these concepts. If you feel a meeting is desirable, we would be glad to arrange one at our District office. Please contact Mr. John E. Tunnell, Chief of Coastal and Special Studies Section regarding any arrangements at Area Code 215/597-4714.

FOR THE COMMANDER:

Signed by: S. J. BUCOLO

NICHOLAS J. BARBIERI, PE
Chief, Planning/Engineering Division

DELAWARE RIVER COMPREHENSIVE NAVIGATION STUDY

UPDATE

NUMBER 2 AUGUST 1985

US Army Corps of Engineers

Philadelphia District

TO KEEP YOU INFORMED...

This is the second in a planned series of newsletters to keep you informed on the progress of the Delaware River Comprehensive Navigation Study being conducted by the U. S. Army Corps of Engineers, Philadelphia District Office. These newsletters allow us to provide you with information about the study and exchange ideas as our study progresses.

The purposes of this second issue are to:

- discuss the results of the Delaware River from Philadelphia to Wilmington Interim Study;
- present the conclusions of our initial parent study analyses and discuss the direction of future studies;
- give you the opportunity to add new interested parties to the mailing list;
- provide us with the opportunity to obtain your input on the waterway improvements under study.

STUDY AREA AND OBJECTIVE

The Delaware River Comprehensive Navigation Study is addressing the navigation related problems of all waterways which support commercial activities along the Delaware River from Trenton, New Jersey to the Sea, including the Chesapeake and Delaware Canal. The waterways within the study area are shown on Figure 1.

The objective of this study is to define the Federal interest in navigation development, especially with respect to future port needs for waterway improvements in the study area.

INTERIM STUDY

The interim or "fast track" study analyzed navigation problems at the lower Schuylkill River and Tioga Marine Terminal in Philadelphia, Broadway and Beckett Street Terminals in Camden, and Wilmington Harbor. The problems at the interim study project areas result primarily from existing channel depths being less than the 40 foot main channel depth. The interim study therefore evaluated the justification for deepening the project areas up to 40 feet.

The interim study was also to have analyzed Federal provision of access to a proposed auto import facility at Hog Island. However, it did not receive local support and was subsequently dropped from the interim study. More recently, the entire proposal was abandoned in favor of the renovation of Pier 96 for an auto facility.

Based on the findings of the interim study, it was determined that only three

PENNSYLVANIA
NEW JERSEY
MARYLAND
DELAWARE
DELAWARE BAY
ATLANTIC OCEAN
TRENTON
CAMDEN
WILMINGTON
PHILADELPHIA
Princeton
Reading
Pottstown
Norristown
Bristol
Burlington
Lumberton
Lancaster
West Chester
Kennett Square
Chester
Marcus Hook
Westville
Woodbury
Glassboro
Williamstown
Penns Grove
Salem
Newark
Delaware City
Chesapeake City
C&D Canal
CHESAPEAKE BAY
Odessa
Bridgeton
Millville
Vineland
Hammonton
ATLANTIC CITY
Ocean City
Smyrna
Port Mahon
Dover
Bowers
Frederica
Big Stone Beach
Cape May Canal
Cape May
Cold Spring Inlet
Stone Harbor
Greensboro
Wye Mills
Denton
Milford
Harbor of Refuge
Cape Henlopen
Lewes
Lewes Rehoboth Canal
Milton
Seaford
Rehoboth Bay
Indian River Inlet
Millsboro
Assawoman Canal
KEY
-INTERIM SITES RECOMMENDED FOR CHANNEL IMPROVEMENTS
SCALE IN MILES
10 0 10
DELAWARE RIVER COMPREHENSIVE NAVIGATION STUDY
US Army Corps of Engineers Philadelphia District
FIGURE 1

of the six areas investigated - Beckett Street Terminal, the lower Schuylkill River, and Wilmington Harbor - had waterway problems requiring channel modifications. The recommended plans of improvement include deepening the existing Federal projects in the lower Schuylkill River from 33 feet to 40 feet, and at the Delaware River in the Vicinity of Camden, New Jersey (Beckett Street Terminal) from the authorized (unconstructed) 37 foot project to 40 feet. The Interim Study also found that further studies were warranted for deepening the channel at Wilmington Harbor beyond the existing Federal project of 35 feet. Based on the scope and cost of the Wilmington Harbor project, these studies will be pursued under the Continuing Authorities or "Small Projects" Program. Under the navigation authority in this program, the Corps of Engineers can plan, design and construct a project without specific Congressional authorization, generally resulting in a shorter time until construction. Depths up to 40 feet in the Wilmington Harbor channel are being considered.

Analyses of existing and projected traffic indicated that the majority of the vessels calling at the Tioga Marine Terminal and Broadway Terminal were not constrained by local access channels. Therefore, there would be minimal benefits to channel deepening at these two sites. It should be noted that although these sites are not being considered further in the interim study, they can be analyzed further under the parent study if channel improvements proposed for the Delaware River or Chesapeake and Delaware Canal generate the need for deeper access channels.

A public meeting was held October 17, 1984, at the Port of History Museum, Philadelphia, Pennsylvania. Details regarding the conduct of the study and the recommendations were presented. The general response to information presented in the public meeting was supportive regarding the conclusions of the interim study. Subsequently, the report was completed and has been approved by the Board of Engineers for Rivers and Harbors in Washington. It will next be reviewed by the Office of the Chief of Engineers and the Secretary of the Army for eventual transmittal to Congress for authorization.

PARENT STUDY

The parent study is evaluating solutions to the problems along the major regional waterways as well as tributary waterways. Currently, initial formulation of all potential measures to solve the problems identified has been completed. This cycle of formulation was to evaluate the large projects which affect the waterway system and to set the direction for subsequent study. A brief discussion of formulation results follows:

- Chesapeake and Delaware Canal - The deepening of the Chesapeake and Delaware Canal from 35 feet to 37 feet or 40 feet is an alternative that has been considered for channel improvements. Economic analyses indicated that deepening the channel to 37 feet or more would benefit container liner services currently lightloading to negotiate the canal and bulk vessels carrying grain for export to Europe from Baltimore. However, deepening the entire channel width did not appear economically feasible. A limited width, one-way channel with periodic passing zones is currently being evaluated. Further coordination with interested port officials and shippers is being conducted.

- Philadelphia to the Sea - The 40 foot channel depth has been identified

as a vessel constraint to exports of grain and coal, imports of crude oil and iron ore, and a minor amount of other bulk vessel traffic. Main channel depths of 42 feet, 45 feet and 50 feet are alternatives that have been considered for channel improvements. Results of these analyses have indicated that further study of deepening the channel up to 45 feet is warranted in order to determine the optimum channel depth. In keeping with current policies of the Administration and directives of the Secretary of the Army, the District is investigating innovative approaches to channel deepening, which may reduce dredging requirements, in addition to traditional alternatives.

- Midstream Deepwater Port - Under existing conditions, traffic lanes between the ocean and Big Stone Beach Anchorage limit vessel drafts to about 55 feet for inbound traffic. Assuming development of a dry bulk transfer system such as that proposed recently by the Delaware River Port Authority, outbound traffic would be limited to vessel drafts of about 50 feet. The initial formulation of alternatives analyzed provision of deeper channels within each traffic lane and a common channel from the Harbor of Refuge to the anchorage. Depths of 55, 60, 65 and 72 feet outbound and 60, 65, and 72 feet inbound were considered. The analyses indicated that export vessels did not generate demand for depths in excess of 60 feet and further studies of an outbound channel to depths between 50 and 60 feet are planned in order to determine the optimum depth. Further studies of deepening inbound access are planned for the entire range of depths in order to determine the optimum. In addition the District is analyzing a single ocean channel for inbound and outbound traffic on a one-way basis.

- Deepwater Port Facility - Analyses were conducted of providing channel depths of 55, 60, 65 and 72 feet between the ocean and a deepwater bulk port island at Big Stone Beach Anchorage. The proposed island would be situated on Lower Middle Shoal and was sized assuming minimal on-island facility development. The District developed this scheme in keeping with the expected level of commodity throughputs projected by our economic analyses. The results indicated that such a concept may warrant further study. However, the design and construction of the island facility and related landside transportation developments are not the responsibility of the Federal government. At the present time there are no completed plans for such a facility and there appears to be little support for further study of a port island to refine its design and establish its technical,institutional, and economic viability. Therefore, no further study of providing access to a deepwater port island is planned at this time.

The parent study will continue to investigate in more detail the leading alternative solutions. In addition, the parent study will address deepening tributary projects including the interim study waterways, main channel realignments, and modification of existing anchorage dimensions. Further study of the Delaware River, Philadelphia to Trenton project does not appear warranted since only a single beneficiary could be identified for project modification.

Navigation problems at the Salem River in Salem County, New Jersey and the Harbor

of Refuge in Delaware Bay, Delaware are being analyzed in "early action studies."

EARLY ACTION STUDIES

The problems at Salem River and the Harbor of Refuge project areas result primarily from existing waterway dimensions being inadequate for safe and efficient operations, thereby limiting vessel sizes and resulting in tidal delays. Since these problem areas are independent of main channel considerations, any project modifications found feasible may be pursued at an accelerated pace in order to expedite solutions to the navigation problems.

The authorized 12 foot project at Salem River was first dredged in 1928. Over the subsequent years commercial traffic dwindled, and until recently maintenance dredging to the authorized depth was not justified. Under the sponsorship of the Port of Salem, a port redevelopment is ongoing, and the river was dredged to a depth of 12 feet in the summer of 1984. Commodities being shipped are grain, fertilizer and containerized general cargo. A need was recently identified for enlarged channel dimensions that will allow safe and efficient navigation by the larger vessels now traversing the Salem River and the future fleet expected to call at the Port of Salem. The study is currently analyzing channel depths up to 20 feet.

The Harbor of Refuge is maintained at its authorized project depth of 15 feet. Under the sponsorship of the Delaware River and Bay Authority, studies are being conducted of providing access at depths up to 20 feet to allow for safe and efficient navigation of larger vessels. Currently, the primary commodity being barged is liquid fertilizer enroute to companies utilizing the Fisher Enterprises facilities in Lewes, Delaware. Shipments of dry bulk fertilizer and fish meal are also expected to benefit from channel improvements.

QUESTIONS AND COMMENTS

We were pleased to receive approximately seventy-five responses to our initial newsletter and have revised our mailing list to include each person or group that expressed interest in being retained or added to our mailing list. If you know of others who may be interested, please notify them. They can call us, send us a request directly, or have their names entered on the attached form. Please remember to include a complete address with zip code.

For additional copies of this UPDATE, or if you have any questions regarding the study, you can either write to Dr. John A. Burnes, Chief of Planning Branch, at the address shown on the last page or call 215/597-5951. We welcome your comments or suggestions at any time during our study. Your ideas and comments are important to our planning process and will assist us in conducting the study. If you care to comment at this time, we have provided room on the attached form for this purpose.

If you wish to be on our study mailing list
please fill out the following

Name: _____

Street Address: _____

City & State: _____

Zip Code: _____

This space is provided for your comments or suggestions
and/or
the names and addresses of other persons to be added to the mailing list

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25 SEP 1985

NAPEN-P

SUBJECT: Safety and Traffic Management Requirements for One-Way and Asymmetric Channels

Commander
U. S. Coast Guard Base
ATTN: Captain of the Port
King and Cumberland Streets
Gloucester, New Jersey 08030

1. Reference letter, NAPEN-P, 7 June 1985, SAB.

2. Attached for your review and concurrence is a memorandum which documents the coordination meeting held on 9 September 1985.

FOR THE COMMANDER:

Encl

NICHOLAS J. BARBIERI, PE
Chief, Planning/Engineering Division

DISPOSITION FORM

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REFERENCE OR OFFICE SYMBOL	SUBJECT
NAPEN-P	Meeting with USCG Regarding Asymmetric and One-way Channels

TO	FROM	DATE	CMT 1
Files	C.L. Ware	10 September 1985 aw/5954	

1. Attendees. The meeting was held on 9 September 1985. Those in attendance included LTC Wynn Harper and Captain Ed Roe from the United States Coast Guard (USCG) Base in Gloucester and Messrs. John Tunnell, Keith Harrington, and Lee Ware of the Philadelphia District.

2. Background. The NED planning criteria and Administration emphasis on economic/innovative project planning was reviewed. In addition, the results of informal coordination were discussed, relating to the viability and safety of one-way and asymmetric channels for projects within the Delaware River system.

3. General Discussions. There are no USCG policies which prohibit or discourage one-way or asymmetric channels. Different versions of these concepts are used in locations around the country and one-way traffic is a standard USCG provision to assure safe vessel transits. They can shut down traffic to permit LNG vessel passage to maximize safety. They can also impose vessel transit restrictions (require tug assist, daylight passage, etc.) to compensate for mechanical problems, loss of radar, or poor maneuverability. The USCG indicated the port community is likely to have diverse views on one-way and asymmetric channels depending on whether the measures are viewed as enhancing safety or inhibiting or restricting free trade. Vessel pilots are likely to object to measures which would increase restrictions or requirements on them and increase their liabilities. Therefore, they would naturally favor a plan which minimizes any restriction on their operations, allowing vessel passages and traffic management to continue in the present manner. In order to properly manage traffic movements with one-way and asymmetric channels, additional information will be needed on vessels moving each day. At present, vessel arrivals are scheduled in advance, however, departures are not. Pilots manage traffic among themselves with the cooperation of the Maritime Exchange. Some mechanism will be required to allow consideration of vessel beams and drafts in order to properly manage traffic with asymmetric channels.

4. Delaware River Main Channel. Three alternatives were discussed for deepening the main channel: full width deepening, an asymmetric channel with widening to provide unrestricted inbound and outbound traffic, and an asymmetric channel without widening which would result in some queuing delays and the need for increased traffic management. The USCG felt each of these alternatives was technically viable and potentially acceptable to the Pilots, since unrestricted two-way traffic would result for the vast majority of vessel trips. However, any one-way proposals for stop and go operations of a deeper channel would not be well received. It may be possible for pilots to handle traffic management between themselves even with an asymmetric channel. At present, they have the flexibility to pass on starboard sides in a non-traditional manner. Further coordination is required with the Pilots' Association on these plans. The USCG could easily issue regulations on operations in a deepened section of channel, such as "No vessel shall be met or overtaken within this channel". Marking an asymmetric channel may not present a problem. At Thimble Shoal channel in

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SUBJECT: Meeting with USCG Regarding Asymmetric and One-Way Channels

Norfolk lit buoys mark the centrally located deeper channel and unlit cans and nuns mark the edges of the auxiliary channels on either side. The Houston ship channel is another interesting example since it provides a minimum width project combined with sophisticated traffic management. This channel allows for two-way tanker traffic in a 400 foot wide, 40 mile long channel. However, this is also acknowledged to be the most hazardous channel in the country. Pelican Island (Galveston) is not a particularly relevant example to the Delaware River since this involved a relatively short one-way access channel to a single user; not a main channel.

5. Access to Big Stone Beach. Either of the options discussed may be viable. A one-way channel would probably be less preferable since some queuing delays would result. The notched inbound and outbound channels within the existing ocean traffic lanes is similar to operations at the port of Seattle. Further discussions with the Pilots' Association regarding these alternatives is also required.

6. Conclusions. Asymmetric and one-way channels are technically viable plans which trade-off queuing delays, increased pilot restrictions, and more sophisticated traffic management for lesser dredging costs in order to achieve an acceptable level of safety. One-way (stop and go) traffic on the main channel is not likely to be supported by the port community, however, the asymmetric concepts which permit unrestricted movement for all but the largest vessels are potentially acceptable. Further coordination with the pilots is necessary on these matters.

Lee Ware

C. L. WARE
Planning Branch

DISPOSITION FORM

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REFERENCE OR OFFICE SYMBOL	SUBJECT
NAPEN-P	COMPNAV Coordination Meeting with Port Interests
TO: Files	FROM: K. Harrington; DATE: 30 Sep 85; CMT 1: kad/5958

1. Attendees:

DRPA - Ray Heinzelmann, James Kelly, Ray Lawler, Jose Brigoli
NAPEN-P - John Burnes, John Tunnell, Lee Ware, Keith Harrington
Port of Wilmington - Ken Mack
DURPC - John Coscia
PABRD - Sam Schellinger
Phila. Port Corp - John Malone
Sun Oil - Woody Toppen
Maritime Exchange - Bill Harrison
DRBA - Bill Miller
DMTA - Dale Schaeffer
Texaco - Tom O'Connor

2. Subject meeting was held by DRPA to determine the interest of the port community in main channel deepening through the COMPNAV study.

3. Feasibility of deepening was discussed w.r.t. salinity intrusion through aquifer contamination and a changed tidal prism. PDO explained that while further study is needed, current findings are not discouraging.

4. The 40' channel limits efficient bulk transport including oil, coal, grain, and possibly bulk cement (Chester & Amstar). Bulk operations are almost exclusively below the Walt Whitman Bridge.

5. The need for main channel deepening with a midstream operation in the Delaware Bay was discussed. Significant savings would still accompany main channel deepening through reduced topping of large bulk carriers. It was indicated that resolution of the current Delaware CZM challenge could take as much as 3 years with continued main channel study preferred.

6. Therefore it was suggested that studies of main channel include with and without midstream operation proposals. The port community generally favors advanced maintenance. However, PDO advised that advanced maintenance is difficult to justify under current Washington policy and that it should not be considered as a substitute for authorization of a deeper channel.

7. Meeting concluded with a unanimous support for study of main channel deepening particularly in light of potential channel improvements to the competing North Atlantic ports. The need to involve the deep-draft shippers more deeply was also agreed upon. In 3-4 weeks a letter of continuing interest/sponsorship from the DRPA & DRBA will be forthcoming.

Keith Harrington
Coastal & Special Studies Section

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United States Department of the Interior

FISH AND WILDLIFE SERVICE
DIVISION OF ECOLOGICAL SERVICES
1825B VIRGINIA STREET
ANNAPOLIS, MARYLAND 21401

October 7, 1985

Lieutenant Colonel Ralph V. Locurcio
District Engineer
Philadelphia District, Corps of Engineers
Custom House - 2nd and Chestnut Streets
Philadelphia, PA 19106

Dear Colonel Locurcio:

Attached is one of two Planning Aid Reports for the Delaware River Comprehensive Navigation Study, furnished under terms of the FY 85 Scope of Work. This report provides a discussion of fish and wildlife resources in the Delaware portion of the study area, based on existing literature and other information. It is submitted in accordance with provisions of the Fish and Wildlife Coordination Act (48 stat. 401, as amended; 16 U. S. C. 661 et seq.). If you have questions on this report, please contact Suzanne Nair of this office.

Sincerely yours,

Glenn Kinser
Supervisor
Annapolis Field Office

Attachment

215-925-8780 •
609-963-6420 •
TELEX 831417 •

PORTS OF PHILADELPHIA
CAMDEN PHILADELPHIA
GLOUCESTER WILMINGTON

DELAWARE RIVER PORT AUTHORITY

WORLD TRADE DIVISION BRIDGE PLAZA CAMDEN, NEW JERSEY 08101

November 26, 1985

Col. Ralph Locurcio
District Engineer
Corps of Engineers, U. S. Army
Philadelphia District
2nd & Chestnut Sts.
Philadelphia, PA 19106

Dear Col. Locurcio:

On September 25, the signators to this letter met to discuss the need to deepen the channel on the Delaware River beyond the present depth of 40 feet. With neighboring ports planning to deepen their channels beyond 40 feet, the future competitive position of the Ports of Philadelphia could be jeopardized. Also, the Ports of Philadelphia have traditionally been a bulk port, accounting for more than 85% of the international cargo tonnage handled. Over the past decade the ports' marketing share of total U. S. bulk tonnage has declined significantly as shown on the attached diagram. A draft limitation of 40 feet is partially responsible for this trend. In order for the Port to continue as a major U. S. bulk port, deepening of the channels will be required.

The Ports of Philadelphia support the continuance of the comprehensive regional navigation study, which includes the study of economic feasibility of dredging the channel deeper than 40 feet. We, the port community, offer the Corps of Engineers our continued cooperation and assistance in carrying out this work.

Respectfully submitted,

James R. Kelly, President
Delaware River Port Authority

William Miller, Executive Director
Delaware River and Bay Authority

W. Oliver Leggett, President
Philadelphia Port Corporation

Robert Pettegrew, Exec. Director
South Jersey Port Corporation

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DEC 04 1985

Planning Branch

Captain Sam Schellenger
Chairman, Mariners Advisory Committee
P. O. Box 89
Morrisville, Pennsylvania 19067

Dear Captain Schellenger:

This is in regard to our Delaware River Comprehensive Navigation Study

As part of our ongoing studies we intend to perform more detailed channel designs for various alternatives related to deepening the main Delaware River channel and access to the Big Stone Beach Anchorage. In order to accomplish this we would like to discuss with you various factors related to vessel operations, traffic management, and physical conditions which affect vessel navigability and design criteria. In addition to traditional designs, we would like to discuss further the concepts of asymmetric and one-way channel layouts.

I have enclosed a list of supplemental information and topics for discussion which you may want to discuss with other members of the Pilots' Association prior to meeting with us. If you have any questions on this matter or wish to make meeting arrangements, please contact Mr. John Tunnell, of this office at (215) 597-4714.

Sincerely,

Nicholas J. Barbieri, PE
Chief, Planning/Engineering Division

RAYMOND G. HEINZELMANN, Ph.D.
DIRECTOR

• 215-925-8780
• 609-963-6420
• TELEX: 831417

PORTS OF PHILADELPHIA
CAMDEN PHILADELPHIA
GLOUCESTER WILMINGTON

DELAWARE RIVER PORT AUTHORITY

WORLD TRADE DIVISION, BRIDGE PLAZA, CAMDEN, NEW JERSEY 08101

January 13, 1986

Mr. John E. Tunnell, P. E.
Chief, Coastal and Special Studies Section
United States Army Corps of Engineers
United States Custom House
2nd and Chestnut Streets
Philadelphia, Pa. 19106

Dear Mr. Tunnell:

Attached is a copy of letter from John H. Bates, Manager, Fleet Operations, Sun Transport, Inc., which supports the need for dredging the Delaware River to 44 feet. As I receive letters of a similar nature, are they of interest to you? If they are, I would be pleased to send them to you in the future.

Sincerely,

Raymond G. Heinzelmann, Ph.D.
Director, World Trade Division

RGH:dlh
enclosure

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REFERENCE OR OFFICE SYMBOL	SUBJECT
NAPEN-P	Delaware River Comprehensive Navigation Study, Jan. 17, 1986 Coord. Mtg. with Mariners' Advisory Committee

TO	FROM	DATE	CMT 1
Files	Lee Ware	4 Feb 86 kad/5954	

1. The meeting was held with the following objectives in mind.

- To establish project segments for design, based on similarity of vessel usage and physical conditions.
- To review the layout of alternative projects under consideration.
- To discuss physical conditions for design at each segment.
- To discuss Corps design criteria and parameters to be determined for ongoing design efforts.

Mariners Representatives	Corps Representatives
Tom Summers, Texaco Oil	Jane Jablonski, Asst. Project Engineer
Bill Frederick, Conrail	Jeff Gebert, Oceanographer
Bill Dorsey, Pilots' Assoc.	Doug Leatherman, Design Engineer
Bill Harrison, Maritime Exchange	Lee Ware, Project Engineer
Jim Wallace, Navios	
Harold Ellwanger, Sun Refining	
Sam Schellenger, Mariners' Adv. Comm.	

3. Study Background. The Corps' Philadelphia District Office (P.D.O.) reviewed the study purpose; methods of formulating projects; results of formulation studies to date, by project area; and alternatives currently being investigated.

4. Project Segments for Design. Three segments were considered appropriate for further studies of deepening the main channel and access to a mid-stream deepwater port. Segments for the mid-stream deepwater port should include the ocean traffic lanes, bay channel between Cape Henlopen and the anchorage, and Big Stone Beach Anchorage. For the main Delaware River channel (Philadelphia to the sea) it is reasonable to continue analyzing the channel according to its existing 1000', 800', and 400' wide segments. P.D.O. indicated the 400' segment was established to provide a channel width through Philadelphia Harbor consistent with the 40' deep Philadelphia to Trenton project which services U.S. Steel. However, attendees were unaware of what physical conditions or navigation practices led to the channel transition from 800' to 1000' at Bombay Hook. (Following the meeting P.D.O. reviewed the authorizing legislation and found that the 800' width was established for the 35' project adopted in 1910, which ended at the Liston Range. When the 40' project was adopted the channel had to be extended through Delaware Bay to deep water and a 1000' width was established based on the input of pilots and vessel captains).

5. Discussion of Alternatives. Discussions centered on the layout and functional requirements of the alternatives under study. Comments on each project are summarized in the following paragraphs.

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6. Access to Mid-Stream Deepwater Port. The 1000' channel width for inbound or one-way traffic seems reasonable, however 650' for an outbound traffic lane seems too narrow. PDO will review this. The one-way concept presents some institutional problems due to its required changes in international law and treaties, charts, etc. Other problems presented by this plan include communications (foreign vessel captains/poor English skills), the potential for queuing problems for inbound vessels, and increased risk of accidents due to failures in equipment or communications. Potential solutions which were offered included advanced testing of equipment prior to arrival at the bay entrance, boarding of pilots further offshore (helicopters are used at Rotterdam to transport pilots 30 miles offshore), and designation or construction of a holding area at the entrance (to avoid the need for circling or to accomodate vessels with equipment problems). Communications and traffic management would still be handled at Lewes. The layout using two separate lanes for inbound and outbound traffic was preferred since it is more in keeping with existing traffic patterns. Separate optimizations of the inbound and outbound channel depths are being conducted with depths ranging up to about 72 feet.

7. Anchorage Layout. Pilots favored full width deepening of the anchorage to facilitate passing of anchored vessels. Existing practice is to allow .75 to 1 mile between vessels, however 0.4 mi. was considered the minimum acceptable spacing. Due to wave activity in the lower anchorage, more extensive deepening up to the northwestern, more sheltered portions of the anchorage was favored. Operating criteria (#vessels/area, space assignments, etc.) may be required and it may be necessary to have a tug on standby if close spacing presents the danger of vessels drifting together if anchors break hold. It was noted that the bay's bathymetry is relatively stable and project maintenance should not be significant. No tug assistance is used in anchoring at Big Stone Beach and none would be required with a deeper project. Large vessels must generally anchor (single point mooring) while proceeding against tidal currents. Breakwaters on Lower Middle Shoal or Brown Shoal were not expected to provide adequate shelter from wave activity since waves propagate up the channel.

8. Main Channel. It was concluded that existing channel widths are safe for two-way navigation of vessels currently using the channel or anticipated to use it when deepened. Since previous studies indicated that full width deepening of the existing channel to accomodate two-way traffic was more economical than asymmetric channels inbound or outbound, no further discussions of asymmetric channels appear warranted. It remains to be determined if main channel deepening plans should include as an integral feature deepening of a portion of Marcus Hook Anchorage to compatible

depths. P.D.O. studies have found that when considered incrementally, anchorage improvements are not justified. It was suggested that widening and deepening (to accomodate vessel width and draft increases due to roll) at bends would be a most beneficial modification. It was noted that proper widening at bends can reduce overall channel width requirements in straight reaches.

9. Realignment Under Ben Franklin Bridge. Although previous studies indicate the realignment is economical, only the Navios fleet has been identified as a beneficiary. Since single beneficiary projects aren't within the Federal interest, P.D.O. should contact Northern Shipping, Tioga (Al Castignola), and Port Richmond users about potential benefits. It was noted that the P.D.O. layout may require modification to provide a milder angle as the realigned channel transitions into the existing channel upstream of the bridge.

10. Physical Conditions and Design Factors. It was agreed that discussions of design physical conditions and critical factors such as squat, roll, pitch, trim, etc. could be better handled by development of a questionnaire. P.D.O. will prepare and forward this questionnaire to Jim Wallace for circulation along with the meeting minutes. It was noted that a 2° roll, for instance, would add about 3' draft and 12' width to a design vessel.

11. Design Vessels. Previous Corps studies have identified the largest anticipated vessels to be about 275,000 DWT tankers (inbound) and 160,000 DWT bulk vessels (outbound). Attendees generally felt that 280,000 DWT tankers and 200,000 DWT bulk vessels represented the largest vessels anticipated to call with the project improvements under study, with Panamax vessels likely to be a common size. Numerous factors need to be considered in establishing what vessels are least manueverable. Further discussions are required on this matter. Mr. Goldbach at McMullin Naval Architects in New York could provide additional information on vessel trends.

Lee Ware
Project Engineer

DISPOSITION FORM

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REFERENCE OR OFFICE SYMBOL	SUBJECT
NAPEN-P	Delaware River Comprehensive Navigation Study, March 26, 1986 Coord. Mtg. with Mariners Advisory Committee

TO Files FROM C. L. Ware DATE 10 April 1986 CMT 1
Ware/tmm/5954

1. The meeting was held to clarify questions on the design criteria questionnaire. Copies of the questionnaire are attached which show the responses agreed upon at the meeting and data yet to be provided.

2. Those is attendance included:

Mariners Representatives

Bill Frederick, Conrail
Bill Dorsey, Pilots' Association
Bill Harrison, Maritime Exchange
Jim Wallace, Navios
Harold Ellwanger. Sun Refining
Sam Schellenger, Mariners' Adv. Comm.

Corps Representatives

Jeff Gebert, Hydraulics Branch
Douglas Leatherman, Design Branch
Lee Ware, Project Engineer, Plng. Br.

3. Responses to Date: Harold Ellwanger has completed the questionnaire and provided it to Captain Wallace. Other responses are to be generated following the meeting.

4. Vessel Distributions (II A on Questionnaire): The distributions presented on the questionnaire generally appeared reasonable. Occassional 275,000 DWT tanker trips are anticipated. It was thought that dry bulk carriers in the 190,000 DWT range might take advantage of the mid-stream port which had been partially loaded at Norfolk. The maximum vessel size from Pier 124 would also be in this range (according to the permit for pier extension).

5. Design Vessels (II C). The largest vessels anticipated would be in the 275,000 DWT class for tankers and 190,000 DWT class for dry bulk vessels. It was suggested that vessels in the range of 160,000 DWT be selected for designs under adverse conditions. Larger ships could be accommodated by restricting transits to daylight or milder conditions and through the use of tugs to improve maneuverability. Drawings showing tranverse sections amidships have been received from Mr. Goldbach at McMullen Holdings Inc., the contact provided by Captain Wallace. Additional information is requested from pilots on the factors which characterize the least maneuverable vessels.

6. Physical Conditions for Design (II A and II B). The most critical factor for design of the ocean lanes, bay channels and anchorage was considered to be roll induced by east or southeast prevailing winds and the resultant swells. Currents were not considered critical to design nor was tide condition. Input is requested on typical visibility conditions, swell, and wind speed, if known, for the most severe conditions under which transits are made. Input is also requested on the parameters for design of the 400' and 800' segments of the main channel. Pilots felt that the same set of physical conditions would generally prevail for design of the ocean lanes, bay channels and anchorage, with different conditions for design of the 400' and 800' main channel sections. The exceedance frequency information provided on the questionnaire was taken from pilot responses in our previous anchorage analyses. Pilots suggested contacting Dave Buchanan (Schuylkill dock of Sonat) regarding the physical conditions which affect lightering operations and frequency of exceedance.

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NAPEN-P
SUBJECT: Delaware River Comprehensive Navigation Study,
March 26, 1986 Coord. Mtg. with Mariners Advisory Committee.

7. Operational Data (IV-A and IV-B). Vessel speeds are typically 10-12 knots or less. This would apply to deepwater port or main channel designs. The mid-stream port proposal (two-way) would require no change to the navigation aids systems. The ocean lanes are marked only by buoys and whistles in the separation zone. The one-way proposal was considered by the pilots to be unworkable and subject to many obstacles. However, since this represents the least cost approach, a strong argument must be presented to eliminate it from further study. Harold Ellwanger suggested designing the channel between Cape Henlopen and Big Stone as two-way for smaller vessels and one-way for the largest. Vessels would transit on the tides if necessary to maximize draft for main channel and deepwater port schemes. Most vessels anchor at Big Stone during an ebb tide, the worst case is with a flood tide at stern. Very large tankers would not attempt to anchor without an ebb current since the tackle won't hold. A key point to be addressed is whether a minimum size anchorage at Marcus Hook is required at a depth compatible with a deepened channel. Economic analyses to date have shown that anchorage improvements are not incrementally justified. However, if rationale exists, such improvements could be considered an integral part of a channel deepening plan, which does appear to be economical.

8. Design Criteria (V-A, V-B and V-C). Vessels reportedly "squat" about 2' in the front when underway. Captain Wallace has information he can provide regarding squat calculations. Squat must be considered for all the channel segments being designed including the ocean lanes. A 2' underkeel clearance for safety is appropriate for each channel location. Vessels generally are in trim within the Delware River. They tend to operate more efficiently when the stern draft is slightly deeper (about 1' in the bay and 2' in the ocean). Roll is the most significant factor in the table. A 1° to 2° roll is common in turns of the main channel (2' to 4' depth increase). A greater roll would commonly be experienced at sea. The most critical conditions would be caused by swell off the beam or quarter. As a result a 3° or 5° roll or more could result. It would be beneficial to analyze swell versus frequency and determine the relationship between swell and roll. Larger ships would tend to roll less than smaller ones under the same swell conditions. A 3° roll would result in about a 6' change for the design vessel of 275,000 DWT. The Hooley formula can approximate the effect of roll on depth (.1' of depth per ft. of beam times degree of roll). Pitch and heave are not critical to design. Fresh water sinkage would vary depending on vessel draft (about 1' for a 40' draft, 1.8' for a 70' draft).

9. Further Actions. The rest of the questionnaires need to be completed and returned to Captain Wallace who will copy them and forward a set to the Corps. He also has contacts for obtaining copies of two pertinent reports on navigation improvements.

Enclosure

C. L. WARE
Project Engineer

2

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REFERENCE OR OFFICE SYMBOL	SUBJECT
NAPEN-P	Delaware River Comprehensive Navigation Study, May 28, 1986 Coordination Meeting with Mariners Advisory Committee

TO Files FROM Lee Ware DATE 22 July 1986 CMT 1
WARE/rpr/5954

1. Purpose. The meeting was held to review the final input of committee members to Corps design criteria questionnaire for the Parent Study alternatives. In addition, information was provided to the committee regarding navigation practices on the Salem River for review and comment.

2. Those in Attendance:

Mariners Representatives
Jim Wallace, Navios
Bill Dorsey, Pilots Ass'n
Bob Kramer, Texaco
Harold Ellwanger, Sun Refining
Bill Harrison, Maritime Exchange
Sam Schellenger, Mariners Adv. Cte

Corps Representatives
Jeff Gebert, Oceanographer
Doug Leatherman, Design Engineer
Barbara Stratton, Asst. Project Engineer
Lee Ware, Project Engineer

3. Data Provided. Captain Wallace provided copies of a Pilots' Association report on Shallow Water Effects in River Channels, background on the Hooghly formula, a copy of the report Navigation of Tankers in Harbours and Port Approaches, and the reference for a report on vessel performance in the confined St. Lawrence River. Completed questionnaires were provided by Captains Wallace, Schellenger, and Ellwanger.

4. Review of Questionnaire Input.

a. Vessel Data. As a comment in the design vessel section, it was noted that more caution is exercized in transits as vessel size increases.

b. Physical Conditions. Wind speeds of 35 knots or more are critical for each channel segment. Northwest winds are most critical in the anchorage at Big Stone Beach; south/southeast winds in the ocean lanes and bay channels. Channel currents are about 1½ knots in the 400' and 800' segments of the main channel. Critical visibility was considered to be one mile (day) to two miles (night) for the 400' to 1000' main channel segments, zero visibility at night for the bay channel and ocean lanes, and zero visibility day or night at Big Stone. Further analyses of navigational aid improvements would be beneficial, relative to zero visibility conditions. RAYCON has been installed at Buoy D and is being installed at DBJ. Since vessels committed to a movement into Big Stone or through the ocean lanes must continue as visibility goes to zero, a system may be required to enhance safety. The Corps will look into this further with the USCG.

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DA FORM AUG 80 2496 PREVIOUS EDITIONS WILL BE USED GPO : 1984 O - 455-151

The mid-stream deepwater port with a single access channel will require that an international treaty be rewritten and coordinated with many nations for approval. This is a very formidable undertaking and the pilots are unsure that this proposal is legal. If the U.S. Coast Guard feels it is legal, the pilots could live with it; however, the proposal is likely to generate a lot of talk and controversy which is likely to delay or preclude implementation. This plan would also require pilots to meet vessels at Buoy D.

d. Design Criteria. The widths of ocean lanes were considered excessive compared to the main channel widths for two-way traffic. Pilots suggested using a mid-range value for bank clearance (say 100% rather than 150%). Although the design vessels are large, special attention is paid to their transits and ocean lanes could be reduced to 700'-800'. Swell of about 3 feet is normally the worst experienced offshore. Pilots indicated that at least 5' underkeel would be required for the ocean lanes. The Corps indicated that with all the factors we've considered for design conditions, nearly 10' would be necessary; this seemed acceptable.

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6. Big Stone Beach Anchorage Layout. The Corps will furnish the Pilots layouts of the upper and lower anchorage alternatives for improvement of the anchorage when available.

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Lee Ware

C. L. WARE
Project Engineer

DELAWARE RIVER PORT AUTHORITY
OF
PENNSYLVANIA AND NEW JERSEY
BRIDGE PLAZA
CAMDEN, NEW JERSEY 08101

(609) 963-6420
(215) 925-8782

April 12, 1988

JAMES R. KELLY
PRESIDENT

The Honorable J. Bennett Johnston, Chairman
Subcommittee on Energy and Water Development
Senate Committee on Appropriations
Washington, D. C. 20510

Dear Chairman Johnston:

I wish to submit this letter in testimony of the strong support of the Delaware River Port Authority for continued funding of the Delaware River Comprehensive Navigation Study, New Jersey, Pennsylvania, and Delaware.

The existing Delaware River navigation system includes six deep draft navigation projects serving the Ports of the Delaware River. These ports support annual vessel passages, according to the U. S. Army Corps of Engineers' records, averaging 44,000 passages and tonnage averaging 114 million tons. The system provides a substantial economic stimulus to the entire region, supporting nearly 100,000 port-related jobs. The major commodities transported are crude oil and refined petroleum associated with seven oil refineries located along the river and its tributaries. Other major commodities include iron ore, scrap, coal, grain, chemicals, limestone, motor vehicles, gypsum and other drybulk shipments, lumber, and containerized general cargo. The system also serves naval vessels at the Philadelphia Naval Base.

The Delaware River Comprehensive Navigation Study is defining the Federal interest in navigation development, especially with respect to future port needs for navigation improvements for the entire Delaware River complex. The main study is addressing the following: Delaware Bay deepwater port for depths to 80 feet; Delaware River deepening to 45 feet; and Chesapeake and Delaware Canal deepening to 40 feet.

The Delaware River Port Authority and the Delaware River and Bay Authority have given their support and sponsorship for the main study.

Due to the extreme economic importance of this study to the Ports of the Delaware River, we urge the Committee to give favorable consideration in continued funding of the study.

Sincerely,

James R. Kelly
President

JRK:JE

RAYMOND G. HEINZELMANN, Ph.D
DIRECTOR

• 215-925-8780
• 609-963-8420
• TELEX 831417

PORTS OF PHILADELPHIA
CAMDEN PHILADELPHIA
GLOUCESTER WILMINGTON

DELAWARE RIVER PORT AUTHORITY

WORLD TRADE DIVISION, BRIDGE PLAZA, CAMDEN, NEW JERSEY 08101

May 19, 1988

Lt. Col. G. William Quinby
U. S. Army Corps of Engineers
U. S. Custom House
2nd & Chestnut Sts.
Phila. Pa. 19106

Dear Colonel Quinby:

This concerns your ongoing Delaware River Comprehensive Navigation Study. The Delaware River Port Authority and the Delaware River & Bay Authority have been the supprting and sponsoring agencies for the main study of that investigation.

As a result of the efforts by the port community to develop a strategy and plan to unify the ports of the Delaware River and maximize channel development, your assistance is requested to reach these goals. It is requested that under your study authority you:

a. Accelerate studies pertaining to the deepening of the main Delaware River channel to 45 feet;

b. Review institutional capability of various agencies within the tri-state region to lead a unified port and provide financial support to your channel development recommendations;

c. Review the infrastructure within the Ports of the Delaware River and determine where improvements should and can be made. We understand that such a review is within the authority provided by your study resolutions.

Please contact us at your earliest opportunity so that we might discuss your capability to accomplish these requests.

Sincerely,

Raymond G. Heinzelmann

Raymond G. Heinzelmann, Ph.D.
Director

RGH:JE

OFFICES IN • PHILADELPHIA • NEW YORK • PITTSBURGH • CHICAGO

NOV 1 0 1988

Planning Division

Dr. Raymond G. Heinzelmann, Director
World Trade Division
Delaware River Port Authority
Bridge Plaza
Camden, New Jersey 08101

Dear Dr. Heinzelmann:

This is in reference to your discussions with Mr. Lee Ware regarding the potential interest of the Delaware River Port Authority (D.R.P.A.) in cost-sharing for the ongoing Delaware River Comprehensive Navigation (Comp. Nav.) study.

The Comp. Nav. study was initiated in 1982 prior to the requirements for cost-shared feasibility studies. Consequently, the Comp. Nav. can be completed at full Federal expense. Our schedule for it's completion has recently been approved. This schedule includes the completion of a detailed feasibility study for the Delaware River main channel in 1990 and the balance of the study, including the feasibility of a mid-stream deepwater port at Big Stone Anchorage, in 1992. The total funds available to complete this work are $1,142,000. These funds will be utilized in Fiscal Years 1989 through 1992. Upon completion of the feasibility study, any recommendations for channel improvements will be eligible for preconstruction engineering and design (PED).

However, since this study is Federally funded, it must compete with all others at the national level for a dwindling pool of PED funds. This could result in delays of several years in project construction. These delays can be avoided. Current policy ensures virtually continuous funding for all cost-shared feasibility studies. This would eliminate the waiting time while the feasibility study is being processed and allow the PED to begin as soon as possible. Therefore, if D.R.P.A. would agree to cost-sharing at some point, this continuous funding can be guaranteed.

There may also be particular study activities which you may want to fund because the results may provide valuable information for marketing purposes or resolve uncertainties in a particular area. Local funding could be used to accelerate such activities. Note also that up to 50 percent of local funding can be in the form of in-kind services which you may want to perform.

We would be happy to meet with you to discuss these options further. If you have any questions, please contact Mr. Lee Ware, Acting Chief of the Project Studies Section at (215) 597-4714.

Sincerely,

Robert L. Callegari
Chief, Planning Division

Let's protect our earth

State of New Jersey
DEPARTMENT OF ENVIRONMENTAL PROTECTION
DIVISION OF PARKS AND FORESTRY
OFFICE OF NEW JERSEY HERITAGE
CN 404
TRENTON, N.J. 08625-0404
(609)292-2023

ONJH-K88-150
November 29, 1988

Mr. Robert L. Callegari
Chief, Planning Division
Environmental Resources Branch
Department of the Army
Philadelphia District
Corps of Engineers
Custom House-2 D & Chestnut Streets
Philadelphia, Pennsylvania 19106-2991

Re: Delaware River Dredging
Main Navigation Channel
Phialdelphia, PA to deepwater in the Delaware Bay
Interim Section 106 Consultation Comments

Dear Mr. Callegari:

Thank you for your letter of October 17, 1988 and the enclosed July, 1988 remote sensing survey report, Submerged Cultural Resources Investigations, Delaware River, Main Navigation Channel, Philadelphia, Pa. to Artificial Island, NJ., prepared by J. Lee Cox, Jr. of the Maritime Historical Institute, Inc. I have reviewed the report and information provided in the accompanying letter.

The report prepared by J. Lee Cox, Jr. is thorough, informative and acceptable without modification. I look forward to receiving the report detailing the results of additional investigation of the six sensitive target areas, if widening the channel at these locations remains part of the proposed project. The six sensitive targets (as classified by Cox) and locations of the discussions in the report are a4:4 (page 32), e-1,1:5 (page 60), e-2,4:16 (page 65), i4:9 (page 90), 11:15 (page 110), and 13:10 (pages 110, 113).

In your letter you indicate that the Corps proposes not to survey the main channel, since up to twenty feet of sediment within the existing channel have been removed as the result of previous dredging. Before I am able to comment on this, I will need additional information to support the conclusion that significant cultural resources are unlikely to remain buried in the sediment within the existing channel. This would need to include information on the nature of the sediments underlying the main channel as well as the dynamics

of this portion of the river. Although dredging of the bottom of the channel was already occurring by the late 1800's, what is the likelihood that intact resources dating to 1750, for example, became deeply buried in the underlying sediments before that time? If this scenario is unlikely, I will need specific information on why this is the case.

I look forward to continuing to coordinate with you on this project, and am anxious to receive the report detailing the results of the remote sensing survey of proposed Federal channel modification areas south of Artificial Island, as well as the analyses of impacts at any proposed disposal locations.

If you have any questions please do not hesitate to contact Deborah Fimbel of my staff at (609)984-6014. All correspondence for this project should continue to be addressed to me, but to the attention of Ms. Fimbel. Thank you again for providing this early opportunity for consultation.

Sincerely,

Nancy L. Zerbe

Nancy L. Zerbe
Deputy State Historic
Preservation Officer

NLZ:DRF
S/P:Geo:drf89029

COMMONWEALTH OF PENNSYLVANIA
PENNSYLVANIA HISTORICAL AND MUSEUM COMMISSION
BUREAU FOR HISTORIC PRESERVATION
BOX 1026
HARRISBURG, PENNSYLVANIA 17108-1026

December 13, 1988

Robert L. Callegari
Planning Division
Dept. of the Army
Philadelphia District, Corps of Engineers
Custon House-2 D & Chestnut Streets
Philadelphia, PA 19106-2991

TO EXPEDITE REVIEW
USE BHP REFERENCE NUMBER

Re: ER 84-1708-042-F
Report on Submerged Cultural Resources Investigations, Delaware River, Main Navigation Channel, Philadelphia, PA to Artificial Island, NJ

Dear Mr. Callegari:

The above named project has been reviewed by the Bureau for Historic Preservation (the State Historic Preservation Office) in accordance with Section 106 of the National Historic Preservation Act of 1966, as amended in 1980, and the regulations (36 CFR Part 800) of the Advisory Council on Historic Preservation. These requirements include consideration of the project's potential effect upon both historic and archaeological resources.

The Bureau for Historic Preservation has reviewed the above-referenced proposal. We find that it meets the standards outlined in the Bureau's Guidelines for Archaeological Survey & Mitigation (rev. 1986) for archaeological survey and will provide us with information concerning the presence of archaeological resources in the project area. We look forward to seeing the final report.

If you need further information in this matter please consult Susan M. Zacher at (717) 783-8946 or 783-8947.

Sincerely,

Kurt W. Carr

Kurt W. Carr, Chief
Division of Archaeology and Protection

KC/smz

Jack Sparks, *President*
George G. Macintire, *Secretary Treasurer*
Richard G. Steers, *Manager*
Edward L. Colaprete, *Business Agent*

The Pilots' Association for the Bay & River Delaware

214 South Eleventh Street
Philadelphia, Pa. 19107

Philadelphia (215) 922-7165
Media (215) 566-1260
Accounting (215) 922-7170
FAX (215) 922-7411

December 21, 1988

Mr. James R. Kelly
Delaware River Port Authority
Bridge Plaza
Camden, NJ 08101

Dear Jim:

As per our conversation about forming an Ad-Hoc Committee for Channel Deepening to serve at the pleasure of the Delaware River Port Authority, I have contacted the following gentlemen and they have agreed to serve on this committee. They are:

Jack Sparks, President
The Pilots' Association for the Bay and River Delaware

George E. Duffy, President
Navios Ship Agency, Inc.

Charles N. Marshall, Senior Vice President - Marketing and Sales
Consolidated Rail Corporation

Captain John H. Bates, Manager - Fleet Operations
Sun Transport

William A. Harrison, Executive Director
Ports of Philadelphia Maritime Exchange

Lewis Caccese, Consulting Engineer
American Dredging Company

You can pass on to Father Nick that all of the above are most anxious to serve the Delaware River Port Authority and Father Rashford.

Sincerely,

Jack

Jack Sparks
President

JS:dfs

STATE OF DELAWARE
DEPARTMENT OF STATE
DIVISION OF HISTORICAL AND CULTURAL AFFAIRS
15 THE GREEN
DOVER, DELAWARE 19901
BUREAU OF ARCHAEOLOGY AND HISTORIC PRESERVATION
TELEPHONE (302) 736 - 5685

January 12, 1989

Mr. Robert L. Callegari
Chief, Planning Division
Philadelphia District
Corps of Engineers
Custom House, 2nd & Chestnut Sts.
Philadelphia, PA 19106-2991

Dear Mr. Callegari:

I have reviewed the report entitled Submerged Cultural Resources Investigations, Delaware River, Main Navigational Channel, Philadelphia, PA to Artificial Island, New Jersey prepared by Maritime Historical Institute, Inc. The report briefly, but adequately outlines the prehistoric and historic use and development of the study area. It fails to reference the State Plans for prehistoric and historic resources. The report clearly details the fieldwork and summary of findings but does not provide any sort of context or frame of reference whereby significance of any resources which may be encountered can be made. Clearly, not all submerged resources are eligible for listing in the National Register of Historic Places. While a detailed discussion is not warranted at this level c survey, some discussion albeit brief should be presented.

Despite the gaps in the background portion of the report, the summary of findings, as presented, are valid. Likewise, the recommendations are appropriate. If, during the continued planning of this project, avoidance fo the six (6) identified targets is not deemed feasible, then a Phase II survey to evaluate these targets for their National Register eligibility and possibly data recovery (Phase III) will be required.

We concur with your determination that no remote sensing survey work is required in the main body of the navigational channel. No intact resources are anticipated.

We concur with your determination that it would be necessary to conduct additional surveys of the range intersections south of the Artificial Island as well as any areas of the navigational channel of the Delaware Bay which may be widened or modified. Additionally, disposal site locations must be given the same consideration unless the location(s) is identified as a previously sanctioned disposal facility.

If you require any additional information or assistance, please do not hesitate to me.

Sincerely,

Faye L. Stocum, Archaeologist/
Environmental Review Coordinator

cc: Jan Ferguson

Planning Division JAN 1 7 1989

Mr. Sam Schellenger
Mariners' Advisory Committee for the
Bay and River Delaware
P.O. Box 89
Morrisville, Pennsylvania 19076

Dear Mr. Schellenger:

This letter concerns the Delaware River, Philadelphia to the Sea Project and the effects of channel deepening being investigated as part of the Delaware River Comprehensive Navigation Study. The District is in the process of conducting detailed studies for modifying the main Delaware River channel. We are again soliciting the comments of the Mariners' Advisory Committee in regards to Corps of Engineers channel design criteria.

In discussions you and the Mariners' Advisory Committee members had with my staff in the spring of 1986, the following conclusions were made:

1. Maximum vessel draft would be 40 feet (freshwater draft) for the existing channel.
2. A 160,000 DWT tanker would be the design vessel for the Delaware River, Philadelphia to Sea project. This vessel would have a 931' length, a 145' beam, and a 58' design draft. Larger vessels would operate with tug assistance during light traffic periods.
3. A minimum sized anchorage at Marcus Hook would be needed for safety reasons.

Attached are the minutes of the May 28, 1986 meeting which concluded the discussions.

Since those discussions, the projected future commodity tonnages and mix of vessels which benefit from a deeper channel were updated. Regional coal exports and iron ore imports are no longer expected to increase. Crude oil imports, once projected to decrease, are now expected to increase, and would be the predominant commodity to benefit from channel deepening. These changes in commodity flow are sufficient to require a re-analysis of a deeper one-way inbound channel. This deeper inbound lane would still allow for increased loading of crude oil tankers and iron ore carriers but would not benefit coal exports. By only deepening the inbound lane, construction costs could be substantially reduced with little loss of benefits. The deeper inbound channel would follow the alignment of the inbound channel and be separate but adjacent to the outbound lane which would remain unchanged.

In addition, a full width deepening of the 800/1000 foot wide channel is being investigated. Both alternatives are being investigated for depths up to 45 feet between the Walt Whitman Bridge and the Delaware Bay. There are insufficient benefits above the Walt Whitman Bridge to justify deepening above this location. Widening at bends is included with any channel deepening.

We request the following information by January 31, 1989 in order to complete our investigation of deepening the main Delaware River channel from Philadelphia to the Sea:

1. Any changes in present operating conditions or present maximum vessel draft.
2. Any dramatic changes in vessel size since 1986. This is the latest vessel data available for our use.
3. Any additional factors which you feel need to be addressed which would affect channel design.
4. The additional problems associated with navigating a deeper inbound channel as opposed to a full width two-way channel.
5. Any changes in navigational aid improvements to facilitate vessel navigation including low or zero visibility conditions.

If you have any questions please contact Mr. Bill Mueller at (215) 597-5959.

Sincerely,

Robert L. Callegari
Chief, Planning Division

DISPOSITION FORM

For use of this form, see AR 340-15 the proponent agency is TAGO

REFERENCE OR OFFICE SYMBOL	SUBJECT
NAPEN-P	Delaware River Comprehensive Navigation Study, May 28, 1986 Coordination Meeting with Mariners Advisory Committee

TO Files FROM Lee Ware DATE 22 July 1986 CMT 1
WARE/rpr/5954

1. Purpose. The meeting was held to review the final input of committee members to Corps design criteria questionnaire for the Parent Study alternatives. In addition, information was provided to the committee regarding navigation practices on the Salem River for review and comment.

2. Those in Attendance:

Mariners Representatives
Jim Wallace, Navios
Bill Dorsey, Pilots Ass'n
Bob Kramer, Texaco
Harold Ellwanger, Sun Refining
Bill Harrison, Maritime Exchange
Sam Schellenger, Mariners Adv. Cte

Corps Representatives
Jeff Gebert, Oceanographer
Doug Leatherman, Design Engineer
Barbara Stratton, Asst. Project Engineer
Lee Ware, Project Engineer

3. Data Provided. Captain Wallace provided copies of a Pilots' Association report on Shallow Water Effects in River Channels, background on the Hooghly formula, a copy of the report Navigation of Tankers in Harbours and Port Approaches, and the reference for a report on vessel performance in the confined St. Lawrence River. Completed questionnaires were provided by Captains Wallace, Schellenger, and Ellwanger.

4. Review of Questionnaire Input.

a. Vessel Data. As a comment in the design vessel section, it was noted that more caution is exercized in transits as vessel size increases.

b. Physical Conditions. Wind speeds of 35 knots or more are critical for each channel segment. Northwest winds are most critical in the anchorage at Big Stone Beach; south/southeast winds in the ocean lanes and bay channels. Channel currents are about 1½ knots in the 400' and 800' segments of the main channel. Critical visibility was considered to be one mile (day) to two miles (night) for the 400' to 1000' main channel segments, zero visibility at night for the bay channel and ocean lanes, and zero visibility day or night at Big Stone. Further analyses of navigational aid improvements would be beneficial, relative to zero visibility conditions. RAYCON has been installed at Buoy D and is being installed at DBJ. Since vessels committed to a movement into Big Stone or through the ocean lanes must continue as visibility goes to zero, a system may be required to enhance safety. The Corps will look into this further with the USCG.

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DA FORM AUG 80 2496 PREVIOUS EDITIONS WILL BE USED GPO : 1984 O - 455-151

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Lee Ware

C. L. WARE
Project Engineer

Delaware River Comprehensive Navigation Study
Design Criteria Questionnaire

I. Background - This questionnaire concerns the data and assumptions relevant to design of projects to deepen the main Delaware River channel and access to a mid-stream deepwater port at Big Stone Beach Anchorage. We have filled in portions of the questionnaire based on previous coordination. Please review this information, revising it as necessary, and provide input where sections are left blank. Figures 1 through 4 show the plans under study and Figures 5 and 6 explain the design criteria being evaluated.

II. Vessel Data

A. Distributions (only vessels benefitting from projects)

Mid-stream Deepwater Port Plans				Delaware River Philadelphia to the Sea			
Inbound		Outbound		Inbound		Outbound	
DWT	%	DWT	%	DWT	%	DWT	%
75,000	0	55,000	0	75,000	23%	55,000	48%
90,000	2%	70,000	17%	90,000	17%	70,000	16%
110,000	8%	90,000	46%	110,000	17%	90,000	16%
135,000	43%	120,000	28%	135,000	26%	120,000	8%
160,000	43%	160,000	9%	160,000	16%	160,000	12%
200,000	2%	190,000 ← Add		200,000	0%	190,000 ← Add	
275,000	2%			275,000	1%		

B. Typical Dimensions

Tankers				Dry Bulk			
DWT	Draft	Beam	Length	DWT	Draft	Beam	Length
				190,000	64' ←	155'	1000'
275,000	70'	204'	1,157'	160,000	58'	145'	931'
200,000	64'	167'	1,026'	120,000	53'	128'	878'
160,000	58'	153'	943'	90,000	48'	112'	855'
110,000	48'	130'	858'	70,000	44'	106'	794'
75,000	41'	124'	744'	55,000	41'	105'	722'
40,000	36'	106'	600'	40,000	37'	95'	600'

C. Design Vessels

Largest - 275,000 DWT tankers and ~~160,000~~ 190,000 DWT dry bulk carriers (mid-stream port and main channel)

Most Common - 135,000 to 160,000 DWT tankers and 70,000 to 120,000 DWT dry bulk carriers (mid-stream port). Tugs and tug/barge units (main channel)

Least Maneuverable - same as largest vessels but with poor controllability (single screw propulsion, no thrusters).

Selected Design Vessels ~~275,000~~ 160,000 DWT tanker (inbound) # use largest vessels for design of ocean lanes & Big Stone anchorage
160,000 DWT dry bulk carrier (outbound)

Comments, if any - Largest Navios ship is ≈ 100,000 DWT. Conrail anticipates 190,000 DWT. from Norfolk. Conrail pier extension permit was based on 190,000 DWT. vessels.

Indicate a contact person or publication from which cross sections of the selected design vessels can be obtained.
Transverse sections were received from Mr. Goldbach at McMullen Naval Architects.

III. Physical Conditions for Design (worst combination of conditions under which vessels navigate)

	Main Channel Segment		Mid-stream Port Segment			
A. Parameters	400'	800'	1000'	Ocean Lanes	Bay Channel	Anchorage
Wind (Speed & Direction)			← S - SE winds, —? mph →			
Current (Speed & Direction)			N/A	N/A	N/A	N/A
Ice (thickness)	N/A	N/A	N/A	N/A	N/A	N/A
Visibility (dist., day/night)						
Waves (height, direction)	N/A	N/A	Swell Generated by S - SE winds			
Tide Conditions (high/low)			N/A	N/A	N/A	Flood tide on stern

(vessels move on tides at Big Stone to facilitate anchoring)

B. Frequency of Exceedance - How often are the physical conditions in the table exceeded? A statistical analysis would be required to determine this.

Main Channel - about 7 days/yr (based on pilot responses to questionnaire on anchorage)
Mid-stream Port Channels - about 7 days/yr (assumed same as main channel)
Big Stone Beach Anchorage - Check with Sonat (Dave Buchanan). 2'-3' waves shut down lightering operations (pulling alongside and hose connections are critical).

IV. Operational Data -

A. Main Channel - Large tankers (275,000 DWT) operate with tug assistance during light traffic situations. No passing/meeting situations are permitted at turns for these vessels. Lesser size tankers and bulk carriers require no tug assistance except for turning/docking maneuvers. Traffic management is accomplished among vessel pilots in cooperation with the Maritime Exchange. Vessels with drafts in excess of 36'6" transit using tides. Maximum allowable draft is 39'6". (38'6" for Navios ships from Fairless)

Typical Vessel Speeds: 10-12 knots or less.

Special Provisions Required for Largest/Least Maneuverable Vessels:
Daylight Transits, Tug Assistance, wait for better weather, restrict passing in bend

Anchoring: A portion of Marcus Hook Anchorage would have to be deepened

Please comment on this assumption and provide rationale for including a minimum size deepened anchorage as a necessary feature of a channel deepening plan.

to a depth comparable to a deepened channel, as an integral part of the plan. Single point mooring is necessary. Mooring dolphins or bouys are not desirable and double anchoring is not a viable option since not all vessels are equipped with stern anchors.

Additional Comments:

B. Mid-stream Deepwater Port - No tug assistance is necessary for transit or anchoring maneuvers. No changes to the existing traffic management system would be required for the plan which provides separate inbound and outbound channels. A one-way channel would require pilots to board vessels further offshore, designation of a holding area for inbound vessels, and earlier testing of equipment by vessel captains. Maximum draft for inbound vessels is 55 feet. It is assumed that the maximum draft (existing conditions) for vessels to be topped off would be 50 feet. Large vessels must anchor while moving against tidal currents. Single point mooring is currently practiced and would continue in the future. Mooring dolphins and buoys are not desirable and double anchoring is not viable since not all vessels are equipped with stern anchors.

Typical Vessel Speeds: 10-12 knots or less

Tide Conditions for Vessels with Max Draft: Vessels would move on tides if necessa

Additional Comments: The one-way concept was described as unworkable. Further rationale is required on why this plan won't functio since it would be more economical due to less dredging.

Changes Required for Navigational Aids:

One-Way Plan -

Two-Way Plan - None

Special Provisions Required for Largest/Least Maneuverable Vessels: The channel from Harbor of Refuge to Big Stone could be operated as two-way for 160,000 DWT vessels and one-way for larger ones.

V. Design Criteria - For factors critical to design indicate an acceptable value or range.

A. Channel Depth (see Figure 5)

Factor	Main Channel 400'	Main Channel 800'	Main Channel 1000'	Mid-Stream Deepwater Port: Ocean Lanes	Mid-Stream Deepwater Port: Bay Channel	Mid-Stream Deepwater Port: Anchorage
Squat (ft)	2'	2'	2'	2'	2'	2'
Safe Underkeel Clearance (ft)	2' ✓	2' ✓	2' ✓	2' ✓	2' ✓	2' ✓
Trim (ft)	0'	0'	0'	0' to 1'	0' to 1'	0' to 1'
Roll (°/ft) 1/	1° to 2° (2'-4' in turns)			3° or more (6' or more)		
Pitch (°) 1/	0	0	0	0	0	0 } Not critic factors
Heave (ft) 1/	0	0	0	0	0	0 }
Freshwater Sinkage (ft)	1'	1'	1'	up to 2' (for 70' draft vessels)		

1/ A single estimate for a combination of these factors may be appropriate.

Captn. Wallace will provide additional information on vessel squat as well as for 2 studies of interest. Further study is needed of swell vs. frequency and roll vs. swell for various vessel sizes. Design for swell off beam or quarter.

B. Channel Width (see Figure 6) - Standard Corps criteria (no tug assistance) generally calls for the following channel widths based on a percentage of design vessel beam width.

Lanes	We have assumed	Vessel Maneuverability: Very Good	Good	Poor	Channels with Yawing Forces
Maneuvering	200%	160%	180%	200%	Judgment *
Vessel Clearance	100%	80%	80%	80%	100% or 100' min.
Bank Clearance	150%	60%	60+%	60+%	150%

* Judgment is to be based on local conditions at each project.

Indicate values or a range of values for factors critical to channel width selection and characterize hazards as indicated below. This information will be used in selecting appropriate percentages from the previous table.

Factor	Main Channel: 400'	800'	1000'	Mid-Stream Deepwater Port: Ocean Lanes	Bay Channel	Anchorage
Roll (°/ft)	1°-2° in bends (2'-4')		3° or more (6' or more)			
Sway (ft)						
Yaw (°)						
Hazardous Cargo (Y/N)	Y (oil)	Y	Y	Y	Y	Y
Congestion Problems (Y/N)				N		
Crosscurrents Present (Y/N)				N		
Hazardous Bank Material (Y/N)	Y	Y (rock)	Y			
Vessel Controllability (V. Good, Good, Poor)						

(Rock/Hard material vs. fluff/soft material)

~~It is assumed that separate buoy clearance lanes (to allow buoy displacement by waves without infringing into navigation lanes) are not required except for ocean traffic lanes. Is this appropriate?~~ None are required. Buoys and whistles in separation zone are the only aids needed.

C. Channel Bends - Corps criteria calls for appropriate channel widening at bends. The following information is given as a general guide for interior channels.

Angle	Vessel Maneuverability: Very Good	Good	Poor	Channels with Yawing Forces
26° Turn	325%	370%	415%	Judgment
40° Turn	385%	440%	490%	Judgment

For critical bends (such as Bulkhead Bar) suggest any improvements which should be incorporated in a channel modification plan. Harold Ellwanger suggested safe depths/widths for improved safety.

Location	Improvement Desired

D. Anchorage Dimensions (see Figure 6)

Anchorage width requirement (diameter of swing) equals 2x (Ship length plus 4 to 5 times the water depth).

E. Proposed Criteria

1. Mid-stream Deepwater Port (Two Ocean Lanes)

Rounded	Beam	Manvg. Lane 200% x beam	Bank Cl. 150% x beam	Ship Cl. 100% x beam	Total
In-bound Lane	204'	408'	612'	---	1020'
Outbound Lane	145'	290'	935'	---	725'
Two-Way Bay Channel	349'	698'	524'	204'	1426'

2. Mid-streamDeepwater Port (one-way channel) - Criteria for the in-bound lane (1020') would be applied to the ocean lane and bay channel.

3. Anchorage. Assuming a plan depth of 72' and a 275,000 DWT design vessel, the anchorage width according to Corps criteria should be: 2 (1157 + 5 x 72) = 3,000' or about 0.57 miles. With allowance for a vessel clearance lane, maneuvering lane, and bank clearance lane, an additional 900 feet would be required. A total width of about 3,900' or 0.74 mi., roughly half the existing anchorage width would be needed to accommodate a mid-stream deepwater port. Dredging the entire width is expected to generate excessive costs. We need to consider alternatives of a) upper anchorage versus b) lower anchorage deepeni

4. Main Channel Deepening. Existing channel widths are considered safe and proper for further designs (1000', 800', 400'). However, the channel is not considered to be of adequate width to accommodate passing of the largest vessels inbound and outbound at the same time. Traffic management practices currently in effect avoid these situations.

5. Please provide comments on the above criteria.

The upper portion of the anchorage would be more sheltered, allowing less interruptions in lightering. However, it is more expensive to dredge than a lower anchorage location which is less sheltered.

NEW CASTLE COUNTY
WILMINGTON
DELAWARE COUNTY
PHILADELPHIA COUNTY
CHESTER
PENNSYLVANIA
NEW JERSEY
DELAWARE
NEW CASTLE
SALEM
DELAWARE RIVER
LOCATION OF WORK
PENNSVILLE
INSERT 1
LOCATION MAP
FORT MIFFLIN, PA
PROJECT OFFICE
TYPICAL SECTION STONE REVETMENT
INSERT 2
AREA WHERE NEW WORK REMAINS TO BE DONE, SHOWN THUS:
THE CHANNEL FROM ALLEGHENY AVENUE TO THE PHILADELPHIA NAVAL BASE, INCLUDING FORT DICKINSON ANCHORAGE HAS BEEN DREDGED TO A DEPTH OF 30 FEET.
CHANNEL DIMENSIONS
LOCATION | DEPTH | WIDTH
A-B WEST SIDE | 40 FT | 400'-500'
A-B EAST SIDE | 37 FT | 500'-600'
B-C | 40 FT | 800'
C-D | 40 FT | 1000'
DELAWARE RIVER
PHILADELPHIA TO THE SEA
PENNA., N. J. & DEL.
40-FOOT CHANNEL
REVISED 30 SEPT 1984
U.S. ARMY ENGINEER DISTRICT, PHILA.

FIGURE 1

N 3
Sheet Nr 2
JERSEY
Millville
Maurice River
PRSL
CRR OF NJ
CUMBERLAND CO
CUMBERLAND CO
CAPE MAY CO
Cohansey River
Leipsic River
Leipsic
Little R.
Little Creek
DOVER
St Jones River
PCRR
Elbow of Cross Ledge Lt.
High Mault Lt.
DELAWARE BAY
14-Ft. Bank Lt.
Brandywine Lt.
DELAWARE
Murderkill R.
KENT CO.
Mispillion River
SUSSEX CO.
Milford
CAPE MAY CANAL
CAPE MAY HARBOR
N.J. Intracoastal Waterway
Cape May
ATLANTIC OCEAN
Roosevelt Inlet
Cape Henlopen
Broadkill R.
Lewes
Fort Miles
Lewes-Rehoboth Cond
LEGEND
Channel indicated thus:
NOTE
Distance in miles below Allegheny Ave., Phila., show along side of channel
DELAWARE RIVER
PHILADELPHIA TO THE SEA
PENNA., N.J. & DEL.
40-FOOT CHANNEL
REVISED 30 JUNE 1969
SCALE OF MILES
U S ARMY ENGINEER DISTRICT, PHILA.

FIGURE 2

N3
Sheet No 2
NEW JERSEY
CUMBERLAND CO
SALEM CO
Cohansey River
Millville
Maurice River
PRSL
CRR OF NJ
Channel Miles to 1000
1000
Ship John Lt.
70
Leipsic River
Leipsic
CUMBERLAND CO
CAPE MAY CO
PCRR
Little R.
Little Creek
DOVER
St Jones River
Elbow of Cross Ledge Lt.
60
Mich Meadl Lt.
DELAWARE BAY
DELA
14-Ft. Bank Lt.
50
Brandywine Lt.
KEPLAGO
Milford
BIGSTONE BEACH ANCHORAGE
BAY CHANNEL (One-Way)
40
Cape Henlopen
Cape May
CAPE MAY HARBOR
Five Fathom Lanes would be eliminated or modified.
ATLANTIC OCEAN
OCEAN LANE (One-Way)
SEP. ZONE
SEP. ZONE
DELAWARE RIVER
MID-STREAM DEEPWATER PORT
BIG STONE BEACH ANCHORAGE
One Way Plan
LEGEND
Channel indicated thus
NOTE
Distance in miles below Allegheny Ave., Phila., show along side of channel

FIGURE 3

N3
Sheet No. 2
NEW JERSEY
CUMBERLAND CO
SALEM CO
Cohansey River
Millville
Maurice River
PRSL
CRR OF NJ
Channel flares to 1000' here
Ship John Lt.
Leipsic River
Leipsic
PCRR
Little R.
Little Creek
DOVER
St Jones River
Elbow of Cross Ledge Lt.
Mich Meull Lt.
DELAWARE BAY
14-Ft. Bank Lt.
Brandywine Lt
DELAWARE
Murderkill R.
KENT CO
Milford
BIGSTONE BEACH ANCHORAGE
BAY CHANNEL (Two-Way)
Cape Henlopen
OUTBOUND OCEAN LANE
CUMBERLAND CO
CAPE MAY CO
Cape May
CAPE MAY HARBOR
OCEAN
SEP. ZONE
INBOUND OCEAN LANE
ATLANTIC
Five fathom lanes unchanged
DELAWARE RIVER
MID-STREAM DEEPWATER PORT
BIG STONE BEACH ANCHORAGE
Two Way Plan
LEGEND
Channel indicated thus:
NOTE:
Distance in miles below Allegheny Ave., Phila., show along side of channel

ENTRANCE CHANNEL WITH WAVE EFFECTS

INTERIOR PROTECTED CHANNEL

CHANNEL WIDTH

ANCHORAGE WIDTH

FIGURE 6

CENAP-PL-PP

PILOT COORDINATION 16 FEBRUARY 1989
COMP NAV - MAIN CHANNEL DEEPENING

FILES

MUELLER

2-17-89

1. A meeting was held with pilots Sam Schellenger and Richard Beebe to discuss responses of the Mariners' Advisory Committee to a Corps letter requesting their input on the Delaware River Main Channel deepening dated 2-17-89. Attending from Planning were Messrs. Ware and Mueller.

2. The letter, see attached, was sent in part to determine if any changes in navigation practices or situations had changed along the Delaware River, Philadelphia to Sea Project since the series of pilot-Corps coordination meetings held in the first half of 1986. In addition pilot views were solicited to determine the practicality of actually navigating a reduced width inbound only channel. Loaded inbound crude oil tankers, which account for about 95% of the bulk vessel movements are the prime beneficiaries of channel deepening.

3. Present tanker movements for the 40 foot Delaware River, Philadelphia to Sea project are scheduled so vessels with drafts up to 40 feet move over the critical Marcus Hook rock outcrop with a rising tide while allowing a minimum of 3 foot of underkeel clearance. While the tide continues to rise to a maximum of 5', vessels would continue to move upstream traveling to the docks and then berthing. Larger vessels (including most tankers) travel in the center of the two way channel all the way upriver unless meeting another ship when they temporarily slow down and move over. Total travel time is 7 1/2 to 8 hours from the pilot transfer point at the Delaware Bay mouth to the uppermost refinery at Eagle Point. Vessel speed decreases as one moves upriver but generally averages about 10 knots.

4. The first discussion centered around the navigation related problems of deepening only the inbound Philadelphia to Sea lane. A tentative one -way channel cross section with a width of 435 feet located within the existing 800 foot channel was presented to the pilots. This section was developed using Corps design criteria to allow separate simultaneous upstream and downstream vessel movement to occur solely in their respective lanes. The pilots thought an indication of the vessel navigability associated with a deeper inbound only channel is the 40 foot deep 400 foot wide Philadelphia to Trenton channel. Movements of the 38'6" draft iron ore ships going to Fairless give some indications of vessel maneuverability. Maximum vessel drafts are limited above Philadelphia due to slower vessel speeds resulting from numerous turns, and side slope drag causing slower speed (7 knots) and more squat.

5. Vessel speed is of paramamount importance in bringing a tanker up the Delaware River while using the tide. There is a critical need to cross the rock outcrop at Marcus Hook at high tide. To do this the tanker must be able to travel upriver from the bay in no more than 10 hours. Using the Delaware River, Philadelphia to Sea channel navigability condition as a surrigate for a inbound only channel deepening scheme it was felt that both effective vessel speed, and vessel maneuverability needed evaluation.

6. In the Delaware Bay (below Arnold Point - R.M.45) the channel is deeper than 45' for about half its length. Vessel speeds of 11.5 knots are not now limited by hard turns or bank drag. The two way channel width is now 1000 feet, based on the perceived need in 19 when the bay channel was last designed to compensate for the added effects of wave action and currents found in the bay. Both pilots felt it was it was imperative that vessel speeds be kept at 11.5 knots done and this is not possible in the Delaware Bay with a one way deepened channel even one with of 500 feet. It was, however, concluded that while the pilots desired that the present 1000 foot wide two way channel be kept with channel deepening, a 800' wide channel like that found on the river itself could be utilized without any measurable navigability impact. There would be sufficient channel width with vessels slowing to allow for two way traffic and for one way traffic at full speed.

7. In the lower Delaware River (between Armold Point and Wilmington - R.M. 72) the pilots generally travel about 10 knots. It is also critical that this speed be maintained in order to cross the rock ledge at Marcus Hook on schedule. A one way channel about 600 foot wide (which could be located within an 800 foot wide two way channel) would be required to maintain the 10 knot speed.

8. In the upper Delaware River (above Wilmington) vessel movement is reduced to about 7.5 knots in the narrowing river corrodor. This is done in order to minimize vessel generated wake effects on piers and docked vessels. A 435 foot one-way deepened channel located within a 800 wide two way channel would be adequate to maintain this speed based on vessel movements in the 400 foot Philadelphia to Trenton Channel. Movement with a rising tide is facilitated by currents giving a vessel a 1 or 2 knot boost as it travels upriver.

9. There has been no appreciable change in pilot operation or tanker traffic from that reported to the Corps in the spring of 1986. There has been some increase in VLCC tankers using Big Stone Beach anchorage but these vessels have not been brought upriver as a rule.

10. In regards to changes in navigational aid requirements the pilots were uncertain as to the effects of a one-way channel and the suggested contacting the Coast Guard. Information found in the Baltimore Harbor Deepening GDM was to be extracted and sent to the pilots.

CENAP-PL-PP SUMMARY OF 21 FEBRUARY 89 MEETING WITH DRPA DREDGING COMMITTEE

TO: FILES FROM: MUELLER 22 FEB 89

1. Attending the full session were committee members; Sparks, Bates, Caccese, Harrison and Heinzelman. Kelley arrived late. Duffy and a unnamed Conrail VP were absent. Attending from the Corps were Callegari, Ware and Mueller.

2. Mr. Ware gave a presentation on the Delaware River Comprehensive Navigation Study and the benefits of DRPA funding a portion of the remaining study. Attached are his notes which were distributed as a handout. Items covered during the meeting included A, B.1 to B.10, D and E.

3. Some uncertainty was expressed by Sparks and others over the specific purposes of this committee. A briefing of the Committee by DRPA Chairman Fr. Rashford who was scheduled to also attend but whose flight was delayed by weather will be needed.

4. Interest was expressed over both the Main Channel Deepening and the Midstream projects. Texaco Marine Company, which has been sold to Saudi interests, now uses a large number of VLCCs, and would benefit even more from a Midstream project than past operations would predict. Discussions included priority between mid-stream and main channel deepening. Captain Bates indicated he thought the oil companies would be interested in both. Priority will continue to be placed on completion of main channel studies.

5. The issue of the State of Delaware's concern over lightering and oil spills was also discussed. A reduction in lightering with Main Channel deepening was perceived by committee members as being a significant factor in getting Delaware's support for that project. It was also noted that John Hughes (Acting Sec. DDNREC) had interest in wetlands protection using dredged material. If both Channel Deepening and the Midstream projects were built, the number of lightering movements would not necessarily increase (as was thought by some) but rather tankers would replace the barges presently being used.

6. The issue of ocean lightering was further discussed by Bates. He said that certain Delaware legislators favor not passing the annual state legislation certifying Big Stone Beach Lightering Operation is in coastal zone compliance. Failure to pass this legislation could halt lightering at the anchorage and would be in retaliation for certain oil companies continuing the slightly cheaper ocean lightering. The problem with ocean lightering (besides the increased chance of oil spills) is the that 40% of the time between December and April weather prohibits ocean

lightering. This could play havoc with crude oil delivery schedules. The decentralization of oil transport operations at many companies makes even identifying the proper decision maker a problem.

7. The possibility of finding additional beneficiaries of channel deepening was also raised. Three ideas (all considered by the Corps previously) were:

a. Introduction 42' draft container vessels to a revived Packard Avenue. (Currently operating on West Coast)

b. Contacting Navios (who handles shipments to U.S. Steel's Fairless Plant) about possible benefits at Pier 122.

c. Considering Agway's proposed phosphate operation at Pier 122.

The absence of two committee members precluded detailed discussions on b and c.

8. The potential of DRBA providing some study funding was also discussed. It was noted that study cost-sharing would guarantee "seamless" funding and save about two years in time to complete. The authority's desire for a balanced project approach between the two states could be met by our project. There is a proposal for some project (unspecified) in Delaware which could be balanced by a project benefitting someone in New Jersey. Both Mobil and Coastal refineries are located in New Jersey.

9. A more detailed description than that presented in defining in detail who would benefit in what way and by how much was promised by the Corps in about a week. Information to be presented includes:

a. Benefits and Costs for the 45' project

b. Timeline

c. Funding over time

Much of this information is contained in the handout but was not discussed at the meeting due to time limitations. Another meeting could then be scheduled if so desired by DRPA. With this input DRPA could go to the oil companies, DRBA, and other beneficiaries to try and see cost sharing studies.

10. Discussions also addressed the disposal problem and potential concerns of Rep. Hughes over more/higher sites in his district. Historically, he has objected due to no other involvement by Delaware/Pennsylvania in providing disposal sites. If other areas are also actively involved in these activities, we may be able to keep him satisfied.

CENAP-PL-PB (1105-2-10a)

5 JUN 1989

MEMORANDUM FOR Commander, (OAN), Fifth Coast Guard District, 431 Crawford St., Portsmouth, VA 23704-5004

SUBJECT: Delaware River Comprehensive Navigation Study, Main Channel Deepening

1. The subject study is analyzing alternatives for deepening the Main Channel of the Delaware River (between 40 and 46 feet). The alternatives include deepening the entire channel width for a two-way channel and deepening only portion of the present channel for a one-way (inbound) channel only.

2. Your assistance is requested in identifying the navigational aids that will be required for these project alternatives. Also needed are the initial and maintenance costs for any required navigational aids.

3. Enclosed are descriptions of the options for deepening the Main Channel of the Delaware River.

4. In discussions with the Delaware River Pilots, the possibility of improvements to navigational aids was also examined. There are presently RAYCON aids located within the Delaware Bay and at the Bay mouth. The Pilots believe that some system of zero visibility navigational aids such as RAYCON could be expanded to provide coverage for the entire Delaware River, Philadelphia to Sea Project based on the impact of fog on safe navigation. This is particularly critical because vessels transit the river using the tide in order to maximize the loaded vessel draft. We would appreciate receiving any information or guidance you may have, based on your agency's experience with navigation aids for reduced visibility conditions, on the feasibility of a system which might allow for safe navigation on the Delaware River.

5. Contact Mr. William Mulloy of my staff at (215) 597-5448 for discussion of the project.

FOR THE COMMANDER:

Encl

ROBERT L. CALLEGARI
Chief, Planning Division

DEPARTMENT OF THE ARMY
PHILADELPHIA DISTRICT, CORPS OF ENGINEERS
CUSTOM HOUSE—2 D & CHESTNUT STREETS
PHILADELPHIA, PENNSYLVANIA 19106-2991

REPLY TO
ATTENTION OF

Environmental Resources Branch

June 15, 1989

NOTICE OF SCOPING MEETING

This is to inform you that a scoping meeting will be held on June 22, 1989 at 10:00, at the Philadelphia District Office of the U. S. Army Corps of Engineers, for the purpose of identifying significant environmental issues of concern with respect to the on-going Delaware River Comprehensive Navigation Study. The current phase of study is considering potential modifications to the Delaware River, Philadelphia to the Sea Navigation Project, from the Walt Whitman Bridge in Philadelphia, Pennsylvania to the mouth of Delaware Bay. Information generated at this meeting will be used for preparation of an Environmental Impact Statement.

The objective of the current study is to improve handling of bulk commodity products, which account for the majority of ship cargoes using the waterway. These commodities, which include crude oil, coal and iron ore, are currently shipped in partially loaded vessels, due to draft restrictions. Consideration is being given to both full-width deepening and providing only a deeper inbound channel lane since the majority of benefits come from imports.

A critical element in the development of any navigation study is the disposal of dredged material. Approximately six million cubic yards of material are annually dredged to maintain the existing 40 foot Delaware River channel between Philadelphia and the sea. Additional disposal capacity will be required to adequately handle dredged material from the existing project past the year 2020. Project deepening would accelerate the use of existing sites. A secondary goal of this study is to upgrade present disposal areas and locate additional sites with sufficient capacity to handle deepening and maintenance dredging operations over the project's full 50-year life (2000-2050). Additional study information regarding the formulation of channel alternatives and the disposal of dredged material is enclosed for your review.

Please plan to attend the scheduled scoping meeting. If you have any questions or require directions to the Philadelphia District Office, please contact Mr. Jerry Pasquale of the Environmental Resources Branch at (215) 597-6840.

Sincerely,

for John A Burner
Robert L. Callegari
Chief, Planning Division

Enclosure

Form ADM-012

MEMO NEW JERSEY STATE DEPARTMENT OF ENVIRONMENTAL PROTECTION

TO File; Jerry Pasquale, Phila. ACOE DATE 6/23/89

FROM Andrew Didun AD

SUBJECT 6/22/89 Scoping Meeting on Delaware River Comprehensive Navigation Study

1. Project Description is attached for details. (also list of attendees)

2. Comments expressed during the meeting by DFGW in the form of questions or discussed with Mr. Pasquale following the meeting. (DFGW attendees - A. Didun, A. Lupine)

   a) Six (6) proposed spoil sites supposedly meet economic, engineering and environmental criteria. We were concerned about the environmental criteria used; their limitations were not given. Therefore, we are still concerned about wetlands (tidal or freshwater) and open water areas that may be negatively impacted by fill. This also applies to existing spoil sites where wetlands/ponds support abundant fish/wildlife. Future analysis must examine these criteria.

   b) Discussions involved future dredging in Delaware Bay and sounded like sand mining. Extensive biological inventories would have to be done to determine impacts.

   c) ACOE was pushing for aquatic disposal to create shallow wetlands. No one seemed to accept this concept. We note for the record that impacts could be devasting; extensive and in-depth biological inventories and research would be necessary prior to even a vague acceptance of this idea.

sk

Attachments

c A. Lupine
A.B. Pyle
J. McClain

DREDGING COMMITTEE MEETING
THE HARBOUR LEAGUE CLUB
AUGUST 2, 1989

A Dredging Committee Meeting was held on August 2, 1989 beginning at 8:00 A.M. at The Harbour League Club, Camden, NJ. Those in attendance were:

Capt. Jack Sparks, Pilots' Association (Committee Chairman)
William A. Harrison, Ports of Philadelphia Maritime Exchange (Secretary)
Joseph Grossi, N.J. Department of Commerce
Rocco Guerri, N.J. Department of Commerce
Rev. Nicholas Rashford, Delaware River Port Authority
Gene McCaffrey, Delaware River Port Authority
Harry Kennedy, Delaware River Port Authority
Raymond Heinzelmann, Ph.D., Delaware River Port Authority
Lewis Caccese, Joint Executive Committee
Warren Barber, Conrail
Capt. John Bates, Sun Transport, Inc.
George Duffy, Navios Ship Agencies, Inc.
Robert Caligari, U.S. Army Corps of Engineers
John Tunnell, U. S. Army Corps of Engineers
Lee Ware, U.S. Army Corps of Engineers
William Mueller, U.S. Army Corps of Engineers

Reverend Nicholas Rashford, Chairman of the Delaware River Port Authority, provided an overview on the purpose of the meeting. He pointed out that no improvement in channel depths has occurred for many years in the Delaware River despite the increase in size of vessels and the changes in the nature of the commodity mix of the port. Continued vitality of the region suggests that there is a need to increase the authorized channel depth and to modernize port facilities in general. He stated D.R.P.A. is the likely agency to provide the leadership in any programs designed to achieve these goals.

The chairman of the committee then called on Mr. Robert Caligari to introduce the Corps of Engineers' staff and they made a presentation which conformed to the enclosed handout. Their discussion included the fact that the Corps' is considering three options for the Delaware River; namely, either a 43' or 45' channel depth over full channel width or three-quarter width or one-half width on the inbound side.

The consensus of the meeting was that a 45' channel over full width should be pursued as it was evident that this provided a favorable benefit cost ratio and is considered to be a safer channel for vessels than one with segmented depths.

The Corps' presentation informed that the 45' full width channel has an estimated cost of $260,000,000; local interests would be required to bear approximately one-third of the cost of the construction and to provide the required disposal areas. The cost of providing disposal areas would be credited against the one-third local contribution. The construction of a 45' channel, full width, would generate approximately 60 million cubic yards of dredged material.

A discussion ensued on the time for completion of the project. Based on the Corps' schedule, it was estimated the earliest start date on construction of the project was 1996. However, this assumes that the Corps will continue to complete the Delaware River Comprehensive Navigation Study as scheduled and that project sponsors will provide disposal areas by 1996. This requires:

1. A letter stating that the local sponsor will cost-share in the feasibility study in the amount of $195,000. D.R.P.A. agreed to pursue accommodating this requirement.

D.R.P.A. agreed to accommodate a Corps' request to provide a statement in September, 1989 as to their plan for meeting disposal area requirements. In this connection, D.R.P.A. indicated they would examine their ability to condemn land if required.

The meeting adjourned at 9:15 A.M.

The next meeting is scheduled to take place September 28, 1989 at 0800 hours at the Harbour League Club, Camden, NJ.

Respectfully submitted,

William A. Harrison

DELAWARE RIVER COMPREHENSIVE NAVIGATION STUDY

UPDATE

US Army Corps of Engineers

Philadelphia District

NUMBER 3 SEPTEMBER 1989

TO KEEP YOU INFORMED....

UPDATE is designed to inform you of the activities of the Delaware River Comprehensive Navigation Study being conducted by the U.S. Army Corps of Engineers, Philadelphia District. These newsletters allow us to provide you with information about the study and to exchange ideas.

The purposes of this particular UPDATE issue are to:

- review study results to date
- discuss ongoing efforts
- give you the opportunity to comment on the different study activities

BACKGROUND

The Delaware River Comprehensive Navigation Study began in 1982 to address the navigation problems of all the tributaries and waterways which support commercial navigation along this tidal estuary (Figure 1).

The study has several different facets. In 1983 the Reconnaissance Report identified problems with both existing Corps projects and other areas identified by the public. Due to the study scope and complexity a decision was made to divide future studies into different efforts which are discussed in the following paragraphs.

INTERIM REPORTS

Delaware River Philadelphia PA to Wilmington DE

This report, released in June 1985, focused on the navigation problems along the Delaware River from Philadelphia to Wilmington at tributary projects which have depths less than the 40 foot deep main channel of the Delaware River. These improvements were authorized in the Water Resources Development Act of 1988.

It recommended deepening the lower Schuylkill River from 33 to 40 feet. The main beneficiary, Tidewater Grain, subsequently closed operations, resulting in suspension of further studies. The report also recommended deepening of the access to the Beckett Street Terminal, Camden N.J. from 37 feet to 40 feet. Currently this improvement is undergoing pre-construction engineering and design studies. This report also recommended that improvements at Wilmington Harbor be studied further under the Corps's Continuing Authorities Program. The

PENNSYLVANIA
NEW JERSEY
MARYLAND
DELAWARE
DELAWARE BAY
ATLANTIC OCEAN
PHILADELPHIA
CAMDEN
TRENTON
WILMINGTON
Princeton
Reading
Pottstown
Norristown
Bristol
Burlington
Lumberton
Lancaster
West Chester
Kennett Square
Marcus Hook
Chester
Paulsboro
Woodbury
Westville
Glassboro
Williamstown
Pennsville
Newark
New Castle
Delaware City
Salem
Hammonton
Chesapeake City
CBD Canal
Odessa
Vineland
Millville
Bridgeton
Smyrna
ATLANTIC CITY
Ocean City
Port Mahon
Dover
Bowers
Frederica
Big Stone Beach
Stone Harbor
Cape May Canal
Cold Spring Inlet
Cape May
Greensboro
Wye Mills
Denton
Milford
Harbor of Refuge
Cape Henlopen
Lewes Rehoboth Canal
Milton
Lewes
Seaford
Rehoboth Bay
Indian River Inlet
Millsboro
Assawoman Canal
SCALE IN MILES
10 0 10
DELAWARE RIVER
COMPREHENSIVE NAVIGATION
STUDY
US Army Corps of Engineers
Philadelphia District

FIGURE 1

channel was to be deepened from 35 to 38 feet in 1988, under that authority.

Salem River

The Salem River studies investigated deepening the channel to depths ranging from 14 to 24 feet from the present 12 foot depth. The tentative recommendations are that an 18 foot channel depth would be the optimum plan to increase the efficiency of commodity movements, chiefly general cargo. The draft report was issued in November 1988 and public workshop meetings were held in January and March 1989. We are presently coordinating with the sponsor on local cooperation requirements including financing. If approved by the Secretary of the Army, the project would proceed to the pre-construction engineering and design phase.

Maurice River

The Maurice River was evaluated to improve the existing 7-foot depth up to depths of 14 feet. The draft report was issued in July 1988. A public workshop meeting was held in February 1989. Based on the commercial shellfishing fleet, ship repair activities, and the anticipated sand and gravel business, up to an 11-foot channel could be economically justified. The Maurice River is also under study for possible designation as a National Wild and Scenic River. We have been working with the National Park Service to design a project which would not impact the cultural and environmental values which the Wild and Scenic River Act seeks to protect. We are presently coordinating with Cumberland County, the local sponsor, on local cooperation requirements including financing.

Harbor Of Refuge, Delaware

An early action study for the Harbor of Refuge at Lewes, Delaware was also conducted. Deepening the channel and turning area was considered to improve access to a fertilizer facility. However, the facility and associated lands were sold and the study was discontinued.

PARENT STUDY

This study was started following completion of the Reconnaissance Report to address possible improvements to the main Delaware River channel, the Chesapeake and Delaware Canal, a mid-stream deepwater port operation, and a deepwater port facility at Big Stone Beach anchorage in lower Delaware Bay. A preliminary feasibility report was completed in April 1988. The following sections discuss the results of that report and current status of the plans.

Main Channel Deepening

The study initially investigated channel deepening to 42, 45 and 50 foot depths. Consideration was also given to asymmetric channels, anchorage modifications, and channel realignments at Marcus Hook and the Ben Franklin Bridge. More detailed studies narrowed the range of channel deepening to between 41 and 45 feet and established the upper limit of the channel deepening at the Walt Whitman Bridge.

The preliminary analysis of commodity movement and vessel usage showed that channel improvements would benefit shippers of bulk commodities, principally imported oil at six refineries (Atlantic Refining, Chevron, Coastal, Mobil, BP Oil, Sun Company) and also the Conrail coal and ore facilities at Piers 122 and 124.

Realignment of the channel at Marcus Hook was considered in an attempt to minimize the costly rock excavation required for a deeper channel; however, it was concluded that deepening along the existing alignment is still the most cost effective option. Realignment was also considered at the Benjamin Franklin Bridge in order to take advantage of the maximum vertical air clearance under the bridge. The identification of only a single beneficiairy eliminated further consideration of this option, although it was economically justified.

Analyses of anchorages concluded that only a partial deepening of the Marcus Hook anchorage was warranted as part of any channel deepening scheme. The ongoing activities are discussed in a later section.

Delaware Bay, Deepwater Port

A deepwater port facility as well as a mid-stream deepwater port were investigated. As a result of preliminary studies, the options have been narrowed to a plan for deepening part of the existing anchorage at Big Stone Beach and deepening the present naturally deep channel originating in the Atlantic Ocean off the Coast of Delaware and extending through Delaware Bay into the anchorage. This plan would provide better access for deep draft vessels that require lightering. Depths of up to 70 feet will be considered. Further studies of this plan will begin this autumn.

Chesapeake and Delaware (C&D) Canal

The Chesapeake and Delaware Canal project consists of a channel maintained at 35 feet deep and 450 feet wide from the Delaware River to the Elk River and a channel through the Chesapeake Bay to deep water of natural 35 feet depth. Vessels using the canal must also transit the Tolchester Section and either the Swan Point Range or the Brewerton Extension channels to enter Baltimore Harbor. Problems identified include limitations in channel width and depth which delay or prevent transit by the larger container and grain vessels. The preliminary studies concluded that further study of deepening would be warranted. However, in response to a June 23, 1988 resolution by the House Committee on Public Works and Transportation, the study of the C&D Canal has been made a separate study.

ONGOING ACTIVITIES

The ongoing activities for the main channel study are discussed in the following section.

Delaware River - Main Channel

The ongoing study is evaluating the costs and benefits of deepening the main Delaware River channel to depths ranging from 41 to 45 feet. Deepening the entire channel to allow deeper inbound and outbound vessel movements is being studied. In addition, two scenarios of deepening only the inbound channel are currently under consideration since the majority of economic benefits come from oil imports.

Some of the tasks currently being completed are: computing benefits, determining construction & maintenance quantities and costs, performing salinity modeling to determine environmental impacts of construction, identifying possible locations for placement of the additional dredged materials for the construction and maintenance of a deeper channel and preparation of an Environmental Impact Statement.

Placement of dredged materials is a critical issue due to the limited

number of suitable and environmentally acceptable locations. Much of our recent effort has involved evaluating the capacities of the eight existing Federal upland sites and the single overboard site (Buoy 10) in the Delaware Bay and trying to identify possible new sites for use in a channel deepening project.

There is a need for disposal sites for new construction and maintenance. The disposal capacity required for a deeper channel ranges up to an estimated 52 million cubic yards for a 45 foot channel. We have conducted studies to assess the suitability and availability of potential new sites using field visits, aerial photography and computer modeling. To date, six new sites have been identified for further consideration. Coordination with the public and environmental agencies will help us to assess their acceptability. We will be meeting with representatives of the Delaware River Port Authority and the maritime community to further discuss the disposal requirements and potential disposal areas for a deeper main channel project.

We are conducting environmental and cultural resources studies at this time. The studies are being coordinated with government agencies and the public to assess project impacts and to help prepare an Environmental Impact Statement for the Main Channel study. Further coordination is also required with the study sponsor regarding financing the local share of project costs and other local requirements such as lands, easements, rights-of-way, relocations, and disposal areas.

YOUR VIEWS

We would be pleased to respond to your questions and comments in the next UPDATE. If you would like to express your views, send in your questions directly or submit the attached form. Your views are important and will assist us in the planning process.

For additional copies of the UPDATE please contact Mr. William Mueller, Project Engineer, at the address shown or telephone 215/597-5959. We appreciate your interest in the Comprehensive Navigation Study.

This space is provided for your comments or suggestions
and/or
the names and addresses of other persons to be added to the mailing list

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U. S. ARMY ENGINEER DISTRICT, PHILADELPHIA
CORPS OF ENGINEERS
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PHILADELPHIA, PA. 19106

FOLD ALONG DASHED LINE

To return, fold along dotted lines so that our address shows.

Then staple or tape the bottom closed.

FOLD ALONG DASHED LINE

PLACE
STAMP
HERE

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Attn: Basin Planning

STAPLE OR TAPE