US Army Corps
of Engineers
New York District

eral Design Memorandum

ervation of Natural Flood Storage -
aic River Flood Damage
ction Project

Report

SYLLABUS

The Preservation of Natural Flood Storage was authorized as part of the overall Passaic River Flood Protection Project by the Water Resources Development Act (WRDA) of 1990, as modified by WRDA 1992. This separable project element consists of the acquisition of 5,350 acres of natural flood storage areas (of which 5,200 acres are wetlands) in the Central Passaic River Basin to prevent increases in flood flows caused by the loss of such areas to development.

This General Design Memorandum (GDM) for the Preservation of Natural Flood Storage is based on the draft GDM for the overall project. Only those sections pertaining to preservation have been finalized and are included as part of this report.

The Preservation of Natural Flood Storage was addressed in the Final Environmental Impact Statement which was filed with the Environmental Protection Agency on January 17, 1989. The Record of Decision was signed on March 8, 1990. The draft Supplemental Environmental Impact Statement dated September 1995 is not applicable to the preservation element and is, therefore, not included in this report.

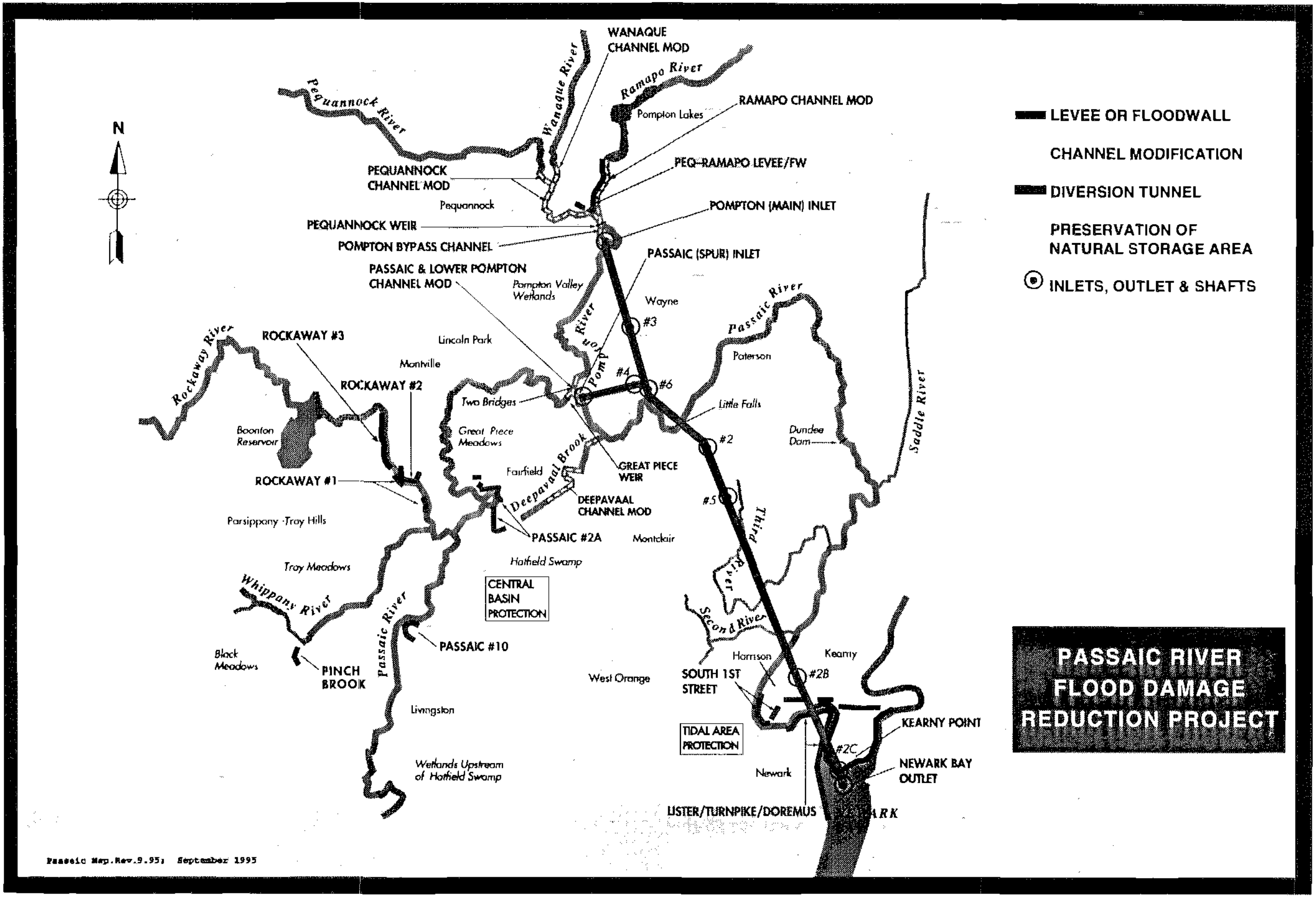
The Preservation of Natural Flood Storage separable project element is recommended for construction at a fully funded cost of $19,710,000. The cost is to be shared by the Federal Government and the non-Federal sponsor, the State of New Jersey. The benefit to cost ratio of the preservation element is 1.2 to 1.0.

This GDM presents detailed information on the plan features and costs of the preservation element.

PRESERVATION OF NATURAL FLOOD STORAGE
PASSAIC RIVER FLOOD DAMAGE REDUCTION PROJECT
FINAL GENERAL DESIGN MEMORANDUM

The Final General Design Memorandum for the Preservation of Natural Flood Storage separable element is based on the draft GDM for the overall project dated September 1995 as follows:

Main Report	Replaced in Total
SEIS	Not Applicable
Appendix A, Public Involvement	Supplemented with additional pages
Appendix B, Environmental	Not Applicable
Appendix C, H & H	No Changes
Appendix D, Cost	Replaced Pages
Appendix E, Geotechnical	Not Applicable
Appendix F, HTRW	Not Applicable
Appendix G, Structural	Not Applicable
Appendix H & I, Real Estate & Economics	Replaced in Total
Appendix J, Passaic 10 Levee/Floodwall System	Not Applicable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FLOOD DAMAGE
REDUCTION PROJECT
LEVEE OR FLOODWALL
CHANNEL MODIFICATION
DIVERSION TUNNEL
PRESERVATION OF
NATURAL STORAGE AREA
INLETS, OUTLET & SHAFTS
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WANAQUE
CHANNEL MOD
Wanaque River
Ramapo River
RAMAPO CHANNEL MOD
Pompton Lakes
Pequannock River
PEQUANNOCK
CHANNEL MOD
PEQ-RAMAPO LEVEE/FW
Pequannock
POMPTON (MAIN) INLET
PEQUANNOCK WEIR
POMPTON BYPASS CHANNEL
PASSAIC (SPUR) INLET
PASSAIC & LOWER POMPTON
CHANNEL MOD
Pompton Valley
Wetlands
Wayne
#3
Passaic River
Rockaway River
ROCKAWAY #3
Lincoln Park
Pompton River
Paterson
Montville
ROCKAWAY #2
#4
#6
Two Bridges
Little Falls
Boonton
Reservoir
Great Piece
Meadows
#2
Dundee
Dam
Saddle River
Deepavaal Brook
GREAT PIECE
WEIR
Fairfield
ROCKAWAY #1
DEEPAVAAL
CHANNEL MOD
#5
Third River
Parsippany -Troy Hills
PASSAIC #2A
Montclair
Hatfield Swamp
Troy Meadows
CENTRAL
BASIN
PROTECTION
Whippany River
Passaic River
Second River
PASSAIC #10
Keamy
Black
Meadows
Harrison
PINCH
BROOK
#2B
West Orange
SOUTH 1ST
STREET
Livingston
KEARNY POINT
TIDAL AREA
PROTECTION
#2C
NEWARK BAY
OUTLET
Wetlands Upstream
of Hatfield Swamp
Newark
LISTER/TURNPIKE/DOREMUS
Passaic Map.Rev.9.95; September 1995

PASSAIC RIVER FLOOD DAMAGE REDUCTION PROJECT
GENERAL DESIGN MEMORANDUM
Main Report and Supplemental Environmental Impact Statement

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MAIN REPORT

SECTION 1

INTRODUCTION

1. INTRODUCTION

1.1 OBJECTIVE

This General Design Memorandum[1] provides the information necessary for implementation of the authorized Passaic River Flood Damage Reduction Project. The authorized project is a product of the Phase I Advanced Engineering and Design studies conducted in response to Section 101 of the Water Resources Development Act of 1976. The objectives of this report are to:

- Establish the project details for each project element as the basis for Feature Design Memoranda (FDM) and construction plans and specifications.

- Establish a current project cost estimate.

- Detail the entire implementation process through construction.

- Establish the Federal and local sponsor responsibilities for construction, operation and maintenance.

1.2 CONTENT

While the main purpose of this report is to advance project implementation, it is also intended to meet the needs of everyone involved in the implementation process including decision makers, concerned public, and agency reviewers at all levels of government. Therefore, extensive information is included from the disciplines of engineering, economics, environmental sciences, and real estate appraisal. Also documented is the cooperation of numerous government agencies with whom the project was coordinated at every step.

1.3 FORMAT

The report is divided into a main report, the Supplemental Environmental Impact Statement and appendices. The main report and the Supplemental Environmental Impact Statement are for readers who desire a comprehensive view of the entire project.

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[1]Prepared in accordance with ER 1110-2-1150, Engineering and Design for Civil Works Projects, dated March, 1994.

Readers wanting detail on all the technical studies and the coordination efforts with the various agencies may refer to the appendices to be found in report volumes as shown in **Table 1**.

Table 1: Report Organization

Contents
Main Report Supplemental EIS
Appendix A - Public Involvement Appendix B - Environmental Resources Appendix C - Hydrology and Hydraulics Appendix D - Cost Engineering Appendix E - Geotechnical Appendix F - HTRW Appendix G - Structural Appendix H - Real Estate Appendix I - Economics Appendix J - Passaic #10 Levee/Floodwall

MAIN REPORT

SECTION 2

PROJECT STATUS

2. PROJECT STATUS

2.1 AUTHORIZING LEGISLATION

The Passaic River Flood Damage Reduction Project was authorized for design and construction by Section 101(a)(18) of the Water Resources Development Act (WRDA) of 1990 (Public Law 101-640) on 28 November 1990 and amended by Section 102(p) of the Water Resources Development Act of 1992 (Public Law 102-580). A copy of Section 101(a)(18) as modified by WRDA 92 is included as **Figure 1.** This section of the Act authorized a variety of flood related measures under three major subsections as follows.

- Subsection A authorized the flood control project elements, defined as the cost-sharing, operation and maintenance responsibilities, particularly the Federal responsibility to operate the tunnel feature, and credits to be allowed for non-Federal work already in place in terms of specified in-kind services and flood protection works. It also authorized the establishment, operation and maintenance of a flood warning system at full Federal expense, before the tunnel system is completed.

- Subsection B authorized the construction of streambank restoration measures in the City of Newark, NJ, requiring construction to begin before other project elements.

- Subsection C authorized the establishment of a wetlands bank whereby the State of New Jersey would establish a Passaic River Central Basin Wetlands Bank, comprised of natural flood storage areas in the Central Basin. The purpose of this subsection is to evaluate and demonstrate, for application on a national basis, the feaibility and methods of obtaining an interim goal of no net loss if the Nation's wetlands base and a long-term goal to increase the quality and quantity of the Nation's wetlands. The lands in the bank would be available for mitigation purposes required under Federal or state law with respect to non-Federal activities in the state, which would continue to own and operate the lands consistent with project purposes. In addition, the state may acquire additional lands related by drainage or stream flow to protect the integrity of the bank; such lands can include transition and buffer areas adjacent to the Central Basin wetlands and other Passaic River Basin areas including the Rockaway, Pequannock, Ramapo, and Wanaque watershed area. The law also provides for the Non-Federal sponsor to be credited with the fair market value of these lands, acquired before, on, or after enactment of this act, as well as costs incurred in converting any of these lands to wetlands, toward its share of the cost of this project and any other flood damage reduction project in the Passaic River Basin.

2.2 PROJECT UNDER IMPLEMENTATION

This report focuses on the flood damage reduction project authorized in subsection A of the authorizing legislation and addresses the cost-sharing credits related to the wetlands bank and additional watershed lands described in subsection C. The streambank restoration measures authorized in subsection B are the subject of a separate report and are, therefore, not addressed in this report.

The authorized flood damage reduction project under implementation is based on the report of the Chief of Engineers, dated February 3, 1989, except that the main diversion tunnel was rerouted to discharge into Newark Bay. The project was authorized at a total cost of $1.2 billion, with an estimated Federal cost of $890 million and an estimated non-Federal cost of $310 million, all at October 1989 price levels. That project has undergone a number of design refinements that are discussed in Section 6 - Changes of this main report.

The project under implementation involves the construction of a tunnel flood diversion system and associated works consisting of channel modifications, gated weirs, levees and floodwalls, and the preservation of natural storage areas. Other project features include recreation facilities, environmental mitigation and a wetlands bank.

2.3 STATUS

Upon completion, and with the support of the non-Federal sponsor, this General Design Memorandum will accompany a project cooperation agreement in support of a request that construction funds be included in the Corps of Engineers budget. If Congress acts favorably and appropriates funds, the engineering and design will continue and actual construction may begin. The implementation process is described in detail in Section 14 - Implementation of this main report.

SUBJECT: Passaic River Main Stem, New Jersey and New York, -Water Resources Development Act of 1990, Section 101 (a)(18) - Modified by WRDA 1992

SECTION 101 (a)(18)(A) FLOOD CONTROL ELEMENTS

(i) IN GENERAL. - The project for flood control, Passaic River Main Stem, New Jersey and New York: Report of the Chief of Engineers, dated February 3, 1989, except that the main diversion tunnel shall be extended to include the outlet to Newark Bay, New Jersey, at a total cost of $1,200,000,000, with an estimated first Federal cost of $890,000,000 and an estimated first non-Federal cost of $310,000,000.

(ii) DESIGN AND CONSTRUCTION. - The Secretary shall design and construct the project in accordance with the Newark Bay tunnel outlet alternative described in the Phase I General Design Memorandum of the District Engineer, dated December 1987. The main diversion tunnel shall be extended approximately 6 1/2 miles to outlet in Newark Bay, the 9 levee systems in Bergen, East Essex, and Passaic Counties which were associated with the eliminated Third River tunnel outlet shall be excluded from the project, and no dikes or levees shall be constructed along Passaic River in Bergen County in connection with the project. With respect to the Newark Bay tunnel outlet project, all acquisition, use, condemnation, or requirement for parklands or properties in connection with the excluded 9 levee systems and the eliminated Third River tunnel outlet works, and any other acquisition, use or condemnation, or requirement for parkland or properties in Bergen County in connection with the project, is prohibited. The Secretary shall certify to the Committee on Public Works and Transportation of the House of Representatives and the Committee on Environment and Public Works of the Senate that no detrimental flood impact will accrue in Bergen County as a result of the project.

(iii) APPLICABILITY OF COST SHARING. - Except as otherwise provided in this paragraph, the total project, including the extension to Newark Bay, shall be subject to cost sharing in accordance with section 103 of the Water Resources Development Act of 1986.

(iv) OPERATION AND MAINTENANCE. - The non-Federal sponsor shall maintain and operate the project after its completion in accordance with the regulations prescribed by the Secretary; except that the Secretary shall perform all measures to ensure integrity of the tunnel, including staffing of operation centers, cleaning and periodically inspecting the tunnel structure, and testing and assuring the effectiveness of mechanical equipment at gated structures and pump stations.

(v) CREDIT FOR NON-FEDERAL WORK. - In recognition of the State of New Jersey's commitment to the project on June 28, 1984, all work completed after such date by the State or other non-Federal interests which is either compatible with or complementary to the project shall be considered as part of the project and shall be credited by the Secretary toward the non-Federal share of the cost of the project. Such work shall include, but not be limited to, those activities specified in the letter of the New Jersey Department of Environmental Protection, dated December 9, 1988, to the Office of the Chief of Engineers. However, only the portion of such work that meets the guidelines established under section 104 of the Water Resources Development Act of 1986 shall be considered as project costs for economic purposes. In applying such section 104 to the project, the Secretary shall likewise consider work carried out by non-Federal interest after June 28, 1984, and before the date of the enactment of this Act that otherwise meets the requirements of such section 104.

(vi) FLOOD WARNING SYSTEM. - The Secretary is authorized to establish, operate, and maintain, at full Federal expense, the Passaic River flood warning system element of the project before completion of construction of the tunnel element of the project.

(B) STREAMBANK RESTORATION MEASURES. - The project shall include the construction of environmental and other streambank restoration measures (including bulkheads, recreation, greenbelt, ~~and scenic overlook facilities and~~ public access to Route 21) on the west bank of the Passaic River between Bridge and ~~Jackson~~ Brill Streets in the city of Newark, New Jersey, at a total cost of ~~$6,000,000~~ $25,000,000. The project element authorized by this subparagraph shall be carried out, in cooperation with the city of Newark, so that it is compatible with the proposed reconstruction plans for Route 21 and the proposed arts center. The non-Federal share of the project element authorized by this subparagraph shall be 25 percent. The value of the lands, easements, and rights-of-way provided by non-Federal interests shall be credited to the non-Federal, share. Construction of the project element authorized by this subparagraph ~~may be undertaken~~ shall be undertaken in advance of the other project features and may not await implementation of the overall project.

(C) WETLANDS BANK. -

(i) PURPOSES. - The purposes of this subparagraph are to evaluate and demonstrate, for application on a national basis, the feasibility of and methods of obtaining an interim goal of no overall net loss of the Nation's remaining wetlands base and a long-term goal to increase the quality and quantity of the Nation's wetlands; of restoring and creating wetlands; of developing public and private initiatives to search out opportunities of restoring, preserving, and enhancing wetlands; and of improving understanding of the function of wetlands ecosystems in order in improve the effectiveness of the Nation's wetlands program, including evaluating the functions and values wetlands,

assessing cumulative impacts and the effectiveness of protection programs, and wetlands restoration and creation techniques.

(ii) ESTABLISHMENT. - The State of New Jersey shall establish a Passaic River Central Basin Wetlands Bank (hereinafter in this paragraph referred to as the "Wetlands Bank") to be comprised of lands which are acquired before, on, or after the date of the enactment of this Act by the State or any other non-Federal interest and which lie within the Passaic River Central Basin, New Jersey, natural storage area discussed in the report of the Chief Engineers and the Phase I General Design Memorandum.

(iii) USE. - The Wetlands Bank shall be available for mitigation purposes required under Federal or State law with respect to non-Federal activities carried out in the State.

(iv) COMPENSATION. - The State may receive compensation for making lands available under clause (iii).

(v) STATE OWNERSHIP AND OPERATION. - The State shall continue to own and operate, consisted with the purpose of the project authorized by this paragraph, lands made available for mitigation purpose under clause (iii).

(vi) ACQUISITION OF ADDITIONAL LANDS. - The State or other non-Federal interests may acquire for the purpose of assuring the integrity of the Wetlands Bank additional lands which are in, adjacent to, or provide drainage for runoff and streamflows into the storage area described in clause (ii) and may use funds provided by sources other than the State for such purpose. Such lands shall include transition and buffer areas adjacent to the Central Basing natural storage wetlands and other Passaic River Basin areas, including the Rockaway, Pequannock, Ramapo, and Wanaque River watershed areas.

(vii) CREDIT. - The fair market value of lands acquired by the State or other non-Federal interests in the Storage area described in clause (ii) before, on, or after the date of the enactment of this Act, the fair market value of the additional lands acquired for the integrity of the Wetlands Bank under clause (vi) before, on, or after such date of enactment, and the costs incurred by the State or other non-Federal interests in converting any of such lands to wetlands shall be credited to the non-Federal share of the cost of the project authorized by this paragraph, and any other flood control project in the Passaic River Basin.

(viii) TREATMENT OF ACQUIRED LANDS. - Lands acquired by the State ~~for the Wetlands Bank~~ in accordance with clauses (ii) and (vi) shall not be treated as a project cost for purposes of economic and financial evaluation of the project.

(ix). EFFECTS ON OTHER LAWS. - Nothing in this subparagraph shall be construed as affecting any requirements under section 404 of the Federal Water Pollution Control Act (33 U.S.C. 1344) or section 10 of the Act of March 3, 1899 (33 U.S.C. 403).

MAIN REPORT

SECTION 3

DEVELOPMENT OF THE PRODUCT

3. DEVELOPMENT OF THE PROJECT

3.1 OVERVIEW

Major flood damage has occurred frequently in the Passaic River Basin since before the turn of the century and has continued to increase as the basin developed. The problem has been studied extensively at both the State and Federal level and many solutions have been proposed but none have been built due to lack of support. The project under implementation is the product of extensive planning that considered the diverse concerns in the Passaic River Basin.

3.2 PLANNING BY NEW JERSEY

Many reports on the development of water resources in the Passaic River Basin have been completed. These reports date back to colonial times when the main emphasis of the studies was on irrigation of the Central Basin, flood protection and navigation in the Lower Valley. The most comprehensive of these reports, published in 1931 by the New Jersey State Water Policy Commission, considered several alternative plans and made an inventory of the total flood control benefits which might be delivered in the Passaic River Basin from each plan. From 1900 to 1940, the State of New Jersey produced eight major reports containing a variety of recommendations, advancing flood control storage as the key to solving the problem. None of these recommendations were implemented.

3.3 PLANNING BY THE CORPS OF ENGINEERS

U.S. Army Corps of Engineers involvement in Passaic River planning was first authorized in the Flood Control Acts of 1936. Since then, reports recommending plans of action were issued in 1939, 1948, 1962, 1969, 1972 and 1973. None of these plans were implemented because they did not receive widespread public support, with opposition based on the concerns of municipalities and various other interests throughout the basin.

Planning to solve the water and related land resources problems and needs in the Passaic River Basin has been plagued by controversy and indecision. In the 60 years since the Corps of Engineers was first directed to plan solutions to the Passaic Basin's flood problems, lack of consensus has prevented the implementation of any of the six plans that were recommended. This strong opposition centered on: the use of the upstream floodplain to protect downstream damage areas; extensive structural measures, including dams, levees and floodwalls; and the vast amounts of land required for implementation. Opposition, based on environmental, economic and social factors, was expressed by various Passaic River Basin interests, including government agencies, organizations and individuals. The many levels of political jurisdiction in the basin has further complicated the resolution of the numerous issues surrounding flood control planning. As a result, the people of the Passaic River Basin remain threatened by economic losses, hazards to health and the threat of injury and loss of life. Following are major events in the history of Corps planning in the Passaic River Basin.

- 1939. As a result of the 1936 Act, a survey report was submitted to the Chief of Engineers in March, 1939. The report recommended a plan consisting of a dry flood detention reservoir on the Pompton and Passaic Rivers at Two Bridges and channel modifications in the Passaic River from Two Bridges to Little Falls. Local interests in the Passaic Basin consumed considerable time in reviewing the report in attempting to resolve their differences, and in April, 1945 it was returned to the District Engineer for updating of changed conditions.

- 1948. In October 1948, a revised report was submitted. It recommended a dam and reservoir at Two Bridges for flood control and water supply, channel modifications downstream of the reservoir, and local flood protection projects at Passaic, Clifton, Lodi and Haledon. This report was returned to the District Engineer in March, 1950 for further study because of the divergent views of local interests.

- 1962. In June 1962, the District Engineer responded to the Governor of New Jersey's expressed desire for a comprehensive plan by submitting an updated and revised draft report. It recommended favorable action on an alternative plan that provided for flood detention reservoirs at Oakland and on the Whippany River, a multiple purpose reservoir on the Passaic River at Millington, channel improvements from these reservoirs to Beatties Dam and along the lower Passaic River, and a 45-foot diameter diversion tunnel from Little Falls to an outlet on the Passaic River at Nutley. This draft report was returned to the District Engineer in October 1962 for further study because of the divergent views of local interests.

- 1969. The 1969 survey report responded to the governor's request for a plan that emphasized conservation storage for water supply in conjunction with flood detention. It recommended a multiple purpose dam and reservoir at Two Bridges for flood control, water supply, hydropower and pollution abatement. The plan also included levees and floodwalls on the Pompton River, and local protection works in the Central Basin and Lower Valley.

- 1972. The most recent survey report prepared by the Corps of Engineers was issued in June 1972 and recommended a plan consisting of a multiple purpose reservoir at Two Bridges for flood control, water supply and water quality in addition to a smaller multiple purpose dam and reservoir at Myers Road on the Upper Passaic in Millington, NJ. It also included channel improvements along the Passaic, Pompton, Pequannock, Wanaque and Ramapo Rivers, and local protection projects at Lodi, Oakland, Denville, Mahwah and Haledon in New Jersey, and at Sloatsburg, New York. The Board of Engineers for Rivers and Harbors, reviewing the report, responded to local concerns by requesting the District Engineer to develop a new alternative to maximize flood protection with minimum environmental impact.

- 1973 The supplemental report identified a flood control plan consisting of a dry detention reservoir at Two Bridges, N.J., which would also include recreation; diversions, channel modifications and local protection works on the Passaic and Pompton Rivers; and tributary local protection works on Molly Ann's Brook at Haledon, NJ; Saddle River at Lodi, NJ; Ramapo River at Oakland, NJ; Mahwah River at Suffern, NY; Nakoma Brook at Sloatsburg, NY; and Rockaway River at Denville, NJ. This became the first Corps of Engineers plan to reach Congress for action; Congress ultimately authorized the Corps to conduct a Phase I Advanced Engineering and Design study.

Subsequent to the completion of the 1972 report as supplemented in 1973, the basin underwent major change that reduced the options available for flood protection. Development occurred on the site of the proposed dry detention reservoir, greatly increasing the cost of acquiring residential, commercial and industrial properties, rendering reservoir plans highly uneconomical.

An alternative to reduce acquisitions would have been to extend the lengths and increase the heights of the proposed levees and floodwalls in order to protect existing development from the ponded waters of the detention reservoir during periods of flooding. However, this alternative was also found to be prohibitively expensive and economically infeasible. The futility of considering reservoir alternatives any further had been confirmed.

3.4 PHASE I ADVANCED ENGINEERING & DESIGN STUDY

Section 101(a) of the Water Resources Development Act of 1976 (Public Law 94-587) authorized the Passaic River Basin Phase I Advanced Engineering and Design Study. The Study followed Congressional guidelines included in the U.S. House of

Representatives Report No. 94-1702, which is the House Public Works and Transportation Committee's 27 September 1976 report on the 1976 Water Resources Development Act. This guidance precluded further consideration of any plan that relies on extensive use of dikes, dams and levees such as those proposed in previous studies.

Under the Phase I study, solutions to the flood problems in the Passaic River Basin, along with allied purposes, were considered for the Passaic River and its tributaries. Studies of all areas were conducted to a level of detail necessary to determine whether flood control solutions have the potential for feasibility as Corps of Engineers projects. Reports recommending Federal flood control were completed for several problem areas in the basin. The Final Report on Flood Protection Feasibility, Remaining Tributaries, was published in January 1990, and summarized all investigations under the Phase I authority.

Flood problems were investigated in 46 municipalities in the Lower Valley and Central Basin. The problem area included the Main Stem Passaic River from its mouth upstream to Millington, N.J., the Pompton River, the lower Ramapo, Wanaque, Pequannock, Whippany and Rockaway Rivers, and numerous small tributaries affected by backwater flooding from the Passaic River, such as Fleischer's Brook, Peckman River, Singac Brook and Deepavaal Brook. The following reports were prepared on the Passaic River and Major Tributaries.

- Feasibility Report. The Phase I Advanced Engineering and Design study authorized in the Water Resources Development Act of 1976 resulted in the Phase I General Design Memorandum, or feasibility report, that included an environmental impact statement (EIS) for the Main Stem Passaic River. It was completed in December, 1987. The report recommendations were concurred in by the Board of Engineers for Rivers and Harbors in July, 1988 and by the Chief of Engineers in February, 1989. The Assistant Secretary of the Army transmitted the report to the Office of Management and Budget for review in October, 1989. The recommended plan consisted of a 39 foot diameter, 13.5 mile long main tunnel; a 22 foot diameter, 1.2 mile long spur tunnel; 5.9 miles of channel modifications; 37.3 miles of levees and floodwalls, and preservation of 5,350 acres of flood storage, 5,200 of which are wetlands. This plan would protect flood-prone areas along the Passaic, Pompton, Pequannock, Wanaque, Ramapo, Rockaway and Whippany Rivers, and Deepavaal and Pinch Brooks.

Three measures identified as possible basin-wide interim projects were also studied under the overall Passaic River Basin Phase I Advanced Engineering and Design authorization.

- Emergency preparedness. A study on flood emergency preparedness including a flood warning system was conducted under the continuing authority for small projects (Section 205 of the 1948 Flood Control Act). It resulted in the Detailed Project Report that recommended a project for authorization. The low Federal first cost of the recommended plan and the relatively short implementation period made the small project program most effective to the need for implementing this flood warning system in the Passaic River watershed. The plan was to improve the timeliness, accuracy and reliability of flood warnings throughout the Basin. It included the establishment of local self-help programs, increased rain and stream gage density and automation, flood warning, flood hazard mapping, improved computer software and flood warning hardware facilities, and enhanced local response programs. The report on this project was approved by the Chief of Engineers in September, 1984 and plans and specifications were subsequently completed by the New York District. The Secretary of the Army approved the recommended plan for construction and signed a Local Cooperation Agreement with the State of New Jersey on 30 October 1986. Installation was completed in 1988 and the project is now operational. This project will be the primary data source governing the operation of the Passaic River Flood Damage Reduction Project.

- Preservation of Natural Flood Storage. The study resulted in a recommendation for no interim action, but for further consideration as an early action measure in conjunction with the overall Main Stem Passaic River Study. The authorized flood damage reduction project contains preservation of key Central Basin natural flood storage areas as a nonstructural project element.

- Snagging and clearing. These measures were investigated as a potential basin-wide interim action as part of the channel clearing feasibility study for the Passaic River and tributaries. However, such measures were determined to be economically infeasible.

3.5 **SUMMARY**

The flood emergency preparedness project is in place and has since been updated with newer computers and software by the Federal Government. No further action was taken on the snagging and clearing plan. With regard to the Main Stem feasibility plan, it is worthwhile to note that the authorized project evolved from more than 150 plans presented in public meeting in the early 1980's which consisted of combinations of channel modifications, levees and floodwalls, upstream reservoirs, flood plain evacuation (buyout), floodproofing of structures, raising structures, diversion tunnels, and other measures. In June 1984, New Jersey DEP Commissioner Hughey developed criteria for plan selection and determined that the a dual inlet tunnel plan best met those criterias. NJDEP asked the Corps of Engineers to proceed to feasibility design of this plan. In 1988, Governor Kean committed the State to working with the Corps on the project to ensure project authorization and resolve fine-tuning decisions during the design of the plan. The project was authorized by the Water Resources Development Acts (WRDA) of 1990 and 1992. These authorizations are the basis for the current project.

MAIN REPORT

SECTION 4

BASIN DESCRIPTION

4. BASIN DESCRIPTION

4.1 OVERVIEW

This section briefly describes the physical features of the Passaic River Basin that produce floods and govern design of the plan of protection. A brief discussion of the flood damage potential in the basin is included along with historical data on flood damages.

4.2 PHYSICAL CHARACTERISTICS

The Passaic River Basin, shown in **Figure 2**, drains an area of 935 square miles of which 787 are in New Jersey and 148 are in New York. Seven major tributaries bring water into the main stem of the Passaic River. They are the Whippany, Rockaway, Pompton, Pequannock, Wanaque, Ramapo and Saddle Rivers. See **Table 2** for data on the characteristics of the Passaic River and its major tributaries.

Of primary significance to the flood problem are the three distinctly different regions that comprise the basin, as delineated in **Figure 3**. The mountainous and heavily wooded Highland Area is 500 square miles in extent, 13 miles wide and 38 miles long. It has steep sided narrow valleys, rushing streams and many natural and artificial lakes. Development is mostly rural in character and there is much open land. Here, the Ramapo, Wanaque and Pequannock Rivers join to form the Pompton River, which flows into the Passaic River.

The Central Basin is 262 square miles in extent, 9 miles wide and 30 miles long. Low lying and marshy lands adjacent to the various streams form extensive frequently inundated floodplains totaling 21,000 acres above Little Falls. These floodplains include the Great Piece Meadows, Hatfield Swamp, Troy Meadows, and Black Meadow as well as the Bog and Vly Meadows adjacent to the Pompton River. The Passaic River passes out of the Central Basin through the narrow rock gorge restriction at Little Falls. Although the Whippany River and Rockaway River tributaries flow as rapidly as streams in the Highland Area, the flood effect is greatly dampened by broad floodplains in their lower reaches and the slow rising of the Passaic.

Table 2 - Passaic River Basin Descriptive Data

CLIMATIC DATA

Annual temperature; 48 F at Charlottesburg and 57 F at Newark
Average rainfall: 48.0 inches
Winds, prevailing direction: Northwest
Average number of rainy days: 121
Average annual snowfall: 33.7 inches
Mean annual relative humidity: 67 - 73%
Average growing season: 171 days

STREAM DATA

Stream	Location	Distance above mouth in miles	Drainage area in square miles	Length in miles	Slope in feet per mile
Passaic River					
At mouth	**Newark**	**0.0**	**935.0**	**87.6**	**7.9**
At Dundee Dam	**Clifton**	**17.40**	**809.9**	**70.2**	**8.9**
At Beatties Dam	**Little Falls**	**29.7**	**762.2**	**57.9**	**8.5**
At Two Bridges	**Lincoln Park**	**33.0**	**740.8**	**54.6**	**9.0**
Pompton River	**At mouth**	**0.0**	**378.1**	**44.8**	**21.0**
Pequannock river	**At mouth**	**0.0**	**192.6**	**30.8**	**35.2**
Wanaque River	**At mouth**	**0.0**	**108.1**	**25.0**	**33.0**
Ramapo River	**At Pompton Lakes**	**0.0**	**160.0**	**35.8**	**25.1**
Rockaway River	**At mouth**	**0.0**	**205.7**	**43.0**	**26.8**

The Lower Valley is 173 square miles in extent, about 7 miles wide and 24 miles long. Heavily urbanized and densely populated, the valley has rolling sides and a comparatively wide rolling bottom land that narrows down to about three-quarters of a mile below Dundee Dam. The major tributary in the Lower Valley is the Saddle River which joins the Passaic about 15.5 miles upstream of Newark Bay. Areas downstream of Dundee Dam are subject to high water levels from tidal events as well as from flow in the Passaic River.

Significantly, the three regions play different roles in producing floods. The rapidly flowing streams in the Highland Area are the greatest flood producers, the effects of which are suffered in the floodplains of flat and slower flowing streams in the Central Basin. In basin-wide floods, the Pompton River peaks at Two Bridges one to two days sooner than the Passaic River. Flooding in the Central Basin upstream of Two Bridges is aggravated by very flat stream slopes of the Central Basin area and the restriction upstream of Little Falls. This promotes the storage of flood waters in those areas thus reducing the flood peaks in the Lower Valley. Tributaries in the Lower Valley below Little Falls peak earlier than the Passaic because of the large runoff from their urbanized watersheds. Flood stages in the Lower Valley are also aggravated by high tides, northeasters and hurricanes. Portions of the Lower Valley floodplain are also affected by coincident flows from the Hackensack River. However, the flooding impact of the Hackensack River is insignificant in comparison to damage caused by tidal events.

4.3 SOCIOECONOMIC FACTORS

The patterns of development and land use in the Passaic River Basin are products of the post-World War II trend of urbanization interacting with the area's natural physical characteristics. From the urban center of Newark, at the river's mouth, to the rural western perimeter of the basin, the Passaic River Basin displays all the characteristics of suburban trend development. Patterns of suburban development radiate from the core central city. In the case of the Passaic River Basin, the urban cores are New York City, and to lesser extent, Hudson County and Newark, which border the basin. Smaller urban cores, such as Paterson and Passaic, generate their own patterns of development, as do Central Basin towns to the west, such as Morristown.

Suburban development is characterized by low-density residential, commercial, and industrial land use, with residential use representing a major portion of the suburban development. This development has consisted almost exclusively single family homes, ranging from one-eighth acre subdivisions in the older eastern suburbs to one and two acres (and larger) lot zoning in many towns in the Central Basin and Highland Area. Commercial activity is automobile oriented, occurring in strip development along major highways and clustered around the intersections of major routes. Industry has been attracted to the suburbs by the availability of less expensive land and the feasibility of modern low-rise facilities with immediate access to major highways. Another trend has been the growing acceptance and prestige of suburban locations as sites for corporate offices and research facilities. The extensive relocation of commerce industry and jobs to the suburbs, have made commutation feasible from new residential suburbs.

4.4 FLOOD DAMAGE POTENTIAL

Major economic activities and land uses in the basin are related to residential, commercial and industrial development. Numerous highways and railroads traverse the area. Communities in the eastern portion of the basin are older with high density multi-family housing and a large industrial base. Such is the case in cities as Newark, Kearny, Harrison, Passaic and Paterson. Near the mouth of the Passaic River there are many port-related activities devoted to the transfer of goods and materials.

With respect to flood-prone communities, the project area consists of 35 communities whose boundaries are partially or entirely within the flood plain. The 35 communities cover a land area of 246 square miles and had a 5.52% reduction in population to 1,068,000 between 1980 and 1990. The area that would be inundated by the 100-year flood is shown on **Figures 93** through **134**.

The Passaic River basin has a long history of flooding dating back to the early 1800's. The flood of October, 1903 is the worst flood on record for most of the basin and the flood of July, 1945 produced record effects on several tributaries. If the 1903 flood were to recur under current conditions of development, the expected damages would amount to about $2,492,000,000 at October, 1994 prices. The most devastating recent flood occurred in April, 1984, when three lives were lost and about $493 million in damages were incurred on about 6,400 properties. Over 9,000 people were evacuated from their homes. The 1984 flood can be expected to be equalled or exceeded once every 25 to 50 years. The basin was most recently declared a major disaster area in lower Essex and Hudson counties during the storm surge from Newark Bay in December, 1992.

The three areas in the basin that are subject to the most serious flooding are:

- The highly developed business, industrial and residential area in the Lower Valley along the Passaic River from Newark upstream to Little Falls.

- The Pompton River Valley.

- The Central Basin, along the Passaic River from Little Falls upstream to Chatham, and the lower reaches of the Rockaway and Whippany Rivers.

The total average annual damages in the basin are estimated at $116,016,000 at October, 1994 prices, of which $49,164,000 is in the Lower Valley, $33,501,000 is in the Central Basin and $33,351,000 is in the Pompton Valley. Damages are expected to increase due to continued urbanization and development of natural flood storage areas. About 23,000 structures and places of business would be flooded by the 500-year event, causing about $3.2 billion in damage. For the 100-year flood the structures affected would number about 19,500 and suffer about $1.6 billion in damage. See **Table 3** for pertinent data on flood damages.

Table 3 - Flood Damages in the Passaic River Basin
(In October, 1994 dollars)

MAJOR RECENT FLOODS	
Event	Damages
May, 1968	$98,800,000
November, 1977	240,000,000
April, 1984	462,007,000
AVERAGE ANNUAL DAMAGES	
Category	Annual damages
Residential	$28,335,400
Commercial	27,310,800
Industrial	38,978,700

Utilities	1,126,200
Municipal	20,264,700
Total	116,016,000

PASSAIC RIVER BASIN

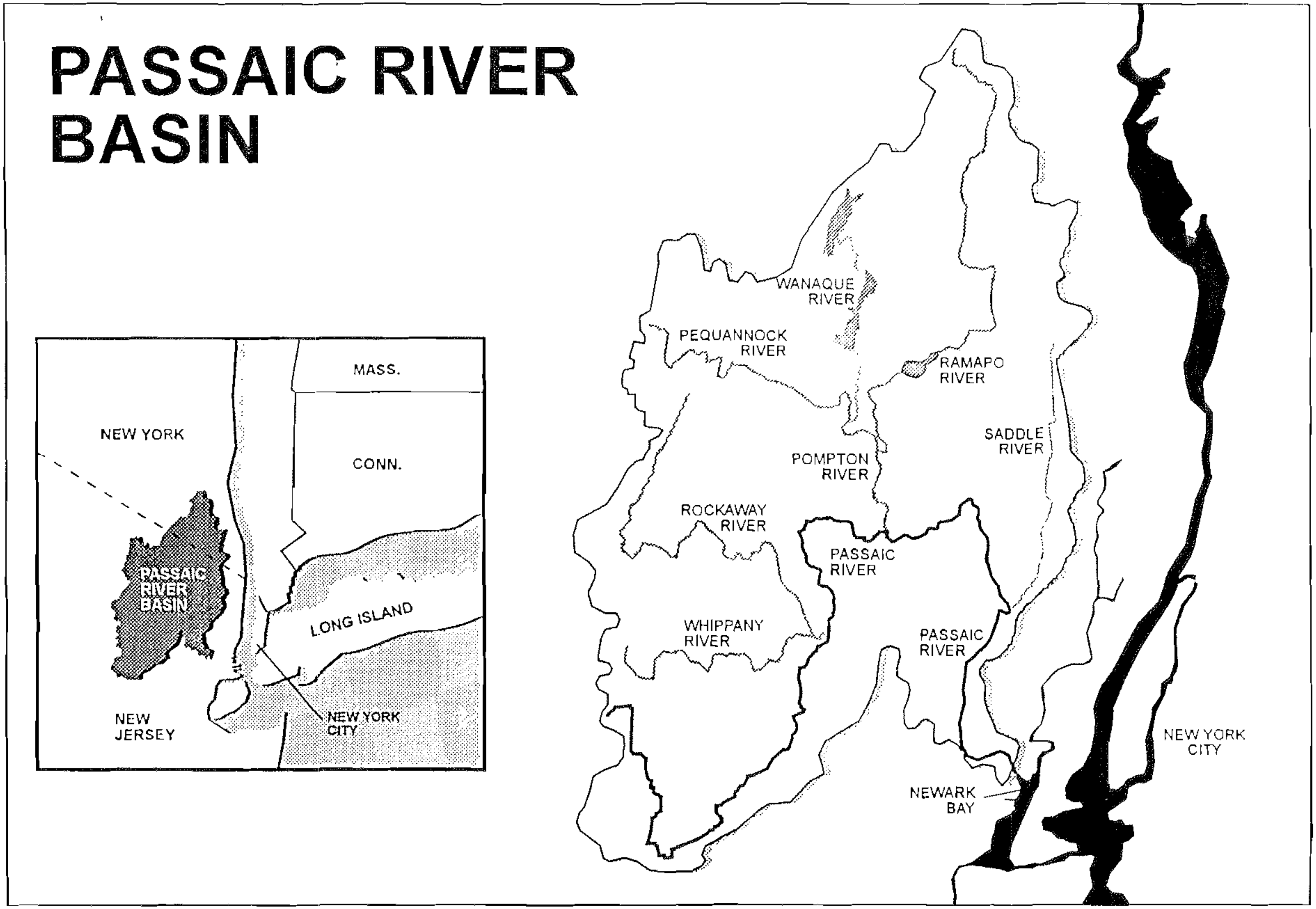
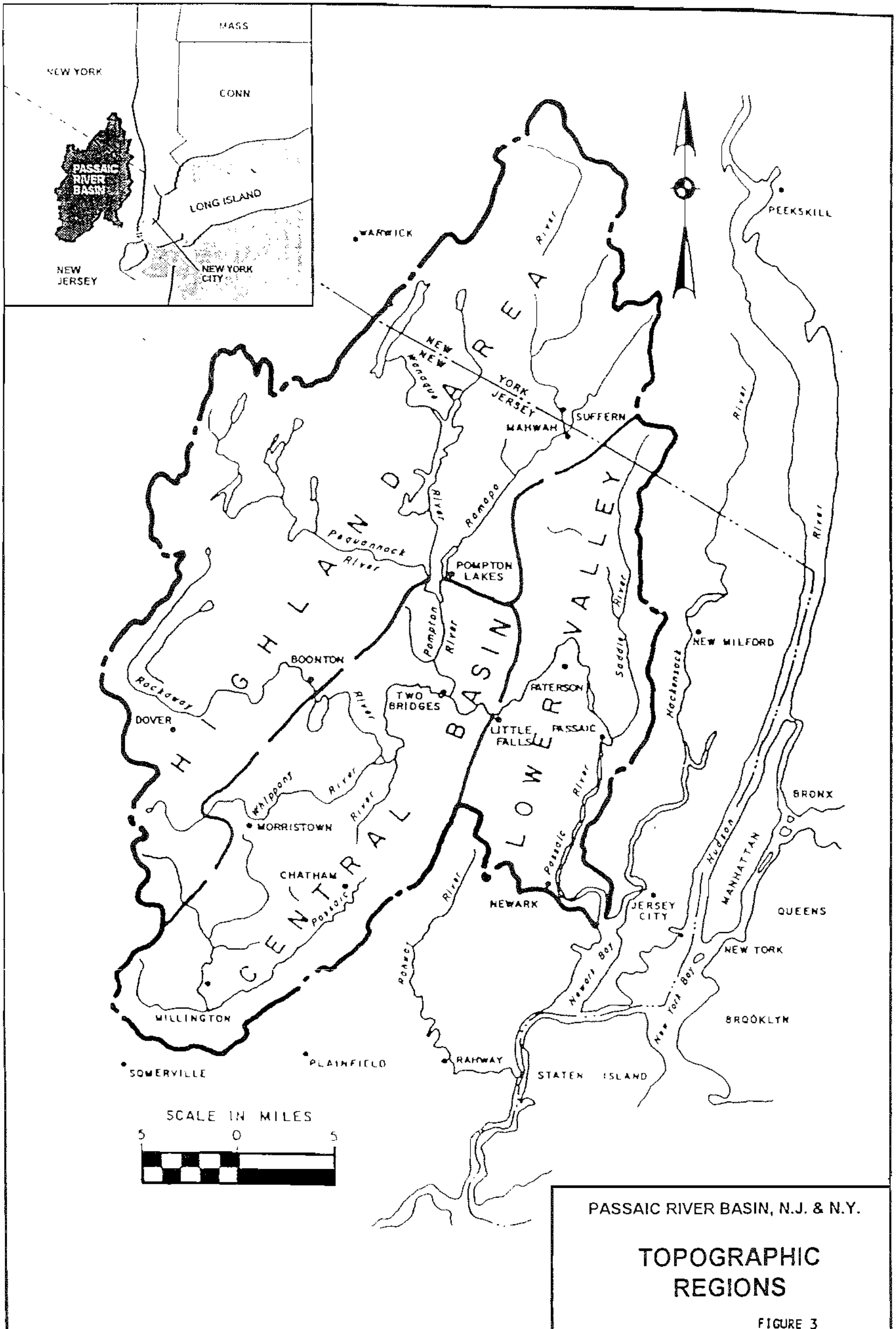


FIGURE 2

mapmain cdwr9-6-95



PASSAIC RIVER BASIN, N.J. & N.Y.

TOPOGRAPHIC REGIONS

FIGURE 3

MAIN REPORT

SECTION 5

PROJECTION DESCRIPTION

5. PROJECT DESCRIPTION

5.1 OVERVIEW

The Passaic River Flood Damage Reduction Project comprises structures and land management measures to establish and maintain a high level of flood protection in the Passaic River Basin. While the New York portion of the basin's drainage area contributes to the floodwaters in New Jersey, the construction of the project features and associated costs, and corresponding flood damage reduction benefits, occur only in New Jersey. The project will reduce the average annual flood damages by 89%. The main protective feature of the plan, a large underground diversion tunnel system, will be supplemented with levees, floodwalls, channel modifications and preservation of natural flood storage. The project will reduce flood levels at major damage areas in the Pompton River Valley, the Central Passaic Basin and the Lower Valley of the Passaic River Basin. Beautification and recreational features are included with certain elements of the project. This section includes a brief description of the project as well as details on each element of the project. An overview of the entire project is shown at the front of this book and on **Figure 4** in the accompanying volume of figures. The area that would be inundated by the by the 100-year flood with the project in place is shown on Figure 93 through 134. Summary data on the project are displayed in **Figure 4.**

5.1.1 Tunnel System. The tunnel system, shown in **Figures 5** through 30, will consist of two parts. The main tunnel will be 20.4 miles long and 42 feet in diameter; it will carry floodwaters from an inlet on the upper Pompton River to an outlet in Newark Bay, 1,850 feet offshore of Kearny Point. The second tunnel will be a 1.3 mile long spur tunnel, 23 feet in diameter that will convey Central Basin floodwaters from an inlet on the Passaic River, just downstream of the confluence of the Passaic and Pompton Rivers at Two Bridges, to an underground connection with the main tunnel. The tunnel system is designed to protect against the 100-year flood event. Eleven shafts will be built at various locations for construction access, removal of material and other purposes.

To direct the floodwaters into the inlets, 5.5 miles of channels in the Passaic, Pompton, Pequannock, Wanaque, and Ramapo rivers will be modified. A levee/floodwall system, consisting of 0.4 miles of levee and 0.6 miles of floodwall will be provided to prevent flooding by water as it flows to the Pompton Inlet. In addition, gated weirs will be built on the Passaic and Pequannock Rivers to prevent upstream headcutting, minimize erosion potential and protect existing wetlands.

5.1.2 Central Basin Protection. Seven local systems, shown in Figures 31 through 71, consisting of levees, floodwalls and channel modifications, will protect flood problem localities on the Passaic River and tributaries. Each system includes interior flood damage reduction facilities, such as culverts, ponding areas and pumping stations, to either hold or safely pass runoff from protected areas during floods. Recreation and beautification features are included at various locations. These features include such items as hiking trails, bicycle trails and aesthetic treatment of levees and floodwalls. The Central Basin Systems are as follows:

- Passaic Levee/Floodwall System #2A
- Passaic Levee System #10
- Deepavaal Brook Channel Modification
- Rockaway River Levee/Floodwall System #1
- Rockaway River Levee System #2
- Rockaway River Levee/Floodwall System #3
- Pinch Brook Levee/Floodwall System

5.1.3 Tidal Area Protection. Three local systems, shown in **Figures** 72 through **91**, consisting of levees and floodwalls, will protect flood problem localities in the Lower Valley from tidal flooding. Each system includes interior flood damage reduction facilities, such as culverts and pumping stations, to dispose of runoff from protected areas during floods. Recreation and beautification features are included at various locations. The tidal protection systems are as follows;

- Kearny Point Levee/Floodwall System
- Doremus/Lister/Turnpike Levee/Floodwall System
- South 1st Street Levee/Floodwall System

5.1.4 Preservation of Natural Storage. The project includes the preservation of 5,350 acres of natural storage in the Central Basin to prevent increases in flood flows caused by the loss of such areas to development. Of that area, 5,200 acres are wetlands. The area to be preserved is shown in Figures 111-114,120-125, 128-131, 133 and through **134**.

5.1.5 Fish and Wildlife Mitigation. Wherever possible, adverse impacts were mitigated by the inclusion of environmental measures into the design of each channel modification, levee, floodwall and other structure. In those cases where impacts could not be addressed in the design of specific elements, mitigation measures were provided separately from the project elements.

5.1.6 The remainder of this section describes each element of the project in detail.

Table 4 - Project Data

Authorization	Water Resources Development Act of 1990 as modified by the Water Resources Development Act of 1992.
Location	State of New Jersey in the Counties of Bergen, Essex, Hudson, Morris, and Passaic
Streams	Passaic, Rockaway, Pompton, Pequannock, Wanaque and Ramapo Rivers; Deepavaal and Pinch Brooks
Project purpose	Flood damage reduction and hurricane protection
Project features	Tunnel diversion system consisting of a main tunnel 42 feet in diameter and 20.4 miles long, a spur tunnel 23 feet in diameter and 1.3 miles long, two inlets, an outlet, two weirs and associated river works comprised of 0.42 miles of levee, 0.55 miles of floodwall and 7.0 miles of channel modification. Central Basin flood damage reduction works consisting of 4.15 miles of levee, 1.84 miles of floodwall and 1.4 miles of channel modification. Lower Valley flood damage reduction works consisting of 2.13 miles of levee, and 10.82 miles of floodwall. Preservation of 5,350 acres of natural wetland storage. Environmental mitigation measures and recreational and beautification features at various locations.
Construction cost	First cost as of October, 1994 prices $1.42 billion Federal cost $1,055 million Non-Federal cost $365 million* Operation and maintenance $3.15 million* Fully funded construction cost, with inflation $1.89 billion *Basic project cost sharing from WRDA 1986 does not include modification to cost sharing by WRDA's 1990 and 1992.
Design flood	Design flood: - 100-year event for Tunnel system, Central Basin system and Tidal Protection Area system.
Flood stage reduction for 100-year flood	Flood stage reduction for 100 year flood: Pompton River at the mouth: from 173.5 to 165.2

Municipalities protected	Passaic County: Clifton City, Little Falls, Passaic City, Paterson City, Pompton Lakes Borough, Totowa Borough, Wayne Township, West Paterson City Essex County: Belleville Town, Fairfield Borough Livingston Township, Newark City, Nutley Town, North Caldwell, Roseland Borough, West Caldwell Morris County: Parsippany-Troy Hills Township, East Hanover Township, Florham Park Borough, Hanover, Lincoln Park Borough, Montville Township, Pequannock Township, Riverdale Borough Bergen County: Elmwood Park Borough, East Rutherford Borough, Fair Lawn Borough, Garfield City, Lyndhurst Township, North Arlington Borough, Rutherford Borough, Wallington Borough Hudson County: East Newark Borough, Harrison Town, Kearny
Economic justification	Annual charges: $130,194,000 Benefits: $173,163,100 Benefit-cost ratio: 1.3
Construction schedule	Begins: September, 1998 Completion: June, 2009

5.2 TUNNEL SYSTEM

The major element of the project is the tunnel diversion system that includes, in addition to a main tunnel and a spur tunnel, a variety of works to support their operation and minimize adverse effects. The tunnel system will divert flood waters from the major damage areas and discharge them into Newark Bay. Included in the system are:

- Two tunnels.

- An inlet structure at the upstream end of each tunnel.

- An outlet structure in Newark Bay.

- Vertical shafts to the tunnel at various locations for construction access and other purposes.

- Gated weirs on the Passaic and Pequannock Rivers and control erosion of channels and preserve existing wetlands.

- Levees, floodwalls and channel modifications on the Pequannock, Ramapo, Wanaque, Lower Pompton and Passaic Rivers to direct flood waters safely and efficiently to the inlet.

Each of the tunnel system components is described in detail in the following paragraphs. Summary details are provided in **Table 5**.

Table 5 - Tunnel System

Component	Type and location	Description
Main Tunnel	**Tunnel, from Wayne to Newark Bay**	**42 feet in diameter, 20.4 miles long**
Spur Tunnel	**Tunnel, from Wayne to Main Tunnel intersection in Totowa**	**23 feet in diameter, 1.3 miles long**
Pompton inlet	**Structure, in Wayne on Pompton River**	**In a semi-circular basin about 220 feet in diameter. 11 vertical lift gates each 60 feet wide and 12 feet high. 216-foot radius semi-circular access basin**
Passaic inlet	**Structure, in Wayne on Passaic River**	**5 vertical lift gates each 50 feet wide and 13 feet high. 150-foot by 300-foot access basin., Inlet channel. Bridge across Fairfield Road**
Outlet	**Structure, in Newark Bay 1,850 feet offshore of Kearny Point**	**3 vertical lift gates each 26 feet wide and 30 feet high. Upshaft 42-45 feet in diameter and 380 deep. Outlet structure about 25 feet high above sea level.**
Shafts	**Structures at various locations**	**11 shafts, see Table 6**
Pequannock Weir	**Structure on right bank of Pequannock River within 200 feet of existing weir.**	**4 gates each 50 feet wide and 15 feet high**
Great Piece Weir	**Structure on Passaic River 600 feet upstream of Two Bridges Road**	**5 gates each 30 feet wide and 10 feet high**
Passaic and Lower Pompton Rivers	**Channel modification at confluence of Pompton and Passaic Rivers.**	**Deepen Passaic over distance of 0.4 mile, and Lower Pompton over a distance of 0.3 mile , by 4 to 5 feet. Create 1.2 mile pilot channel in Passaic downstream of Spur Inlet.**

Ramapo River	Channel modification from the proposed Pequannock Weir to Paterson-Hamburg Turnpike	Over a distance of 1.3 miles, deepen by up to 10 feet, and increase bottom width to range from 60 to 100 feet and top width to 150 feet.
Wanaque River	Channel modification from mouth to just south of Paterson-Hamburg Turnpike	Over a distance of 0.8 miles, deepen by up to 7 feet, and increase bottom width from 50 to 74 feet and top width to 125 feet.
Pequannock River	Channel modification from Pompton inlet to just downstream of Paterson-Hamburg Turnpike.	Over a distance of 2.4 miles, deepen by up to 10 feet, and increase bottom width to range from 34 to 100 feet and top width to range from 135 to 160 feet.
Bypass channel	New channel in conjunction with the Pequannock Weir excavated on the right bank of the Pequannock River	0.3 mile long, 120 to 250 feet wide, and 2 to 14 feet deep. Create 0.3 mile long pilot channel in Pompton downstream of Main Tunnel Inlet.
Pequannock-Ramapo Levee/Flood System	Levee and floodwall on the right bank of the Ramapo River where it joins the Pequannock River to form the Pompton River.	2,200 feet of levee, 7.0 average height and 52 feet average bottom width. 2,910 feet of floodwall, 6.0 average height. Interior Flood damage reduction facilities consisting of 4 ponding areas, 8.5, 0.3, 0.4 and 5.0 acres in extent, and a 3-cfs pump providing protection varying from 80- to 200-year.

5.2.1 **Tunnels.** The 42 foot diameter main tunnel will carry floodwaters from an inlet at the upper Pompton River in Wayne to an outlet in Newark Bay. A 1.3-mile long, 23-foot diameter spur tunnel will convey Central Basin area floodwaters from an inlet on the Passaic River just downstream of Two Bridges, also in Wayne, to an underground connection with the main tunnel. Plans and profiles of the tunnel are shown in **Figure** 4,5,13 and **14**.

The tunnels will be entirely in bed rock, about 175 feet from surface to tunnel invert at the Pompton Inlet, about 170 feet at the Passaic Inlet, and approximately 400 feet at the outlet.

The intersection of the main and spur tunnel inverts will be about 185 feet below ground level. At its deepest point, under the Watchung Mountains in the vicinity of the Little Falls-Clifton border, the main tunnel invert will be 480 feet underground. Excavation will be performed mostly by a tunnel boring machine (TBM), but some drilling and blasting will be done where necessary for shaft construction. The tunnel will be lined with 15 inches of cast-in-place concrete.

The system will significantly lower flood stages even when the tunnel capacity is exceeded. The largest areas benefiting from the system will be in the Passaic River from Dundee Dam in Clifton to the Rockaway River confluence, in the entire Pompton River and in the lower Ramapo, Pequannock and Wanaque Rivers. Reductions in the 100-year flood will be as high as 8 feet on the Passaic and as much as 10 feet on the Pompton, Ramapo, Pequannock and Wanaque Rivers.

Several locations in the tunnel were selected to vent air out of the tunnel during flow diversion. The two primary locations are the tunnel inlets, each of which will have a de-aeration chamber. Air will be entrained at each inlet by hydraulic jumps that occur when water levels in the tunnel are low and by plunging flow when water levels are higher. The diameters of the chambers will be larger than the diameter of the tunnel to provide additional area when the flow is "bulked up" with air. A vertical air vent will be placed at the optimum location in each de-aeration chamber. At the Pompton inlet, the chamber will be 500 feet long, 52 feet in diameter and will have a 15-foot diameter vent shaft. The Passaic inlet de-aeration shaft will be 420 feet long, 30 feet in diameter and will have a 12-foot vent shaft.

5.2.2 Pompton (Main) Inlet. As shown in **Figure 11**, the inlet portal will be upstream of the Pompton Plains Cross Road (Jackson Avenue) Bridge in Wayne Township on the east bank of the Pompton River. The site is immediately downstream of the confluence of the Ramapo and Pequannock Rivers. Currently, this area is occupied by a topsoil manufacturing operation with material stockpiled on the site as well as adjacent to it. The area around the site is generally an undeveloped low lying floodplain to the west and north, and agricultural to the east. Stream slopes in the area are very mild.

Details of the Pompton inlet are shown in **Figures 17, 18 and 19.** The surface structures consist of a semi-circular gated diversion spillway, access basin, inner weir and a sloping tunnel inlet. The inlet will be located in a basin that is approximately 480 feet in diameter and excavated to a depth of about 20 feet. There will be 11 vertical lift diversion gates, 60 feet wide and 12 feet high. The gates will divert and regulate flow into a 216-foot radius semi-circular access basin that will be excavated to a depth of about 20 feet. The inner weir will be the highest point on the sloping drop into the main tunnel. The drop inlet will slope and converge from the 125-foot radius semi-circular inner weir to the 26-foot radius circular main tunnel chamber, about 170 feet below. The configuration of the inlet is a semi-cone shape.

The semi-cone inlet design limits flow to only one side of the inlet while permitting air to escape the other side, producing superior performance in both flow capacity and safety. This design will be model-tested during later stages of follow-on engineering and design work. Also, a 0.3 mile long pilot channel will extend downstream from the Main Inlet deepening the existing channel by 2 to 4 feet.

5.2.3 Passaic (Spur) Inlet. The Passaic spur inlet, shown in **Figure 11,** is located on the east bank of the Passaic River, about 500 feet upstream of the Interstate Route 80 bridge crossing, adjacent to Fairfield Road in Wayne. To utilize this site for the inlet, a bridge for Fairfield Road will be built across the approach channel to the inlet structure. The surrounding area is lightly developed for residential use and mostly consists of undeveloped low lying wetlands.

Details of the Passaic Inlet are shown in **Figures 20, 21 and 22.** The inlet structure, which is similar to the Pompton River tunnel inlet, will consist of a straight gated side channel diversion spillway, an access basin, a semi-circular inner weir and a sloping tunnel inlet. There will be 5 vertical lift diversion gates, 50 feet wide by 13 feet high, to regulate the diverted flow into a 300-foot wide access basin that will be excavated to a depth of about 20 feet. The inner weir will be the highest point on the sloping drop into the spur tunnel. The drop inlet will slope and converge from the 75.5 foot radius semi-circular inner weir to the 15 foot radius circular spur tunnel chamber about 160 feet below, directing water into the 23-foot diameter, 1.3-mile long spur tunnel which connects to the main tunnel at a deep underground connection. The inlet will also use the semi-cone design but it contains a straight approach access basin.

5.2.4 Tunnel outlet. The tunnel outlet, shown on **Figure 5,** will be located about 1,850 off shore in the upper end of Newark Bay where the Passaic and Hackensack Rivers meet. The diverted floodwaters will flow through an upshaft from a depth of 399 feet vertically into the outlet structure which extends from a depth of about 26 feet below mean sea level to about 20-feet above mean sea level. The outlet will contain three 26-foot wide by 30-foot high vertical lift gates to distribute flow into Newark Bay. The outlet is not expected to have an adverse impact on navigation. To confirm this, however, both physical model and ship simulation study will be conducted during later stages of engineering and design work.

5.2.5 Shafts. As shown in **Figure 4**, there will be a total of 11 vertical shafts along the tunnel alignment for various purposes, such as the entrance and exit of construction equipment and materials, muck removal, dewatering and venting. Work shaft 2, located at Montclair State College, will function as the Tunnel Operations Center. Workshaft 2C, located at Kearny Point will house the equipment that will dewater the tunnel for inspection and maintenance purposes. The pumping station and equipment are shown in **Figure 15** and **16**. The purposes and locations of the various shafts are shown in **Table 6**.

5.2.6 Pequannock Weir. The new Pequannock weir is designed to supplement the existing Morris Canal feeder dam system. Its purpose is to assist in the passage of flood flows in excess of the 1-year event and to preserve the existing wetlands by maintaining existing water levels at a normal elevation of 177 NGVD. The new weir, details of which are shown in Figures 25, 26 and 27 will be placed on the right side of the Pequannock River within 200 feet of the existing weir. It will consist of 4 tainted gates each 50 feet wide by 15 feet high. The gate sill elevation will be set at elevation 164.0, which is 3 feet above the new upstream channel invert. The tainter gates will normally be operated in the down position (closed) and will only operate during flood events greater than the annual flood. The weir will be directly linked to the main tunnel inlet by a new bypass channel, described below.

A maintenance access bridge will be located at the top of the weir and will span each gate opening. An access road will be provided to the site from the end of Garden Place Road.

5.2.7 Great Piece Weir. The Great Piece Weir, shown in Figure 11, will be situated in the Town of Fairfield and the Borough of Lincoln Park. Its purpose is to prevent upstream headcutting, minimize erosion potential, and maintain the viability of the wetlands; an incidental benefit will be the prevention of channel erosion upstream of the Passaic Inlet. The weir is approximately 600 feet upstream of the Two Bridges Road that crosses over the Passaic River just upstream of the Passaic River and Pompton River confluence. The weir structure, details of which are on Figure 28, will incorporate five 30-feet wide gates providing a total river opening of 150 feet. The five torque tube bascule gates will rest on a gate sill set at elevation 156, approximately 6 feet above the proposed river bottom elevation.

The gates will have a total height of 10 feet and will be capable of creating a backwater pool to elevation 166, thereby maintaining water levels in the Great Piece Meadows upstream of the weir.

The weir will be provided with an overhead operating deck which will be supported by the weir abutments and four 10-foot wide intermediate piers. The operating deck will provide access for operation and maintenance from both the south and north banks of the river. The south access will be provided from a driveway that will branch off from an existing office complex. The weir will also have access from a short driveway to the north which ties into Two Bridges Road.

5.2.8 Passaic and Lower Pompton Rivers Channel Modification. A modified transition channel, shown in **Figures 11** and **12**, which will direct flows into the Passaic spur inlet, will extend along the Passaic River about 0.4 mile upstream of Two Bridges down to the Route 80 Bridge, and for about 0.3 mile along the lower Pompton River. This channel will have a maximum base width of 240 feet and will be deepened an average of 4 to 5 feet. The resulting cut of the new modified channel will be approximately 260 feet. The new channel cut will be entirely within the existing channel, which has an average top width of approximately 280 feet. In addition, a small pilot channel 20 feet wide, 3 feet deep, will extend past the spur inlet for a distance of 6,500 feet. The purpose of this pilot channel will be to prevent sediment from accumulating directly in front of the spur inlet. Thus the pilot channel will convey the suspended sediment and smaller bedloads down river, and therefore maintain the improved channel at the spur inlet.

5.2.9 Ramapo River Channel Modification. The Ramapo River channel modifications, shown in **Figures 9** and **10**, will extend for 1.3 miles from the newly proposed Pequannock Weir to just upstream of Paterson-Hamburg Turnpike near Pompton Lakes Dam. The modification includes deepening the existing channel up to 10 feet and widening the channel bottom to an average of 60 to 100 feet. The average top width of the modified channel will be approximately 150 feet. The top width of the existing channel averages approximately 110 feet. Almost the entire length of the modified channel will be protected with riprap. As a beautification measure, the river bank will be stabilized based on bioengineering techniques, a developing technology that involves the use of plant material or a combination of plant and inert material to improve plants over time as they become better established. About 5,415 feet of riprap will be used to protect this channel.

5.2.10 **Wanaque River Channel Modification.** The Wanaque River channel modification, shown in Figures 6 and 7, will extend from its mouth for 0.8 mile upstream to just below the Paterson-Hamburg Turnpike. The proposed modification includes deepening the existing channel by as much as 7 feet and increasing the channel bottom width from 50 to 74 feet. The resulting average top width will be approximately 125 feet. The existing channel top width averages approximately 90 feet. About 650 feet of riprap and 2,650 feet of crushed stone will be used to protect the channel from erosion. As a beautification measure, the river bank will be stabilized using bioengineering techiques.

5.2.11 Pequannock River Channel Modification. The Pequannock River channel modification, shown in Figures 6, 7 and 8, will extend from the Pequannock Weir, upstream for 2.4 miles. The modification includes deepening the existing channel up to 10 feet and increasing its bottom width to an average of 34 to 100 feet. The top width of the modified channel will range from 135 to 160 feet. The top width of the existing channel averages approximately 100 feet. About 2,000 feet of the proposed channel will be protected with riprap and about 150 feet of crushed stone. As a beautification measure, the river bank will be stabilized using bioengineering techniques.

Table 6 - Shafts

Shaft	Location	Size	Purposes
Workshaft 2C (Pump Station)	Near sewage treatment plant at Kearny Point	42 feet in diameter, 400 feet below the ground surface	Muck removal, dewatering, personnel and equipment access, concrete placement and house pump station facilities
Workshaft 2c (Vent shaft)	Near sewerage treatment plant at Kearny Point	15 feet in diameter, 400 feet below ground surface	ventilation
Workshaft 2B	Keegan landfill, Bergen Avenue, Kearny	42 feet in diameter, 390 feet below the ground surface	TBM access, muck removal, construction support, concrete placement, ventilation

Vent/hook hole shaft 5	Broad Street near the Garden state Parkway and interchange, Bloomfield	15 feet in diameter, 170 feet below the ground surface	Concrete delivery. Disassemble TBM head to enable backout. To be retained as vent.
Workshaft 2 (Tunnel Operations Center)	Montclair State College	42 feet in diameter, 349 feet below the ground surface	TBM access, muck removal, construction support. concrete placement, maintenance access. Operations Center.
Vent shaft 6	East of Routes 80, 46 and 23 interchange	15 feet in diameter, 140 feet below the ground surface	Vent air entrained by highly turbulent flow at the junction.
Workshaft 3	Near Wayne Department of Public Works Yard	42 feet in diameter, 167 feet below the ground surface	Removal of two TBM's. To be retained as vent shaft.
Pompton (Main) Inlet	Downstream of confluence of the Ramapo and Pequannock Rivers	Sloping semi-circular inlet with a 15 foot diameter shaft, 160 feet below ground surface	Main Tunnel inlet, TBM access, muck removal, maintenance access. Ventilation shaft
Passaic (Spur) Inlet	Upstream of Route 80 bridge on east bank of the Passaic River	Sloping semi-circular inlet with a 12 foot diameter shaft, 156 feet below ground surface	Spur Tunnel inlet, TBM removal. Ventilation shaft.
Newark Bay Outlet Shaft	1,850 feet offshore in upper end of Newark Bay	42 feet in diameter, 380 feet below mean sea level	Tunnel discharge, sediment removal
Workshaft 4	East of Route 80, 46 and 23 interchange	23 feet in diameter, 160 feet below the ground surface	TBM access, muck removal, construction support. concrete placement

5.2.12 **Pompton Inlet Bypass Channel.** A new bypass channel, shown in Figure 10, approximately 0.3 mile in length, will be built in conjunction with the landside-based Pequannock Weir, described previously. The relocated channel will extend from the Pequannock Weir to the Pompton Inlet. It will vary from 130 to 230 feet in width, be cut to a depth of 2 to 14 feet into an existing field for a length of 1,830 feet and hydraulically connect flood waters to the main tunnel inlet. As part of the bypass channel, 400 feet of the Upper Pompton River and 600 feet of the lower Ramapo River (just downstream of the Old Morris Canal Ramapo Feeder weir) will be modified to allow flood flows to enter into the main inlet. The Pompton River channel improvements will be confined to the immediate area of the inlet above the existing low water weir (just upstream of the Jackson Avenue bridge). The channel will be deepened up to 3 feet and will have a new channel bottom width of about 100 feet. Although the bypass channel will be used rarely, it will generally be maintained wet due to downstream tailwater levels. A pilot channel, 0.3 miles long, will extend downstream from the Pompton Inlet.

5.2.13 Pequannock/Ramapo Levee/Floodwall. This levee/floodwall shown in Figure 9, will be located on the right bank of the Ramapo River and provide protection to existing structures in Pompton Lakes. To significantly reduce fluvial flooding, 2,200 feet of levee and 2,910 feet of floodwall will be required. The levees will have an average height of 5.9 feet and base width of 45 feet. The floodwalls will have an average height of 6 feet. To assure that local drainage in the protected area is maintained, new gravity outlets will be provided, along with four ponding areas, 0.3 acre, 0.4 acre, 8.5 acres and 5.0 acres in extent, the latter two being part of the natural storage areas to be preserved. A 3-cfs capacity pumping station will be provided to improve drainage. Profiles of the system are shown on Figures 29 and 30.

For recreation, a riverside trail will be provided. Access to the trail will be from Riverview Road. A platform for sitting, fishing and small boat launching will be located in Stiles Park. For beautification, the levees will be seeded with native wildflowers. Where the floodwall passes through residential rear yards, it will be hidden by a solid wood fence. Both sides of floodwalls passing through borough-owned property will be provided with growing vines.

5.3 CENTRAL BASIN PROTECTION

To supplement the tunnel system, protection will be provided in the Central Basin at seven localities by means of levees, floodwalls and channel modifications. The Central Basin systems are described below and summary details are provided in Table 7. Recreation and beautification features are included where they apply. Interior flood damage reduction facilities consisting of gravity culverts, sluice gates, flap gates, ponding areas and pumps, as appropriate for each system, will convey surface runoff from the protected areas to the river in times of flood.

Table 7 - Central Basin Protection
(Dimensions in Feet)

LEVEE-FLOODWALL SYSTEMS								
System	Location	Levee Average			Floodwall Average		Interior facilities	Deg. of prot. in yrs
		Height	Base	Length	Height	Length		
Passaic #2A	Passaic River right bank in Fairfield and West Caldwell	7	52	6,216	5.5	3,082	Culverts; 5 ponds 42.5, 117, 53.3, 26.0 and 3.9 acres; 4 pumps; 5, 3, 1, and 2 cfs	100
Passaic #10	Passaic River right bank in Livingston	8	60	4,853	11	97	Culverts; 10 acres pond, 2 - 3 cfs pumps	100
Rockaway #1 -Downstream -Upstream	Rockaway River right bank in Parsippany-Troy Hills	5.9 10.3	45 72	818 2,421	3.3 ----	521 ----	Downstream: Culverts; 3 ponds; 7.5, 15.0 and 16.6 acres Upstream: Culverts; 2 ponds; 30.1 and 7.4 acres, 1 cfs pump	100
Rockaway #2	Rockaway River left bank in Montville	10	70	3,172	___	___	Culverts; 41.8 acre pond, 10 cfs pump	100

Rockaway #3	Rockaway River right bank in Parsippany-Troy Hills	7	45	1,850	8.5[1] 5.1[2]	5232[1] 1470[2]	Uses existing facilities	100
Pinch Brook	Pinch Brook right bank in East Hanover	N2 S8	N25 S60	2,397	9.4	415	Culverts, 10.5 acre pond, 1 - 3 cfs pump	100
CHANNEL MODIFICATION								
	Location	Length		Top width		Bottom width		
Deepavaal Brook	Deepavaal Brook in Fairfield and West Caldwell	7,660		60 to 85		30		100

(1) Floodwall to be placed on existing levee.

5.3.1 Passaic River Levee/Floodwall System #2A. This element of the plan, shown on **Figures 31** through 42, comprised four separate segments situated along the Passaic River in the southeastern portion of Fairfield Township and northwestern portion of West Caldwell Township. The total length of levee and floodwall is 9,298 feet of which 6,216 feet are levee and 3,082 feet are floodwall. The Interstate Route 80 embankment is integral to the overall line of protection. The system protects residential, commercial and industrial development in an area bounded by the right bank of the Passaic River, Interstate Route 80, Bloomfield Avenue and the area adjacent to the left bank of the Deepavaal Brook. The levees will average approximately 7 feet in height with an average base width of 52 feet. The floodwalls will have an average height of approximately 5.5 feet. To prevent flanking of the system, numerous culverts under Interstate Route 80 will require sluice gates and flap gates. A closure structure will be required at the Route 80 bridge crossing over Horseneck Road, tying into the bridge abutment. In addition, the Passaic #2A levee system was designed to supplement the proposed tunnel system. Without tunnel diversion, this system would need to be reconfigured to prevent the Passaic River from entering the area and causing significant damages. Any reconfiguration would require some type of levee or floodwall system near the confluence of Deepavaal Brook and Passaic River and in all likelihood a pump station.

The northern segments, located entirely in Fairfield, will start approximately 2,400 feet north of the intersection of Interstate Route 80 and the Passaic River. The levee proceeds east adjacent to an abandoned borrow pit filled with water, then curves gently to the southeast where it ties into high ground. The levee starts again at the southwestern boundary of the Fairfield Industrial Park between the industrial park and a large surface water body, then continues southeast to the rear of an industrial water body, then continues southeast to the rear of an industrial building on Evans Drive. A floodwall will then be constructed at the top of bank of a portion of a former oxbow meander of the Passaic River and end at the Route 46 embankment.

Proceeding southward, the next segment, a proposed levee and floodwall, will begin at Route 46 approximately 1,000 feet south of the end of the northern levee and run south along the eastern banks of the Passaic River in Pio Costa Commercial Park to Bloomfield Avenue in Fairfield.

The southern segment continues from Bloomfield Avenue and extends in a southerly then easterly direction through woodlands and wetlands between the Passaic River and Broadway Lane and ends east of Broadway Lane in West Caldwell.

Interior flood damage reduction facilities will be provided by supplementing existing culverts with new gravity outlets, sluice gates, flap gates and 5 ponding areas, 42.5, 117.0, 53.3, 26.0 and 3.9 acres in extent. Four pumping stations with capacities of 5, 3, 1, and 2 cfs will also be provided.

The Passaic #2A system provides excellent opportunities for recreational enhancements. The northern portion will be provided with a parking area at the end of Evans Street, a boat launch at the man-made lake, a picnic area near the boat ramp, an interpretive display and a trail system. A second trail system will begin at Bloomfield Avenue and connect to one of the roads in the small residential area. Site beautification will be provided by planting the levees with native wild flowers. The river sides of floodwalls will be beautified by vines growing up the wall. The portion of the land side of the floodwall visible from Bloomfield Avenue will be finished with a textured surface.

5.3.2 Passaic River Levee System #10. This element, shown on Figures 43 through 49, consists primarily of 4,853 feet of levees located on the right bank of the Passaic River in the Township of Livingston. A 10-foot length of floodwall founded by a 42 foot and 45 foot I-wall transitioning into the levee on both sides of the closure wall will be provided where an existing elevated sanitary sewer passes through the levee. Protection will be provided to structures in the area bounded on the west by the Passaic River and on the east by Eisenhower Parkway.

The levees will be set back approximately 800 feet from the river to avoid existing wetlands. The height of the levees will average 8 feet and the base width will be about 60 feet. They will be planted with native wildflowers as a beautification feature.

Interior flood damage reduction facilities will be provided by new culverts with sluice gates, flap gates and a 10.0-acre ponding area, contained in the area natural storage area to be preerved, and two 3 cfs pumping stations.

Passaic River #10 will be the first element of the project to be placed under construction and is described in greater detail in Appendix J - Passaic #10 Feature Design Memorandum.

5.3.3 Deepavaal Brook Channel Modification. This supplemental channel modification element of the plan, shown on **Figures 50** through **54**, provides flood protection in the areas of West Caldwell and Fairfield. This element also was designed assuming that the proposed tunnel system is operational. For basin wide floods, the tunnel would lower Passaic River flood stages (as well as on Deepavaal Brook) while the channel modification enhances stage reductions along Deepavaal Brook. However, for localized rainfall events on Deepavaal Brook (no Passaic River flood) the channel modifications would significantly lower flood stages in this area. It begins at about 500 feet south of the Jersey City water supply aqueduct right-of-way and extends to the area of Long Meadow Lane and the Fairfield-West Caldwell boundary. The 7,660 feet of existing channel, which borders the Essex County Airport, will be enlarged by increasing its bottom width to 30 feet and its top width from 60 to 85 feet, compared to the existing top width that varies from about 30 to 50 feet. An additional 560 foot long modification will be constructed farther downstream in the vicinity of the Fairfield Office Center. This consists of increasing the bottom width to 50 feet upstream and downstream of the building and deepening the channel.

5.3.4 Rockaway River Levee/floodwall System #1. This system, shown on **Figures** 55 through 60, will consist of two sections on the right bank of the Rockaway River in the Township of Parsippany-Troy Hills. The total length of the system will be 3,760 feet.

The downstream portion includes 1,339 feet of levee and floodwall to protect the area bounded by the Rockaway River, New Road, Edwards Road and Vail Road. The levees downstream of Route 80 will be set back approximately 200 feet from the river. This S-shaped system begins with a floodwall at the Route 46 east embankment and continues about 521 feet adjacent to the Rockaway River, a service station and a shopping mall. At that point the levee will begin and extend about 818 feet where it will tie into existing grade south of a commercial building on New Road. The average heights of the levee will be about 5.9 feet for the levee and range up to 5 ft in height for the floodwall.

The upstream portion is a levee 2,421 feet long north of Route 80 in the Township of Parsippany-Troy Hills. The levee will be set back approximately 1,100 feet from the river. The average height of the levee will be about 10.3 feet and the base width will be about 72 feet. The southern tie-out of the levee will be about 200 feet north of an existing gravel road parallel to Route 80. The northern end will be slightly northeast of the intersection of Edwards Road and Larkspur Drive. The upstream portion of Rockaway #1 will be protected from flanking by the Rockaway #3 system, which consists of raising in place the existing Lake Hiawatha levee/floodwall system.

Interior flood damage reduction facilities for the downstream portion will be provided by new gravity culverts, sluice gates, flap gates and 3 ponding areas, 7.5, 15.0 and 16.6 acres in extent, the first two being in the natural storage area to be preserved.

Interior flood damage reduction facilities for the upstream portion will be provided by a new culvert, sluice gate, flap gate and 2 ponding areas, 30.1 and 7.4 acres in extent, both in the natural storage area to be preserved. In addition, a 1-cfs pumping station will be provided.

Recreational features will be included in the system. A trail will be provided on the upstream levee, extend beyond it and meet the dirt road for access. A short trail will be provided in the downstream portion along the river side of the wall and levee. Beautification measures include the planting of native wildflowers on the levees, planting of vines on the river side of the wall and texturing the concrete face on the land side.

5.3.5 Rockaway River Levee System #2. This system, shown on **Figures 61** through **63**, will be located on the left bank of the Rockaway River in the Township of Montville. This system is designed to protect a residential area bounded by Change Bridge Road and Konner Avenue. The proposed levee system is an open U-shaped system approximately 3,172 feet in length with an average height of 10 feet and an average base width of 70 feet.

The levee will begin approximately 500 feet east of the Lancaster Avenue/Change Bridge Road intersection and proceed southeast behind residences along Change Bridge Road for approximately 650 feet. The levee will then proceed due east immediately adjacent to the Change Bridge Road right-of-way for approximately 600 feet where it changes direction to northeast for 400 feet. The levee will proceed east and tie in to high ground behind residences along Dogwood Circle.

Interior flood damage reduction facilities will be provided by a 41.8 acre ponding area, contained in the natural storage area to be perserved; it will discharge into the Rockaway River by means of a new 24-foot wide, 6-foot high box culvert to supplement the existing facilities. In addition, a 10 cfs pumping station will be provided.

The recreational feature of the system will be a trail constructed with an extension over the levee to connect it with Change Bridge Road. For beautification, the levee will be planted with native wildflowers. The side facing the road and residences will have shrubs by it. Where the levee passes residences, the toe of the levee will be planted with small ornamental flowering shrubs.

5.3.6 Rockaway River Levee/Floodwall System #3. This system, shown in **Figures 64** through **69**, will consist of 8,552 feet of levees and floodwalls located on the right bank of the Rockaway River in the Township of Parsippany-Troy Hills. Protection will be provided to residential structures in the area bounded by the Rockaway River on the east, River Drive, Mohawk Avenue and Sandalwood Drive on the west, Vail Road on the south and the northern terminus of River Drive to the north.

Rockaway #3, which will augment the existing Lake Hiawatha levee/floodwall system, will consist of 5,232 feet of floodwall, 1,850 feet of levee and 1,470 feet of floodwall placed on existing levee. The average height of the existing levees will be increased by approximately 7 feet and the average base width increased by approximately 45 feet. The average floodwall height will be approximately 8.5 feet, while the average floodwall height above grade on top of the existing levees will be approximately 5.1 feet. The existing levee system in the area of the Rockaway #3 project has levee elevations ranging from elevation 177.5 to 179.5, compared to the new levels ranging from 183.6 to 184.6.

The new construction will consist of approximately 1,025 feet of new floodwall at the northern portion of River Road, 376 linear feet of new floodwall at the north and south ends of the existing levee. The existing levee will have additional fill placed on its land side over a distance of 825 feet. The remaining portions are existing floodwalls that will be replaced and small areas of levee that will have their heights extended by constructing a floodwall on top of the levee.

Currently, the existing levee contains five closure structures. The new levee/floodwall system will contain four closures, two closures will maintain access to the clubhouse area, one closure at the end of Hiawatha Road will be replaced for channel maintenance purposes, and one will be constructed adjacent to the Tenneco gas transmission lines which presently has two closures. The existing closure in the area of Chesapeake Avenue will become a floodwall. Also associated with the existing levee are interior flood damage reduction facilities that include a pump station with a capacity of 183 cfs located near the end of Wilbur Avenue.

Interior flood damage reduction facilities for the existing project are expected to be adequate for the modification, subject to further studies that will be performed for the feature design memorandum.

For recreation, a path will be provided on the river side of the levees and floodwalls. A number of beautification features are included. On the land side, the treatment of floodwalls will include shadowbox fencing to hide the walls in residential rear yards, and the provision of shrubs by the small park. The river side of the floodwalls will be planted with vines. The river side of levees will be planted with native wildflowers. Because the land side is close to the backs of residences, lawn grass will be planted.

5.3.7 Pinch Brook levee/floodwall system. This system, shown on **Figures 70** and **71**, will be located on the right bank of Pinch Brook in East Hanover Township, Morris County, New Jersey. This system is bounded by Pinch Brook, Great Meadow Lane and Brentwood Drive. This open U-shaped levee/floodwall system will be approximately 2,812 feet in length, consisting of 2,397 feet of levee and 415 feet of floodwall and will protect the existing commercial and residential properties against floodwaters backing up from the Whippany River.

The southern levee will have an average height of approximately 8 feet and a base width of approximately 60 feet while the floodwall will have an average height of 9.4 feet. The northern levee will have an average height of 2 feet with an approximate base width of 25 feet.

The upstream end will start in the vicinity of Sheldon Court and proceed behind the residences on Brentwood Drive. As the levee proceeds downstream, it will change to a floodwall in the area of the industrial park. After a distance of approximately 415 feet, the floodwall will change back to a levee and proceed parallel to the Jersey Central Power and Light Company high voltage transmission lines for approximately 1,122 feet to its termination near the end of Great Meadow Lane at the rear of the residential area.

Interior flood damage reduction facilities will be provided by two 36-inch diameter culverts with flap gates and sluice gates, and a 10.5-acre ponding area contained in the natural storage area to be preserved. In addition, a 3-cfs pumping station will be provided.

Beautification measures include planting the levee with native wildflowers. Also, on the portion facing the residences, small shrubs will be added at the levee toe. The floodwall will have vines on the wetland side.

5.4 TIDAL AREA PROTECTION

In the Lower Valley, no structural features are included from Beatties Dam downstream to the Second River. The tunnel will divert portions of the damaging flood flows away from flood problem localities in this reach. From the Second River downstream to Newark Bay, intermittent levees and floodwalls are required to protect against flooding from coastal flood events. They will provide protection against both fluvial flows and storm surges in Newark Bay. These systems include about 2.13 miles of levees and 10.82 miles of floodwalls. Interior flood damage reduction facilities will be required behind these levees and floodwalls in order to carry surface runoff from the protected areas to the rivers and bay. These facilities will include gravity culverts and pumping stations. Summary data on the tidal protection systems are displayed in **Table 8**. Plans and profiles are shown on **Figure 72** through **89** and typical details are shown on **Figures 90** and **91**.

Table 8 - Tidal Protection
(Dimensions in feet)

System	Location	Levee Ht.	Levee Base	Levee Length	Floodwall Ht.	Floodwall Length	Interior facilities	Deg. prot.
Kearny Point	**Hackensack right bank and Passaic left bank in Kearny and Harrison**	5.2	41	3,908	7.4	33,771	**Culverts; 1-75 cfs pump**	**100+**
Lister/Turnpike/Doremus	**Passaic River right bank in Newark**	5.5	44	5,599	8.1	17,657	**Culverts; 1-100 cfs pump 1-50 cfs pump**	**100+**
South 1st Street	**Passaic River left bank in Harrison**	6.5	50	1,750	6.2	5,700	**Culverts; 1-75 cfs ump 1-70 cfs pump 1-30 cfs pump**	**100+**

5.4.1 Kearny Point Levee/Floodwall System. This system, shown on **Figures** 72 through 80, consists of approximately 3,908 feet of earthen levee and approximately 33,771 feet of concrete floodwall. It will protect an industrial area from tidal flooding on the left bank of the Passaic River around Kearny Point and upstream along the right bank of the Hackensack River in Kearny. Also included in this system are floodwalls and closures to protect the Port Authority Trans-Hudson (PATH) line from tidal flooding that will occur from both the Hackensack and Passaic Rivers. The levees have an average approximate height of 5.2 feet and approximate base width of 41 feet. The average floodwall height is approximately 7.4 feet.

PATH Line protection will begin in Harrison and consist of a small floodwall to protect the north PATH tracks. Another segment will be required in Kearny to protect the north track. Protection of the south PATH track will begin approximately 2,200 feet east of the NJ Turnpike bridge and continue east to the Conrail embankment.

The Kearny Point segment will begin at the Conrail embankment approximately 500 feet east of the NJ Turnpike bridge, continue south along the left bank of the Passaic River, proceed around Kearny Point, north along the right bank of the Hackensack River, and tie into a containment berm on Public Service Electric and Gas Company property. The floodwall will begin again on the north side of the containment berm and continue east to Fish House Road, which will be raised. The floodwall will begin again on the north side of the raised road, cross the Transco Gas pipelines and proceed east. The floodwall will change direction to the north, cross an existing roadway and tracks with gated structures and terminate in the Conrail embankment. The final segment of floodwall will proceed west for approximately 905 feet to high ground adjacent to the Conrail tracks. A floodside clay blanket or concrete pavement will be provided for the Conrail embankment to control through seepage. Present and future access to the river will be maintained by gated structures. Interior flood damage reduction facilities will be provided by new gravity culverts with flap gates and sluice gates, along with a 75 cfs pumping station.

5.4.2 Lister/Turnpike/Doremus Levee/Floodwall System. This system, shown on **Figure** 81 through 87, lies on the right bank of the Passaic River and will consist of floodwalls, levees and associated closure structures in the City of Newark to protect industrial structures against tidal flooding. The protected area is bounded by the Passaic River, Ferry Street and Freeman Street, the N.J. Turnpike, Routes 1 & 9, and the Conrail yards adjacent to Port Newark. The total system consists of approximately 5,599 feet of levee, averaging approximately 5.5 feet in height with a base width of approximately 44 feet and approximately 17,657 feet of floodwall (including gated structures) averaging approximately

3.1 feet in height.

The floodwall will begin approximately at the intersection of Raymond Boulevard and Oxford Street in the City of Newark and continue on the right bank of the Passaic River to the Conrail embankment, approximately 1,300 feet north of the New Jersey Turnpike extension Newark Bay Bridge. Closure structures will provide access for existing and future docking facilities as well as protection from flanking.

Protection from flanking of the levee system requires additional measures within the interior of the protected area. The tie-out at the Conrail embankment will continue along the Conrail embankment to the New Jersey Turnpike embankment where a small levee will be required between the two embankments. A 3-foot high closure about 45 feet wide will be required at the Wilson Avenue overpass to prevent flanking. An unnamed overpass 700 feet north of Wilson Avenue will be eliminated and fill will be placed to bring the area up to existing N.J. Turnpike road grade as part of the Turnpike widening project. An additional small closure or track raising may be needed at the Conrail underpass at Route 1 and 9 to the New Jersey Turnpike embankment to complete the line of protection.

Interior flood damage reduction facilities will be provided by new gravity outlets along with two pumping stations with capacities of 50 and 100 cfs.

The Joseph G. Minish Waterfront Park and Historic Area, planned by the Corps of Engineers and the State of New Jersey, will lie to the west of the project in the City of Newark. This system, which is not part of the project, will include a public boat basin with a boat ramp, and a promenade along the bulkhead. At the western end of this floodwall in the park, the promenade will be sloped so that the wall functions as a 3-foot high railing while permitting river views. The path will continue beside the existing storage tanks and on top of the levee behind the apartments. For beautification, the western 1,000 feet of the floodwall will be cast with a textured concrete face. All floodwalls will have vines planted on the river side; the levees will be planted with native wildflowers.

5.4.3 South 1st Street Levee/Floodwall System. This system, shown on **Figure 88** and **89**, is situated on the left bank of the Passaic River in the Town of Harrison. The levee/floodwall system will provide protection to residential, commercial and industrial structures from tidal floods from the South 4th Street bridge up to the New Jersey Transit rail bridge just south of the Route 280 bridge.

A total of approximately 7,450 linear feet of levee and floodwall with eight closure structures will be required. The levees will total 1,750 feet in length with an average height of about 6.5 feet and an average base width of 50, feet while the 5,700 feet of floodwall will have an average height of 6.2 feet. A continuous line of protection will be provided by gated structures across Passaic Avenue and adjacent to South 4th Street. River access and access to property on the east side of South 4th Street will be provided through gated structures at several sites adjacent to the Passaic River and South 4th Street.

The South 1st Street floodwall system will begin on the east side of Passaic Avenue just south of the New Jersey Transit rail line bridge structure and cross Passaic Avenue with a closure about 40 feet wide. A levee will continue parallel to the Passaic River for approximately 650 feet up to the Harrison Street bridge just beyond the Hess Station, where it ties into the north embankment. The floodwall will begin again on the south embankment of the Harrison Street bridge and continue onto the Tenneco manufacturing Refining Companies property where two 30-foot closures will be provided. The floodwall will proceed adjacent to an existing baseball field approximately 250 feet to the site of J. Supor Trucking along the Passaic River and the site of Diamond Shamrock Chemical Co. The floodwall will continue along the Passaic River adjacent to the Hartz Mountain Industries site where a closure about 30 feet wide will be provided. The floodwall will then continue and tie into the Amtrak/Conrail rail line embankment.

The floodwall will extend south from the Amtrak/Conrail line embankment adjacent to Public Service Electric and Gas Company's (PSE&G) Harrison plant facilities along the Passaic River where two 30-foot closures are provided. The rest of PSE&G's frontage will be protected with a floodwall and tie into the South 4th Street bridge embankment. An additional section of floodwall to prevent flanking runs north from high ground, adjacent to Cape May Avenue, to the Conrail bridge embankment. This section of floodwall will be approximately 1,425 feet in length and contain two 30-foot closures, one for Tri-Chem line, and one for an adjacent parking lot.

Interior flood damage reduction facilities will be provided by new gravity culverts with flap gates and sluice gates, along with three pumping stations with capacities of 75, 70 and 30 cubic feet per second.

As a beautification measure, the side of the floodwall facing the river and the side facing the athletic field will be decorated with vines.

5.5 PRESERVATION OF NATURAL STORAGE

The preservation of 5,350 acres of natural storage areas in the Central Passaic Basin is a significant flood damage reduction element in the project. The main purpose of the natural storage areas is to prevent further encroachment and development in the Passaic's Central Basin wetlands. This will help allow the tunnel to function at design capacity. The acquisition of these lands will insure the long term maintenance of the project's degree of protection by preventing increases in flood flows that might be caused by the loss of these areas to new development. This acquisition, in conjunction with nearly 16,000 acres already protected under existing Federal and state programs, will preserve the flood storage and environmental characteristics of the Central Basin wetlands. In addition, the project also requires that the existing floodways in the areas of acquisition be maintained at their present widths. Concerns over possible flood stage loss due to increase in Phragmites and Puple loosestrife lead to analysis of the 5,350 acres of natural storage to be preserved. The results indicate that the preservation area approximates the same cover type conditions as the entire Central Basin wetlands in the project area. Approximately 3,800 acres are scrub/shrub-emergent, and emergent wetlands. About 640 acres have already been invaded with Phragmites or purple loosestrife. These approximate proportions hold in the area to be preserved as part of the project for the 5,200 acres of the 5,350 acres of natural storage which are wetlands. The wetland areas to be preserved are shown on **Figures 111-114, 120-125, 128-131, 133** and **134**.

Analysis of potential storage loss due to the invasion of exotic flora was conducted on the entire Central Basin project area wetlands (13,700+ acres). Results indicated that even if all the wetlands susceptible to Phragmites and purple loosestrife invasion were infested (highly unlikely), and the root mat accumulated to a depth of two feet (very unlikely), incremental increases in water surface elevations would not be sufficient to change tunnel functioning in a substantial way. Hence control of exotic vegetation in the subset (5,350 acres) to be preserved as part of the project is not required to maintain storage function. However, it is noted that some control, especially for purple loosestrife, is included for biological mitigation. The associated costs have been identified in Section 6 of the Environmental Resources Appendix.

Tables 9 and **10** list the acres proposed for acquisition by municipality and major wetland area.

As previously stated in the descriptions of the local protection systems, certain portions of these lands will also be used for ponding as elements in interior flood damage reduction facilities.

The preservation of natural storage under this plan involves the following considerations:

- The retention by the State of New Jersey of existing approved Federal Insurance Administration Floodways at their current limits in the areas to be acquired;

- A determination, based on New Jersey Department of Environmental Protection estimates for final delineations, of floodways in communities where they have not yet been adopted, without attempting to take this plan into account; and

- The retention of current State of New Jersey regulations regarding both no "net fill" in the Central Basin and storm water management.

Table 9 - Natural Storage Areas to be Acquired, by municipality

System	Wetland	Acres
East Hanover	Black Meadows Troy Meadows Upstream Passaic	143 215 2
Fairfield	Hatfield Swamp Great Piece Meadows Long Meadows	12 1,014 46
Florham Park	Upstream Passaic Black Meadows	22 370
Hanover	Black Meadows	684
Lincoln Park	Bog and Vly Meadows Pompton Valley Wetlands Great Piece Meadows	393 16 774
Livingston	Upstream Passaic	85
Montville	Great Piece Meadows Hatfield Swamp Bog and Vly Meadows	69 6 36
Parsippany- Troy Hills	Troy Meadows Hatfield Swamp	978 104
Wayne	Pompton Valley wetlands Great Piece Meadows	18 9
Chatham	Upstream Passaic	8
Pequannock	Pompton Valley wetlands	94
Pompton Lakes	Pompton Valley wetlands	11

Riverdale	Pompton Valley wetlands	10
Roseland	Upstream Passaic wetlands	2
West Caldwell	Hatfield Swamp	256
Total		5,350

Table 10 - Natural Storage Areas to be Acquired, by Wetland area

Wetland	Municipality	Acres
Great Piece Meadows	Wayne Lincoln Park Montville Fairfield	9 774 69 1,014
Bog and Vly Meadows	Lincoln Park Montville	393 36
Pompton Valley Wetlands	Pequannock Lincoln Park Wayne Riverdale Pompton Lakes	94 16 18 10 11
Hatfield Swamp	West Caldwell Fairfield Parsippany-Troy Hills Montville	256 12 104 6
Long Meadows	Fairfield	46
Troy Meadows	Parsippany-Troy Hills East Hanover	978 215
Black Meadows	East Hanover Hanover Florham Park	143 684 370
Upstram Passaic	Chatham Roseland Livingston East Hanover Florham Park	8 2 85 2 21
Total		5,350

5.6 FISH AND WILDLIFE MITIGATION

The engineering and design effort included thorough consideration of opportunities to mitigate known and potential impacts of the project. Wherever possible, such impacts were addressed in the design of each element as part of standard engineering practice. In those cases where impacts could not be addressed in the design of specific elements, mitigation measures were included separate from the project features. Mitigation features include measures at degraded wetland sites, hydraulic controls and pumps to regulate site hydrology and instream structures. Both kinds of mitigation features are described in Section 8 - Environmental Analysis.

5.7 PROJECT OPERATION

The tunnel system allows the existing natural channels in the Central Basin and the Highland Area (Pompton Valley) to function as they would today until floods are expected. The system is not expected to operate for events approximately less than the 1-Year flood. A floodwarning and forcast system will advise when floods are expected to exceed the 1-Year event, whereupon the project will be activated.

The design of the tunnel system will take advantage of the flood hydrograph timing relationship between the Passaic and the Pompton Rivers. For example, should the 100-Year flood occur, the Pompton will peak about 40 hours earlier than the Passaic River. With this in mind, the spur tunnel gates will operate based on stages at the Pompton Inlet.

Control structures will open and cause the diversion of flood waters into the tunnels and allow the water to be managed with minimum impact on existing conditions.

5.7.1 Pompton Inlet. The plan of operation at the Pompton Inlet is to permit a continuous bypass flow for all flood events ranging from 4,300 to 7,000 cfs. Such operation will keep the peak flow at Pompton Plains from exceeding what now corresponds to approximately the 1-Year flood event. The gate operation will be designed to release flows approximating bank-full capacity for all floods between the 1-year and 100-year events. At the mouth of the Pompton River, the 100-year flow will be reduced from 28,500 to 7,420 cfs.

5.7.2 Passaic Inlet. Under non-flood conditions, normal flows will continue to remain with the Passaic Riverand flow over Beatties Dam. When floods greater than the one-year are anticipated, the gates on the diversion spillway will open to divert Passaic flows into the tunnel. The Central Basin flow into the lower valley must be minimized early in the storm to prevent or reduce flooding in the Lower Valley caused by concurrent peaks.

5.7.3 **Tunnel flows.** Since the Pompton River's input to the main tunnel peaks first and is the main contributor to flooding, the water allowed into the spur tunnel will depend on conditions in the Pompton. This rule will generally give priority to diverting Pompton River flows into the tunnel over those of the Passaic. Thus, for flows between 50- and 500-year, the Passaic inlet will be closed for a period of time to permit only flow from the Pompton inlet. During a 100 year event, the tunnel will carry only Pompton water for about 11 hours as the Pompton peaks. No water will be allowed into the tunnel from the Passaic Inlet. The maximum bypass flow at the Passaic Inlet will be approximately 9,000 cfc during the 100-year event. The Lower Valley will not be affected because at this time the peaks in that reach will have passed.

During the later portion of the rainfall/runoff event, after Pompton peaks have passed, the Passaic inlet will open to allow the peaks from the Passaic to enter the tunnel. These flows could arrive up to two days later then the Pompton flows. In more frequent storms from 1- to 50-year, the tunnel will have sufficient capacity to allow inflow from both inlets simultaneously.

The Passaic inlet will continue to divert flow until: the rain stops, peak stages downstream of Little Falls recede, and Passaic River stages downstream and upstream of the inlet fall to below non-damaging levels. Then the Passaic spillway diversion gates will be gradually closed.

MAIN REPORT

SECTION 6

CHANGES

6. CHANGES

6.1 OVERVIEW

Since authorization of the Passaic River Flood Damage Reduction Project, preconstruction engineering and design studies have been performed. This, in addition to further coordination with state and other Federal agencies, has resulted in various design refinements made using by current engineering, economic and environmental conditions. As an example, four levee/floodwall systems in the Pompton Valley are no longer included because of the more efficient hydraulic design of the inlets and channels that will convey floodwaters to the Pompton Inlet. A revision, as the term is used here, will mean any change from the project authorized in the Water Resource Development Act of 1990, as modified by the Water Resource Development Act of 1992.

6.2 REVISIONS

Table 11 displays the revisions to the authorized project along with the reasons why they were made.

Table 11 - Project Revisions

Project element	Revision	Reason
TUNNEL SYSTEM		
Tunnel	Main tunnel increased in length from 20.0 to 20.4 miles; diameter from 40 to 42 feet. Spur tunnel increased in length from 1.2 to 1.3 miles; diameter from 22 to 23 feet.	Tunnel lengthened to move outlet closer to the existing navigation channel to minimize dredging. Diameters enlarged to maintain a 100-yr. level of protection.
Pompton Inlet	Inlet changed from morning glory type to semi-circular sloping inlet. Pompton River flow restructure eliminated.	Improve hydraulic performance, safety, and reduce air entrainment.
Passaic Inlet	Inlet changed from morning glory type to semi-circular sloping inlet. Buyout of three structures now required.	Improve hydraulic performance, safety, and reduce air entrainment.

Outlet	Moved to 1,850 feet offshore of Kearny Point.	To direct discharges into Hackensack River Navigation Channel so as to minimize erosion of existing mudflats. Also to minimize dredging and disposal of potentially contaminated sediment.
Shafts	Number of work shafts increased from 4 to 8. One access shaft and one vent/hook hole shaft added. Work shaft 2 to be used as control center.	To accommodate tunnel route changes made to allow tunnel boring machine to bore predominantly uphill. Air vent added at critical location to avoid unstable hydraulic conditions.
Passaic and Lower Pompton Rivers Channels	Length of deepening shortened from 1.1 to 0.7 mile. Average top width increased from 235 to 280 feet; bottom width increased from 175 to 240 feet. Pilot channel added, extending past inlet for a distance of 6,500 feet	Channels were slightly redefined to accommodate new inlet design. Added sediment bypass channel to prevent sediment from accumulating at entrance of Passaic Inlet.
Pequannock River Channel	Length of deepening decreased from 2.6 to 2.4 miles; deepening increased from 7 to 8 feet.	Channel redesigned to accommodate new Pompton Inlet configuration.
Bypass Channel	Enlarged bypass channel to 0.5 mile long, 2 to 14 feet deep, and 130 to 230 feet wide.	To accommodate redesign of the Pequannock Weir and its new siting on the land side of the Pequannock River, thus allowing access during flood events for emergency equipment.
Wanaque River Channel	Length of deepening increased from 1.0 to 1.1 mile; maximum deepening increased from 6 to 7 feet; added 2,000 feet of riprap and 600 feet of crushed stone.	Channel redesigned to accommodate new Pompton Inlet configuration.

Ramapo River	Length of deepening increased from 1.1 to 1.3 mile; deepening increased from 4 to 10 feet. Almost entire length to be lined with riprap.	Channel redesigned to accommodate new Pompton Inlet configuration.
Pequannock/Ramapo levee/floodwall	Length of levees decreased from 9,230 to 2,200 feet; average height decreased from 9.4 to 5.9 feet; average bottom width decreased from 66 feet to 45 feet. Length of floodwalls increased from 1,500 to 2,910 feet; average height decreased from 10.8 to 5.7 feet.	Levee shortened due to redesign of channels and main inlet based on updated topographic mapping. Some levee replaced by floodwall to minimize disturbance to existing structures.
Shore Road	Deleted	No longer needed due to channel and inlet redesign.
Stiles Court	Deleted	No longer needed due to channel and inlet redesign.
Hill Court	Deleted	No longer needed due to channel and inlet redesign.
Wanaque Avenue	Deleted	No longer needed due to channel and inlet redesign.
Pequannock Weir	Relocated for land side access and changed from two 85-foot bascule gates to four 50-foot wide and 15-foot high tainter gates. Raised gate sill to elevation 164.0.	To provide emergency access during large flood events and ease maintenance requirements. Raised gate sill to alleviate sedimentation in weir area.

Great Piece Weir	Relocated weir downstream. Placed c. 17,000 cy of fill and raised 6-7 existing residences and 1,000 LF of roadway; gates changed from single 100' bascule to 5-30' torque tube basque gates.	Relocated weir to reduce impacts on wetlands and eliminate need for overbank levee. Raised roadway to provide accessibility to gate structure during flood events.

CENTRAL BASIN PROTECTION		
Passaic River #2A	Total length shortened from 20,660 to 9,298 feet. For the 6,216 feet of proposed levee the average height decreased from 8.6 to 7.0 feet, base width decreased from 61.6 to 52 feet; For 3,082 feet of floodwall, with average height decreased from 9 to 5.5 feet. Eastern section eliminated. Western section realigned to north.	Levees along Deepavaal Brook were replaced by Deepavaal Brook channel improvement. Western section realigned to minimize impacts to open water and wetland habitat.
Passaic River #10	No significant change.	
Rockaway River #1	Average height of downstream protection decreased from 8.7 feet to 5.9 feet. Downstream portion changed by replacing part of levee with 521 feet of floodwall having average height of 3.3 feet and an 818-foot long levee section with an average height of 5.9 feet.	Refinements in hydraulic design based on updated site information.
Rockaway River #2	Length of levees decreased from 3,300 to 3,172 feet. Average height increased from about 8 to 10 feet. Bottom width increased from 60 to 70 feet.	Refinements in hydraulic design based on updated site information.
Rockaway River #3	Total length of works increased from about 6,320 feet in length to 8,550. Length of new levee decreased from 6,320 to 825 feet with average height reduced from 10.3 to 7.0 feet, and bottom width decreased from 72 to 52 feet. Floodwall continues for 6,702 feet of which 1,525 feet is new and 4,282 feet will replace existing floodwall or be driven into existing levee.	Refinements in hydraulic design based on updated site information. Most of levee replaced with floodwall to minimize disturbance to existing structures.

Pinch Brook	Shortened from 3,380 feet of levee to 2,812 feet (2,397 feet in two sections and 415 feet of intervening floodwall). Average height of levee increased from 6.6 to 8 feet and the base width increased from 49.6 to 60 feet. Average height of the added floodwall would be 9.4 feet.	Redesigned levee alignment to shorten overall length and reduce footprint of the system.
Deepavaal Brook	Levee eliminated and replaced by 7,660 feet of channel improvement to increase the bottom width to 30 feet, and the top width to vary from 60 to about 85 feet.	Channel improvements are more effective in conjunction with tunnel drawdown during basin-wide flood events. Also, complex interior damage reduction facilities works were voided by eliminating levees.
TIDAL AREA PROTECTION		
Kearny Point	Total length increased from 34,520 feet to 37,679 feet, 33,771 ft of floodwall and 3,908 ft of levee. Levee average height decreased from 8.8 to 5.2 feet; bottom width decreased from 63 to 41 feet. Floodwall average height decreased from 8.0 to 7.4 feet. Elevations of tops of levees and floodwalls have not changed.	Lengthened to protect north and south tracks of the PATH line and to protect from Hackensack River flooding. Some levee replaced by floodwall to minimize impact on existing structures. Changes were also affected by updated topographic mapping.
South First Street	Lengthened from 5,930 to 7,450 feet, 1,750 feet of levee and 5,700 feet of floodwall. Average height of levee decreased from 7.9 to 6.5 feet, base width decreased from 57.4 to 50 feet. Average height of floodwall decreased from 8.3 to 6.2 feet. Elevations of tops of levees and floodwalls have not changed.	Southern portion of system at South 4th Street Bridge and along South 4th Street extended to prevent flanking. Some levee replaced by floodwall to minimize impact on existing structures. Changes were also affected by updated topographic mapping.

Lister/Turnpike/ Doremus	Three original separate systems, totalling 14,470 feet of levees and floodwalls are now combined into one continuous system 23,256 feet long. System includes 5,599 ft of levee and 5,700 ft of floodwall. Average height for levee decreased from minimum of 7.4 to 5.5 feet, and base width decreased from minimum of 54.4 to 44 feet. Average height of floodwall changed from varying between 5.5 and 10.3 feet to an average of 8.1 feet. Elevations of tops of levees and floodwalls have not changed.	To prevent flanking of the systems. Extended approximately 8,000 feet in City of Newark Area to tie in to existing railroad embankment and provide added protection to heavily urbanized area. Some levee replaced by floodwall to minimize impact on existing structures. Changes were also affected by updated topographic mapping.
PRESERVATION OF NATURAL STORAGE		
Land acquisition	Minor changes in location of the designated 5350 acres were made.	To reflect developmental changes and to address geographical and ecological efficiencies.
FISH AND WILDLIFE MITIGATION		
At various localities	Incorporation of wetland hydrology in ponding site criteria in accordance with good engineering design resulted in reduction of impacted wetlands from 905 acres to 94 acres. Remaining wetland impacts are addressed specifically by restoration of disturbed wetlands.	To compensate for adverse impacts.

MAIN REPORT

SECTION 7

ENGINEERING DESIGN

7. ENGINEERING DESIGN

7.1 OVERVIEW

The Passaic River Flood Damage Reduction Project was developed to alleviate flood problems in the basin. An understanding of the flood-producing characteristics was achieved by analyzing the hydrology of the basin including the hydraulic capacities of its valleys, lakes and streams. The elements of the plan have been designed to manage the water resources of the basin by providing the maximum flood relief consistent with economy of construction. Geotechnical analysis, testing and modeling were done in connection with structural design studies to the level of detail that assures the works remain stable, reliable and functional throughout the project life. Thus the cost estimate of the project reflects a soundly engineered project. This section summarizes the engineering design studies performed for this design memorandum. Further detail on the various disciplines may be found in the technical appendices as noted in the discussion.

7.2 SURVEYS AND MAPPING

Aerial photography and field control surveys performed in 1988 and 1989 were employed to develop topographic mapping and stream cross-sections for the project area. The topographic mapping was prepared at a scale of one inch equals 30 feet and one inch equals 200 feet, with one- and two-foot contour intervals respectively, utilizing the National Geodetic Vertical Datum (1929 adjustment) as established benchmarks. The mapping coordinates are referenced to North American Datum (NAD) 27 and are in feet based on the New Jersey State Plane Coordinate System (SPCS) 27. Stream cross-sections were prepared through a combination of field surveys for the channel and bridge sections, and photogrammetric procedures for overbanks. A utility survey was also performed in conjunction with the topographic survey. The digital mapping, in connection with computer-assisted design techniques, provided a high degree of flexibility in the design of the project components.

7.3 HYDROLOGY AND HYDRAULICS

Starting with existing conditions, the hydrologic and hydraulic studies focused on the conditions that would exist both with and without the project in the Passaic River and Newark Bay.

Consideration was also given to the Hackensack River as it affects conditions in the Passaic River and Newark Bay. The hydrologic and hydraulic studies graphically illustrate how the plan will work as an integrated system. Accurate modeling tools were used to reproduce existing conditions. With the existing conditions firmly calibrated and verified, it was possible to compare future conditions with and without the project. Full details on the investigational studies performed are in Appendix C - Hydrology and Hydraulics.

7.3.1 Modeling The 935 square mile basin was subdivided into 189 subbasins, ranging in size from 0.46 to 50.9 square miles. The flood-producing characteristics of the basin were considered, including natural physiographic and manmade effects such as urbanization, reservoirs, and water supply diversions.

7.3.1.1 UNET model. A modeling tool, not formerly applied to previous Passaic River studies, was used to more accurately predict the complex flood behavior in the basin. The model had to be capable of reproducing flows and flood stages over large geographical regions and time periods. It also had to be capable of simulating unsteady and network flow. A review of available models resulted in the selection of the UNET model developed by the Army Hydrologic Engineering Center (HEC). This model has been in use and under development for over 10 years. With this tool, one model would capture the basin's response to rainfall and produce a stage-frequency-relationship. Information necessary to drive the UNET model was obtained by linking it to the physical characteristics of the subbasin in the HEC-1 model that simulates basin rainfall runoff. Following a rigorous calibration and verification process, the UNET and HEC-1 models were accepted as being capable of reflecting both historical and hypothetical events, and thus appropriate for project design.

7.3.1.2 Tidal surge modeling. The lower 17.7 miles of the Passaic River downstream of Dundee Dam are subject to occasional flooding due mainly to storm surges. Therefore, the stages of the Passaic from Newark Bay to Dundee Dam are influenced by a combination of fluvial and tidal flooding.

The outlet structure and tidal area protection levees adjacent to Newark Bay will affect flow patterns in the upper end of the bay. A storm surge analysis was conducted to determine the extent of this change. The primary objective of the study was to relate the stages and frequencies (stage-frequency curves) for tidal events in the lower Passaic and Hackensack Rivers and Newark Bay. The curves are based on the combined effects of hurricanes and northeasters for conditions expected to exist in the year 2050.

All future condition analysis assumed a 0.5 foot future sea level rise by the year 2050. The added sea level rise was used in the design of the height and extent of the tidal levees overtopping and flanking. The study also determined the correlation between tidal surge levels and peak river flows, which was not addressed in previous studies. Factors such as separation of residual storm surges from observed tidal heights, time lags and correlation factors were addressed. Another objective of the study was to determine if the tunnel and/or tidal levees would raise water levels in Newark Bay and the tidal reaches of both rivers. No significant impact on Newark Bay is expected as a result of the project.

7.3.1.3 Discharge-frequency analysis. The effectiveness of the project in reducing flood damages required a statistical analysis of historical flood events. By relating the damages caused by such events along with hypothetical ones, it was possible to estimate the benefits of a project. For this project, a frequency analysis was performed on six stream flow gages with long periods of records. Annual series frequency analyses were performed using computer program HECWRC, Flood Frequency Analysis, dated April, 1987, which incorporates procedures from EC 11102-249 "Hydrologic Frequency Analysis," and "Water Resources Council Bulletin 17B, Guidelines for Determining Flood Flow Frequency." All statistical computations were performed on gage data through Water Year 1994, as adjusted for partial duration and urbanization.

7.3.1.4 Hydrodynamic Models. In the estuary portion of the study area that includes Newark Bay, Passaic River to Dundee Dam and Hackensack River to Oradell Reservoir, 2- and 3-dimensional numerical models were developed to assess project impact. Models were used to predict changes in salinity, temperature and circulation patterns in and around the bay and outlet structure. Data collection efforts were performed to calibrate and verify models to a known set of historical information. Hypothetical events were then evaluated with and without the project in place, with model output providing the hydrodynamic response to both the sediment transport and water quality models for further analysis.

This effort included the evaluation of a series of variables that consisted of:

- Tunnel Water: empty or partially filled tunnel.
- Time of Year: cold or warm receiving bay waters.
- Flood magnitude: hypothetical 2-, 25- or 100 year with and without the project.

Model results indicated that the effect of the tunnel diversion on circulation patterns is very localized and would basically be a zone around the outlet structure. Generally, impacts are not significant due to the outlet citing in an area that already has high currents during existing flood events. However, cross currents to shipping with the project in place are more likely and this will be more accurately assessed during the FDM when a physical model would be built and a ship simulation study performed.

7.3.1.5 Sediment Transport. As part of this study effort, sediment evaluations were made for the upland riverine areas on the Passaic River upstream of Dundee Dam, a 2-dimensional sediment transport model in the Newark Bay area, and a trapping efficiency study of tunnel discharges. For the upland areas, a limited sediment assessment study was conducted by the Corps of Engineers Waterways Experiment Station in 1990 to test for potential adverse impacts of the project. The study made recommendations that resulted in the establishment of a sediment data collection program. Four data collection sites have been selected where data was collected for two minor flood events. The sites are 1) the Pompton River at Pompton Plains, 2) Passaic River at Little Falls and 3) Passaic River at Pine Brook, and 4) the Hackensack River at New Milford. After data collection was completed, the sediment transport process was evaluated; the primary goal will be to assess sediment movement in and around the tunnel inlets and to determine the impacts of the tunnel on sediment transport capabilities and changes on the Passaic River, its tributaries and Newark Bay. In addition, an evaluation was made of the effect of sediment on the operation and maintenance of the tunnel. Model results indicated some areas of potential deposition and erosion may occur.

7.3.1.6. Water Quality. A water quality model was created to help determine the impacts of the project on water quality in Newark Bay, the lower Passaic River and the lower Hackensack River. The model was developed at the Corps of Engineers Waterways Experiment Station (WES) in Vicksburg, Mississippi. A CH3D computer program that simulated flow in three directions was used in the analysis. To insure that the tidal propagation was accurately reproduced, the model included most of New York Harbor. The model extended from Sandy Hook, NJ to Troy, NY, and included a large portion of Long Island Sound. Detailed field data such as tide levels, salinity, water temperature, and dissolved oxygen levels were collected to calibrate the model in and around Newark Bay. Other data sources were used to calibrate the remainder of the model. Passaic River water samples were collected and kept in "tunnel-like conditions" to monitor changes in the water quality. The final model was run to determine water conditions with and without the tunnel project. The analysis was closely coordinated with the National Marine Fisheries Service (NMFS) and other environmental agencies. Conclusions were that it is unlikely the tunnel will have any substantial impact on the Aquarian community.

7.3.2 Tunnels. The analyses and procedures were performed in accordance with standard Corps of Engineers design guidance. With a systematic 54-year period of record dating back to 1940, and an historical extension to October, 1903, ample data are available to reliably determine the flow for the 100-year design event. Peak flow frequency curves were developed in accordance with Bulletin 17B of the U.S. Water Resources Council. The Corps' standard computer program was used to calculate the expected probabilities for the frequency curves. Existing condition computations were used to develop curves for future conditions (year 2050) with the tunnel system in place. Having established existing conditions (1992) and 2050 conditions, based on the expected probability, adjustments were made to the UNET peak flows. This permitted the design flow for the tunnel to be established at 29,000 cubic feet per second (cfs).

The maximum tunnel head was limited to an upstream elevation of 175.0 (National Geodetic Vertical Datum) at the Pompton Inlet with a downstream elevation of 6.2. The downstream elevation of 6.2 allows for a rise in future sea level and for a storm surge in Newark Bay. A series of elevation-discharge curves were established for several different tunnel diameters. Each diameter was then evaluated over a range of tunnel roughness. A statistical analysis demonstrated that a 42 foot diameter tunnel would reliably convey 99.9% of all floods (100-year level of protection.)

7.3.2.1 Pompton Inlet. The location of this inlet is critical to the establishment of design flow, diameter and overall cost of the tunnel element. Floodwaters entering the tunnel at this point will travel 20.4 miles to Newark Bay. The Pompton Inlet will divert up to 29,000 cfs of excess floodwaters allowing between 4,300 and 7,000 cfs, representing the range of the 1- and 2-year frequency events, to be bypassed. Generally, the bypassed flow will increase as the size of the storm increases. These flows will be out of bank but will not cause significant (1% of the 500 yr flood) damages. A risk and uncertainty analysis was performed at this inlet. Hydraulic studies allowed the elevation of the inlet to be low enough to significantly reduce the need for extensive upstream levee/floodwall systems.

7.3.2.2 Passaic Spur Inlet. This inlet will divert up to 13,400 cfs of excess floodwaters out of the river into the spur tunnel. Between 5,550 and 6,500 cfs, representing the range of the 1- and 1.5-year frequency events, will be allowed to bypass the inlet. Generally, these bypassed flow will increase as the size of the storm increases, but will remain within the banks.

7.3.2.3 Outlet. The diverted floodwaters will flow from a depth of 399 feet vertically into the outlet structure, which will extend from a depth of about 26 feet below sea level to about 25 feet above sea level. It will contain three 26-foot wide by 30-foot high vertical lift gates that will distribute flow through an angle of about 70 degrees and across the full channel depth of 30 feet. If one or more of the gates were to fail to open during a major flood event, flow will still be able to exit the tunnel through a 140-foot long overflow section located at the back of the outlet.

7.3.3 Channel modifications. All channel modifications were designed in accordance with the Corps of Engineers manual on the Hydraulic Design of Flood Control Channels[1]. Areas considered for erosion protection included locations to be modified and unimproved locations where channel velocities are expected to increase by at least 25% as a result of the project. Channel velocities used to determine erosion potential were obtained from the UNET model for improved conditions.

7.3.4 Levees and floodwalls. For the Central Basin and Pequannock-Ramapo levee/floodwall systems, heights were determined by adding an allowance for uncertainties to the water surface elevations for the 100-year flood event. The uncertainties associated with flow, channel roughness, debris obstruction at bridges and blockage of tunnel inlet gates, were estimated. Sensitivity analyses were performed for various conditions. The combined effects of uncertainties in discharge, blockages and other conditions were used to set the minimum design water surface profiles.

Since all levee/floodwall systems provide limited protection, consideration was given to overtopping which can be expected to occur at some time. To minimize the hazard of overtopping, the design calls for it to occur at the least hazardous location, which could be either at the downstream-most end of the levee/floodwall systems or at a ponding site in a protected area. The flowline that overtopped the levee at the least hazardous location was then determined and superiority height was added

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[1]EM 1110-2-1601

along the remaining locations.

7.3.5 Interior Flood Damage Reduction Facilities. Each levee-floodwall system will drain storm water from the protected area during and after flood events. Interior drainage facilities will include culverts, sluice gates, flap gates, pumps and ponding areas. Facilities designed to maintain the current level of effectiveness were evaluated along with enhanced facilities. In some instances small pump stations were included to reduce the overall project footprint, reduce the amount of replacement wetlands required by Green Acres legislation and to evacuate the ponding areas promptly. In other cases, interior facilities were enhanced because it was economically desirable to do so.

All interior facilities were evaluated for a range of seven events (2-year to 500-year). To compute the interior ponding elevations, the same hypothetical event was used to determine both the interior and the exterior runoff. The rainfall conditions used to compute the drainage behind the levee were also used to compute the rate of rise in the river. Seepage through the levees and floodwalls was only analyzed for the Passaic #10 system where it was found to be negligible. Data on interior flood damage reduction facilities are shown in **Table 12.**

Table 12 - Interior Flood Damage Reduction Facilities

System	Facilities to match without project condition	Recommended Upgrade	Economically Maximized Facilities
Pequannock/Ramapo	Culverts with sluice gates and flap gates Four ponding areas	3 cfs pump	
Passaic #10	Culverts with sluice gates and flap gates One ponding area	two 3-cfs pumps	
Pinch Brook	Culverts with sluice gates and flap gates One ponding area		3 cfs pump

Passaic #2A	**Culverts with sluice gates and flap gates Five ponding areas**	5 cfs pump 3 cfs pump	2 cfs pump 1 cfs pump
Rockaway #1	**Culverts with sluice gates and flap gates Five ponding areas**	1 cfs pump	
Rockaway #2	**Culverts with sluice gates and flap gates One ponding area**	10 cfs pumping station	
Rockaway #3	**Existing facilities are used**		
Lister/Turnpike/ Doremus	**Culverts with sluice gates and flap gates**		**100-cfs pump** **50-cfs pump**
Kearny Point	**Culverts with sluice gates and flap valves**		**75-cfs pump**
South First Street 1st	**Culverts with sluice gates and flap valves**		**75-cfs pump** **70-cfs pump** **30-cfs pump**

With respect to tidal protection area interior flood damage reduction facilities, exterior conditions are controlled by tidal stages. Study showed that there is a low degree of coincidence between peak tidal stages and high Passaic River runoff events. It was found that a normal tide plus a 1.5- to 2.0-foot surge could be adopted as coincident within the Passaic River Basin. Seepage rates were found to be negligible. Ponding areas were not used in this area because of the lack of space in these heavily urbanized areas for either natural or excavated ponding areas. Various levels of pumping capacity beyond that necessary to match non-project conditions were evaluated to determine the optimum protection. As a result of the optimization process, additional pumping was found to be justified at all three of the tidal protection areas as shown in **Table 12**. Interior flood damage reduction facilities for the tidal levee/floodwall systems consist primarily of gravity culverts with sluice gates, flap gates, and pumping stations.

7.3.6 **Improved conditions** Implementation of the project will reduce flood damages in numerous localities in the Passaic River basin. Tunnel diversions will result in the largest flood level reduction, although individual levee/floodwall systems, and channel modifications will provide high levels of protection at their respective locations. Generally, the project will reduce the 100-year flood to non-damaging or low level residual flooding in the principal damage areas of the Central Basin and Lower Valley. Areas upstream and downstream of the tunnel inlets will have water level reductions as a result of the tunnel's operation. In the Lower Valley tidal areas, where the tunnel diversion will have little to no impact, the levee/floodwall systems will provide protection for the heavily urbanized areas in the vicinity of Newark Bay.

The effect of these systems on flood elevations of the project at various locations is displayed in **Table 13** .

Table 13 - Project Effects
Reduction in Water Level, (In feet)

River	Location	Flood event			
		1-yr.	10-yr.	100-yr.	500-yr.
Passaic River	Pine Brook	0.1	0.3	1.2	2.1
Wanaque River	At Mouth	5.2	6.2	5.7	4.4
Pequannock River	Near proposed Pequannock Weir	1.8	6.1	6.9	5.8
Ramapo River	1.5 mile above mouth	1.8	6.1	4.9	3.8
Pompton River	Above inlet	0.6	7.7	10.7	6.6
Pompton River	At mouth	0.4	5.3	8.3	6
Deepavaal Brook	At mouth	0.3	4.8	7.8	5.9
Passaic River	Little Falls	0.1	4.8	8.1	5.8
Passaic River	Dundee Dam	0.1	1.6	1.7	2.0

7.4 GEOTECHNICAL

A preliminary geotechnical design was performed for each project feature to ensure a sound cost estimate. Diverse geotechnical studies were conducted in support of the design of the tunnels, inlet and outlet works, levees, floodwalls and other elements of the project. These included geotechnical analyses and studies of groundwater, construction materials, subsurface explorations and laboratory testing. However, it should be noted that a subsurface exploration and testing program of much greater magnitude along with more detailed geotechnical analyses will be necessary for feature design memorandum studies. Full details are in Appendix E - Geotechnical.

7.4.1 General Geology A substantial amount of exploration is needed to assure that a project of this magnitude is compatible with the geological conditions expected along the 21.7 miles of tunneling, and other works. For this General Design Memorandum, over 40,000 linear feet of borings were made for tunnel design including almost 34,000 linear feet of rock coring. Prior to preparation of plans and specifications, another 40,000 to 80,000 linear feet of borings are planned. The more detailed the explorations, the less risk of injury there will be to construction personnel. At the heart of the exploration program is the need to assure that the location and definition of all buried valleys that may exist along the tunnel alignment have been determined. For the tunnel boring machine (TBM) to encounter unconsolidated soil deposits in a buried valley will be unacceptably hazardous and costly.

7.4.2 Groundwater Studies. A comprehensive groundwater study was performed because of the importance of the potential impact of tunnel construction on groundwater resources. The study results will be the basis for follow-on design studies of the various project elements over the implementation stage of the project. Quantitative studies were made for the tunnels and Great Piece Meadows and qualitative evaluations were made for other project features. Groundwater conditions were observed by means of a boring program, as part of which some borings were converted to observation wells that allow monthly measurements to be made.

A hydrogeologic investigation was performed along the alignment of the tunnel elements. The purpose of the investigation was to estimate the potential effects of groundwater on tunnel design, and the effects of tunnel construction and operation on the regional groundwater conditions. Six field pumping tests were performed at shaft locations and groundwater modeling was performed for seven areas along the tunnel alignment. The objectives were to:

be 3,000 psi. The concrete liners will have no expansion joints due to the interlocking strength of the concrete liner and the rough rock surface.

7.5.2 Tunnel Shafts. Eleven shafts will serve as air vents and/or maintenance and equipment access ways to the tunnel. During construction, five shafts will serve as TBM access and muck removal points. After construction, one shaft at Kearny Point will serve as a housing for a pump station for the tunnel. The shafts will vary in diameter from 12 to 45 feet with their liner thicknesses varying from 12 to 24 inches. Compressive strength of the concrete will vary from 3,000 to 4,500 psi. It was assumed that the rock surrounding the shafts would be self-supporting thereby transmitting no load to the concrete shaft liner. The hydrostatic and soil pressure, which increase with depth, determined the sizing of the concrete shaft walls and liners.

7.5.3 Pompton (Main) Inlet. This component of the project includes a variety of structural elements. The inlet will be radial and consist of a concrete spillway with 11 hydraulic lift gates attached to reinforced concrete piers supported on H-piles to resist horizontal and vertical loads. The piers will also support gate-lifting equipment and a maintenance bridge, and provide guideways for gates and maintenance bulkheads. An unregulated weir and chute floor will control flow into the tunnel. Tie-back, rock anchored basin walls and pile founded T-Walls surrounding the inlet will serve to retain exterior soil and groundwater pressures. The design of each structural element was based on combinations of headwater and tailwater elevations and forces induced by earthquakes, uplift and ice. The concrete compressive strength will be 3,000 psi and the structural steel will conform to ASTM A36 steel.

Eleven 60-foot wide vertical lift gates will be located over each spillway section to control the flood flow. Each gate will be operated hydraulically, and consist of a skin plate and four wide flange beams designed to resist water pressure as well as ice pressure. Each gate will weigh approximately 63,000 pounds.

The unregulated weir will be a concrete gravity structure that would control the inflow to the tunnel. It was designed to resist uplift, lateral water and earthquake pressures, and vibrations caused by a sudden flood discharge. The chute floor is located below the unregulated weir and provides a smooth transition into the tunnel. Drain holes tying into drain pipes running radially behind the chute floor will serve to minimize water pressure thus reducing uplift forces on the chute floor and the instability of rock wedges and joint blocks.

- Evaluate existing groundwater conditions along the length of the tunnels.

- Evaluate potential seepage into the tunnel during and after construction.

- Estimate the drawdown in local aquifers and nearby water wells.

- Assess the potential for contaminants to accumulate as a result of tunnel construction.

The groundwater modeling indicates that drawdown of groundwater in shallow overburden areas is not expected along the tunnel alignment as a result of tunnel construction or operation. Many bedrock wells are located within 5,000 feet of the tunnel along the southern end of its route. They could experience drawdowns ranging from 10 to 50 feet during construction. After construction is complete, well drawdowns due to tunnel seepage will be significantly reduced by grouting and tunnel lining. The lower tunnel will operate in a wet condition, so that long-term well drawdown will not exist. Thereafter, the wells will only be affected to a lesser degree for short periods during dewatering and maintenance activities.

The groundwater studies provided the basis for developing a procedure to limit seepage into the tunnel to acceptable levels during and after construction. Reduction of seepage will be accomplished by cement grouting and concrete liner placement. Grouting ahead of the tunnel boring machine will be performed in the most pervious rock zones, determined by probe holes drilled radially and ahead of the TBM. After placement of the tunnel liner, grouting will again be performed to fill any voids between the liner and the rock. These grouting and liner procedures will minimize groundwater drawdowns. It estimated that long term steady state seepage into the fully grouted and concrete lined tunnel will be on the order of 1,000 to 2,000 gallons per minute (gpm) or similar to the discharge from single high capacity municipal or commercial wells. Since drawdown in overburden aquifers will be negligible, no damaging settlement of structures above the tunnel is expected. During excavation of the tunnel shafts through the overburden soils, slurry/concrete walls or freeze walls will be used to control seepage.

7.4.3 Tunnels The preconstruction engineering and design phase exploration program, while designed primarily for the tunnels, also provided information for shafts, inlets and outlet. In rock, the coring and pressure permeability testing was performed in all boreholes, and video surveys and geophysical testing were performed in selected boreholes. In the overburden, split spoon and undisturbed sampling were performed in selected borings. For the geotechnical exploration a total of 119 borings have been drilled for the main tunnel and 10 for the spur tunnel.

The geology of the tunnel route was analyzed as to its suitability for tunnel construction and the associated inlets and shafts. The need to drive the tunnel through competent rock was considered a basic requirement for the alignment of the tunnels. Information for the entire route of both tunnels was obtained. Areas of weakness such as buried valleys and discontinuities were identified and considered in the design.

A laboratory rock and soils testing program was conducted to determine the significant design characteristics of the tunnel route such as compressive strength of soil and rock. Design parameters were selected and stability analyses performed.

With regard to construction, alternative ways to construct the tunnel were considered including conventional excavation procedures using drilling and blasting techniques. It was concluded that a tunnel boring machine is the most economical approach for construction of the tunnel. TBMs have been used to bore 40' diameter tunnels in Europe and it has been determined to be well within the ability of manufacturers to produce TBMs to bore the proposed 44-1/2 foot diameter tunnel. Geologic conditions along the tunnel alignment are considered to be suitable for use of a TBM, which has high productivity, requires little temporary support, and minimizes concrete lining. It is expected that several TBM's will be required to work concurrently in view of the size of the project.

The muck produced by the TBM will have to be removed to a place of disposal. It is probable that a horizontal tunnel and vertical shaft conveyor system will be used in conjunction with the TBM-driven tunnel for muck removal. The tunnel muck will be transported to the disposal sites either by train, barge or truck. The disposal of the tunnel muck is not expected to be a problem as there is known to be interest in using it as engineered fill and quarry owners have expressed interest in obtaining this material for quarry fill.

7.4.4. Shafts The project provides for 11 shafts serving varying purposes such as muck removal, dewatering, personnel and equipment access, concrete placement and ventilation, as described in Section 5 - Project Description. Subsurface explorations were conducted for each shaft. Structural support for shaft excavation through the overburden soils will be provided by slurry/concrete or freeze walls. Rock support for the shafts will be provided by resin encapsulated rock bolts, where necessary. For added protection from rock falls, welded wire mesh will be used between the bolts as determined by the size of the shafts.

7.4.5 Inlets The geotechnical design for the Pompton Inlet was based on foundation design and settlement, excavation, water and seepage control. Design features include:

- Control of surface water and groundwater by a cellular sheet pile cofferdam and sheet pile wall.

- A large diameter slurry/concrete wall for advancing the shaft through the overburden. Backfilling of excavations with structural concrete to create its semi-cone shape.

- Founding of the gate structure and access basin on H-piles.

- A concrete wall will be utilized for the back retaining wall, incorporated into the back portion of the structure and tied into rock.

- A 15-foot diameter air vent located 200 feet along the alignment of the tunnel.

The Passaic Inlet is similar to the Pompton Inlet except that it is smaller and has a straight control weir instead of a circular one. The Passaic Inlet design includes:

- Control of surface water and groundwater by a combination slurry wall and berm around the structure excavation.

- Use of a large diameter slurry/concrete wall for semi-cone shaft excavation and construction.

- Founding of the gate structure and access basin on H-piles.

- A tied back retaining wall.

- A 12-foot diameter air vent located 200 feet along the alignment of the tunnel.

7.4.6 Fairfield Road Bridge and Passaic Inlet Approach Channel. The geotechnical design features associated with the bridge and the approach channel generally include: anchored sheetpile retaining walls to support the bridge approach roadway embankments; the approach roadway embankment and new pavement section, pile foundations for the bridge abutment and piers, anchored sheetpile retaining walls to support inlet approach channel walls, and the temporary road to allow Fairfield Road to remain open during construction.

The bridge will be a multi-span reinforced concrete structure. The superstructure will be supported by abutments and piers constructed within braced sheetpile excavations and founded on H-piles driven in to the dense natural glacial soils or to the underlying bedrock. The Passaic Inlet approach channel will be rectangular in shape and 300 feet wide. It will be lined with stone and riprap and be supported by vertical anchored sheetpiling. The anchoring system will be a series of tie-rods connected to continuous concrete deadmen embedded in the natural soil.

7.4.7 Tunnel Outlet. The exploration program, conducted from a floating platform in Newark Bay, involved drilling and sampling, borehole geophysical investigations and a pumping test to observe hydrogeology. The outlet structure will be of reinforced concrete with three vertical lift gates. The significant geotechnical design features are as follows:

- Construction of a circular sheet pile cofferdam around the inlet shaft. After the cofferdam is filled with sand, a freeze wall will be constructed to advance the shaft excavation into rock.

- The reinforced concrete gate structure will be constructed concurrently offsite in a dry dock.

- A concrete shaft liner will be placed and keyed into rock. The freeze wall will thaw and the cofferdam will be removed. The site will be excavated for the structure and outlet channel and then a pile foundation driven under water.

- The gate structure will be floated in and sunk into position onto leveling pads. A sheet pile skirt will be driven around the structure and grout injected for connection to the pile foundation.

7.4.8 Great Piece Weir. The site geology was derived from the boring programs conducted in the vicinity of the site. Laboratory soil testing was performed on selected samples. Appropriate soil design parameters were selected for geotechnical design based on the laboratory soil testing and the standard penetration test blow counts from the borings. The weir will be constructed in the existing Passaic River channel using a two-stage cellular sheetpile cofferdam. The gate structure and wing walls will be founded on steel pipe piles driven to refusal in glacial till or rock.

7.4.9 Pequannock Weir. Subsurface explorations were performed at the site of the weir and soil parameters were based on the standard penetration blow counts. The weir will be constructed in a new channel adjacent to the existing Pequannock River channel and weir. An earthen cofferdam will surround the excavation and a slurry wall will be utilized to control seepage into the excavation. A pile foundation was selected for the gated weir and the four adjoining wing walls to provide adequate bearing capacity, sliding stability, and erosion resistance. Levees, required to provide closure between the new weir and high ground to the west and the existing weir to the east, will be constructed of semi-pervious material with riprap armoring on the upstream face.

7.4.10 Tidal Area Protection. For each of the three tidal protection systems, consisting of over 11,000 linear feet of levee and 57,000 linear feet of floodwall, studies included a limited boring and laboratory testing program, development of design parameters, and geotechnical analyses. Subsurface soil conditions at all three system areas are generally considered as poor for support of levees or floodwalls. The soft organic and laucustrine soil deposits affect stability for levees and require pile support for floodwalls. Accordingly, levees, with side slopes of one vertical to three horizontal and a-10 foot crown, are located in areas where adequate land is available along the waterfront for stability; floodwalls are used where space is constrained by existing structures or utilities along the river; floodwalls comprise 84% of the tidal area protection. For stability, the river side toe of levees must be at least 80 feet from the edge of any existing bulkhead structure, and at least 30 feet from the top edge of banks without bulkheads or other structures. Fill material will be obtained either from commercial sources or from tunnel excavation. Floodwalls will generally consist of continuous cantilever PZ-27 steel sheetpiling with a reinforced concrete cap. The sheet piling will penetrate the ground to a depth at least three times the wall height, with a minimum depth of 10 feet. In isolated areas, box pile and cellular sheetpile floodwalls will also be used. In all instances where existing embankments or walls are used as part of levee and floodwall systems, Corps of Engineers criteria will be applied during feature design memorandum studies to assure stability.

7.4.11 Central Basin Protection. The levee and floodwall designs in the Central Basin are similar to those described under paragraph 7.4.10. Geotechnical analyses were performed on the Central Basin elements using limited existing subsurface information. No soil or rock testing was performed for the Central Basin elements. Additional borings will be made as part of the follow-on engineering and design phases.

7.4.12 Pequannock/Ramapo Levee/Floodwall and Channel System. Studies included a design of the levee and floodwall structures, a soil analysis to evaluate existing site conditions based on limited existing boring data, and a check on seepage and slope stability. Levees will have a 10-foot crown with side slopes of one vertical to three horizontal. One alternative for levee fill is to utilize the tunnel muck in conjunction with a river side clay blanket to limit through seepage. It was determined that one vertical to two and one-half horizontal channel slopes are adequate based on low water and sudden drawdown analyses.

7.4.13 Passaic River Levee System #10. This system is scheduled to be the first element of the plan constructed. Therefore, a detailed geotechnical design was performed as a basis for preparation of plans and specifications. All required subsurface investigations and laboratory soils testing were performed. Appendix J - Feature Design Memorandum contains full details. The levee will generally have one vertical on three horizontal side slopes, a 10-foot wide crown, and will be constructed of on-site borrow.

7.5 STRUCTURAL

A preliminary type structural design was performed for each project feature to ensure a reasonably sound cost estimate. In general, external project stability was analyzed but detailed design such as that necessary to design reinforcing steel and connections was not performed. All elements of the project were designed on the basis of sound engineering practice and design principles and in accordance with Corps of Engineers design manuals for each type of structure. Additional details on each structural element are located in Appendix G - Structural.

7.5.1 Tunnel Liners. Design of the 42-foot diameter main tunnel and the 23-foot spur tunnel considered both rock and hydrostatic loads. The rock surrounding the tunnels will be self-supporting thereby transmitting no load to the concrete tunnel liner; thus, the concrete liner was designed to withstand full hydrostatic pressure. Since the tunnels will be driven by tunnel boring machines, varying the liner thickness will not be possible. Therefore, the liner will be held constant at 15 inches. The only variable in the liner design is the compressive strength of the concrete; for the main tunnel it will vary from 3,000 pounds per square inch (psi) to 6,500 psi, and for the spur tunnel it will

The approach channel wall will be a reinforced concrete T-wall supported by H-piles driven to refusal, and designed to resist overturning and sliding forces exerted by floods and the surrounding soil. The design considered a range of flooding and soil conditions. The basin wall is a reinforced concrete L-shaped wall with counterforts and tie-back rods, and will rest on rock and be as high as 66 feet above the rock. High strength rods grouted into rock will resist soil and water pressure applied behind the wall. The counterforts will resist water pressure applied in front of the wall. A rock-anchored basin wall, one foot thick, will lie just under the tie-back basin wall with drain holes installed behind the wall to reduce water pressure.

Three maintenance bulkheads consisting of two girders and a skin plate were designed to resist water pressure on its skin plate face and will weigh approximately 20,000 pounds each. The maintenance bridge will be built for access and inspection and to allow for a crane to install and remove the maintenance bulkheads. The bridge will consist of three 4-foot by 4-foot prestressed concrete box girders, supporting a reinforced concrete deck and steel guardrail.

Electrical and mechanical systems to operate the gates and support equipment will be located at the Pompton Inlet. The gates could be controlled locally on-site or from the Operations Center at Workshaft 2.

7.5.4 Passaic (Spur) Inlet. This component of the project will also include a variety of structural elements similar to that of the Main Inlet. The inlet will consist of a straight spillway regulated with five hydraulic lift gates attached to reinforced concrete piers, a basin floor, an unregulated weir, and a sloped chute floor which leads into the tunnel. The spillway will be of reinforced concrete supported by H-piles driven to refusal to resist horizontal and vertical loads. The piers will also support the gate-lifting equipment, a maintenance bridge and provide guide ways for gates and maintenance bulkheads. The design of each structural element was based on combinations of headwater and tailwater elevations and forces induced by earthquakes, uplift and ice. The concrete compressive strength will be 3,000 psi and the structural steel will conform to ASTM A36 steel.

Five 50-foot wide vertical lift gates will be located over each spillway section to control the flood flow. Each gate will be operated hydraulically, and consist of a skin plate and four wide flange beams designed to resist water pressure as well as ice pressure. Each gate will weigh approximately 45,000 pounds.

The unregulated weir is a concrete gravity structure that will control the inflow to the tunnel. It was designed to resist uplift, lateral water and earthquake pressures, and vibrations caused by a sudden flood discharge. The chute floor is located below the unregulated weir and provides a smooth transition into the tunnel. Drain holes tying into drain pipes running radially behind the chute floor will minimize water pressure thus reducing uplift forces on the chute floor and the instability of rock wedges and joint blocks.

The approach channel wall is a 28-foot high reinforced concrete T-wall supported by H-piles driven to refusal, which are designed to resist overturning and sliding forces exerted by floods and the surrounding soil. The design considered a range of flooding and soil conditions. The basin wall is a reinforced concrete L-shaped wall with counterforts and tie-back rods, and will rest on rock and be as high as 67 feet above the rock. High strength rods grouted into rock will resist soil and water pressure applied behind the wall. The counterforts will resist water pressure applied in front of the wall. A rock-anchored basin wall, one foot thick, will lie just under the tie-back basin wall with drain holes installed behind the wall to reduce water pressure.

Three maintenance bulkheads consisting of two girders and a skin plate were designed to resist water pressure on its skin plate face and will weigh approximately 17,000 pounds each. The maintenance bridge will be built for access and inspection purposes and to allow for a crane to install and remove the maintenance bulkheads. The bridge will consist of three 4-foot by 4-foot prestressed concrete box girders, supporting a reinforced concrete deck and steel guardrail.

Electrical and mechanical systems to operate the gates and support equipment will be located at the Passaic Inlet. The gates could be controlled locally on-site or from the Operations Center at Workshaft 2.

7.5.5 Newark Bay Outlet. Located 1,850 feet south of Kearny Point, in Newark Bay, the outlet will consist of pile supported reinforced concrete structure with three vertical hydraulic lift gates to regulate flow from the vertical tunnel outlet shaft. The outlet structure will be built off-site and floated into position over the vertical outlet shaft and pile supports. Allowable unit compressive strength of reinforced concrete will be 4,000 psi and the specified yield strength of reinforcement steel will be 60,000 psi. Structural steel will have a yield strength of 36,000 psi and conform to ASTM A36.

Flow from the outlet will be controlled by three steel-framed gates, each having a continuous steel skin plate. Each gate will be 26 feet wide and 30 feet high with a 25-foot opening height from the gate sill elevation of -20 feet, and will be operated by two hydraulic cylinders. Each gate was designed to withstand a 30-foot hydrostatic load from the bay side with the interior dry, and a maximum interior water elevation and low tide bay water elevation. The design of the foundation was based on a range of conditions that would be encountered during construction, operation, storms, floods and earthquakes.

Electrical and mechanical systems to operate the gates and support equipment will be located at the Newark Bay Outlet. The gates could be controlled locally on-site or from the Operations Center at Workshaft 2.

7.5.6 Fairfield Road Bridge. The Fairfield Road Bridge will be built approximately 200 feet upstream of the Passaic Inlet to replace the existing roadway and to allow for Fairfield Road to cross over the 300-foot wide Passaic Inlet approach channel. It will serve to ensure project integrity during flood events by minimizing the obstruction to river flow while providing continuous local access to the surrounding areas.

The bridge consists of five simply supported spans, each approximately 85 feet long to produce a total length of 430 feet between abutment backwalls. The bridge will support a 40-foot wide two-lane roadway on a reinforced concrete deck slab supported by prestressed concrete I-beams set on reinforced concrete piers and abutments founded on H-Piles. The bridge will also support a 60-inch diameter aqueduct line set on prestressed concrete I-beams adjacent to the deck slab. As part of the bridge construction, I-wall retaining walls will channel floodwaters to the Passaic Inlet after it passes under the bridge. The bridge was designed in accordance with current American Association of State Highway and Transportation Officials (AASHTO) and New Jersey Department of Transportation (NJDOT) criteria.

7.5.7 Great Piece Weir. This weir, located downstream of the Great Piece Meadows in the Central Basin Area, will be built to prevent upstream headcutting, minimize erosion potential and to maintain the existing upstream wetland habitat. The weir includes five 30-foot wide torque tube bascule gates resting on a gate sills 6 feet above the Passaic River bottom; an operating deck supported by the weir abutments and four 10-foot wide intermediate piers; and a short access driveway. Wingwalls will retain the embankments of river adjacent to the weir. The abutments and piers are set on a reinforced concrete continuous slab founded on concrete-filled steel pipe piles. The design of the foundation was based on a range of conditions including construction, normal and flood flow, and maintenance.

Electrical and mechanical systems to operate the gates and support equipment will be located at the Great Piece Weir. The gates could be controlled locally on-site or from the Operations Center at Workshaft 2.

7.5.8 Pequannock Weir. The Pequannock Weir will be located in a new channel just southwest of an existing weir. The existing weir is located on the Pequannock River at its confluence with the Ramapo River in Pompton Plains New Jersey. A new channel will be constructed just to the west of the Pequannock River to provide sufficient capacity to pass flood flow efficiently. The new Pequannock Weir has two functions. During flood conditions, the new weir would reduce damaging flood elevations upstream and permit the bypass of flows around the Old Morris Canal Feeder Dam. During normal conditions (approximately 97% of the time) it would preserve the existing wetlands by maintaining the water levels that exist today.

The weir consists of a concrete monolith footing founded on a timber pile foundation. The footing will support four spillway sections with tainter gates set between five piers, and a maintenance access bridge with three 8-foot deep girders spaced at eight feet supporting a 20-foot wide reinforced concrete deck. A wheeled 45-ton crane will be stored on the bridge for maintenance purposes and to install stoplogs. Critical load cases for the foundation and tainter gates were analyzed including 100-year flood flow, ice loading, gate lifting, earthquake, and cable break.

Electrical and mechanical systems to operate the gates and support equipment will be located at the Pequannock Weir. The gates could be controlled locally on-site or from the Operations Center at Workshaft 2.

7.5.9 Tidal Area Protection Floodwalls. As part of the authorized project, three levee/floodwall systems will be required to protect existing industrial areas along the Passaic and Hackensack Rivers from tidal flooding near the Newark Bay. The systems include approximately 57,128 feet of floodwall. Floodwalls were chosen at locations where space constraints prevented the use of levees and where it was desirable to minimize disturbance to suspected hazardous, toxic and radioactive waste sites. Standard Corps I-wall sheet pile floodwalls will be located at the top of the riverbanks, box pile I-wall floodwalls will be constructed in the river where existing structures are located in close proximity to the river's edge, and cellular cofferdam structures will be built at the Kearny Point system to close off two abandoned boat basins along the right bank of the Hackensack River. Specified design stresses will be 3,000 psi for concrete, 60,000 psi for reinforcement steel and 38,500 psi for steel sheet piling.

7.5.10 Central Basin and Pompton River Floodwalls. As part of the authorized project, approximately 13,630 feet of floodwall will be required as part of six levee/floodwall systems to protect existing commercial and residential properties from flooding along the Passaic, Rockaway, and Ramapo Rivers. All of the Central Basin and Pompton River floodwalls will be standard Corps I-walls consisting of a steel sheet pile foundation with a reinforced concrete cast-in-place cap. I-Wall floodwalls were chosen where space constraints limited the use of a levee.

The design of Rockaway #1 and #3, Pinch Brook, and Passaic #2A floodwalls was performed using the conventional method. The design of the Pequannock/Ramapo floodwall was performed using the Corps engineering manuals and computer design programs. All sheet piles will be standard regular carbon grade steel with a specified design bending stress of 38,500 psi. The reinforced concrete cap will consist of 3,000 psi concrete and grade 60 steel reinforcement.

7.5.11 Passaic #10 Floodwall. The Passaic #10 Levee/Floodwall System will protect several industrial properties in Livingston Township from flooding. As part of the system, a 10-foot closure wall with adjoining I-Wall floodwalls transitioning into the adjacent levees will maintain the line of protection across the alignment of an existing exposed 52-inch diameter sanitary sewer line. The design was based on Corps engineering manuals and computer design programs. As this project element would be the first constructed, complete design details are provided in Appendix J - Passaic #10 Feature Design Memorandum.

7.5.12 Closure Structures. Closure structures will be needed at several locations along the Tidal Area Protection levee/floodwall systems and Central Basin and Pompton River levee/floodwall systems. Several types of gates were studied and swing gates were selected because of their economy, simplicity of making the closure, and mechanical reliability. The swing gates will be supported by top and bottom hinges attached on one side to a reinforced concrete vertical support member tied into a footing founded on timber piles. The gates will be closed by latches attached to the supporting structure on the opposite side of the opening. Two types of closure structures are presented with varying closure widths, a pedestrian/vehicular and railroad closure. The gates and foundation were designed to resist maximum hydrostatic pressures from a 100-year flood. Design of the gates was performed in accordance with Corps of Engineer design manual on load and resistance factor design criteria for local protection project closure gates.

7.5.13 Pumping Stations. Pumping stations behind levees and floodwalls of the Tidal Area Protection levee/floodwall systems will be needed to remove storm runoff from the protected areas. Conceptual drawings for six pump stations were developed. Wall and floor slab thicknesses were computed and the flotation stability of each station was determined. The pump stations are essentially large concrete box structures constructed in the ground housing pumps to remove interior drainage from the protected areas. Bearing and rotation calculations were performed treating the pump stations as spread footings. The thicknesses of walls and floor slabs were designed to resist full hydrostatic pressure when the pump station is empty.

7.6 HAZARDOUS, TOXIC AND RADIOACTIVE WASTE

Investigations were conducted to determine the potential effects of existing hazardous, toxic and radioactive waste contamination on construction and operation of the project and the potential effects of the project on existing HTRW contamination. All project elements were investigated including the main and spur tunnels and associated inlets, shafts, river channel modifications, weirs, levees and floodwalls.

Field investigations were conducted at the tunnel inlet and outlet locations, at several proposed shaft locations, and at one proposed levee location. Environmental records were also searched to identify HTRW sites in the vicinity of each project element. Based on the field investigations and records search data, qualitative analyses were performed to determine occupational exposure to risk from contaminated soil, groundwater or surface water generated during construction activities. Alternatively, the potential risk of adverse effects of construction activities on existing contamination were also assessed. In addition, the collected data were compared to the regulatory criteria established by the United States Environmental Protection Agency (USEPA) and the New Jersey Department of Environmental Protection (NJDEP). Response alternatives were evaluated based on these criteria. The alternatives addressed whether soils to be excavated or groundwater to be pumped during construction or operation will require special handling due to the presence of contaminants.

Special handling for soils includes disposal or beneficial reuse; special handling for pumped groundwater includes removal of contaminants prior to its discharge to surface water. Conservative cost estimates for special handling of excavated soil and discharged groundwater, and for additional investigations where current data are incomplete, were developed for each feature.

In summary, there are proposed project features that may impact or be impacted by the presence of HTRW. There are several sites where further intrusive investigations are required. The total cost of construction and investigation for remediation of HTRW impact for the flood damage reduction project is estimated at about $29,000,000 of which $1,900,000 are for additional investigations. As discussed in Section 14 - Implementation, any project costs that are incurred as a result of the presence of HTRW contamination are the responsibility of the local sponsor. Full details on HTRW considerations are provided in Appendix F - Hazardous, Toxic and Radioactive Waste.

7.7 COST ENGINEERING

Each component of the project was engineered to assure the minimum cost of construction consistent with project effectiveness, reliability and safety. Alternative means of accomplishing the objectives of each component were considered. The project cost estimate was further minimized by providing for effective management and timing of each project element throughout the construction phase. The overall cost estimate is comprised of 36 individual M-CACES[2] estimates, all of which are included in Appendix D - Cost Engineering. Cost engineering for levees, floodwalls, channel modifications, weirs and pumping facilities was in accordance with standard Corps of Engineers manuals for such works. For the tunnel system components, special cost engineering studies were performed.

7.7.1 Main Tunnel. Several factors influenced the selection of the main tunnel's location. The availability of work shaft locations and proximity to roads and railroads suited to the transportation of the tunnel muck was critical in this highly urbanized area. Another important consideration was the minimization of the length of tunnel that had to be driven through rock. Curves in the tunnel alignment had to be limited to a minimum radius of 1,500 feet to accommodate the maneuverability of the tunnel boring machine. The need to avoid deep buried valleys in the lower portion of the tunnel resulted in the lowering of the tunnel invert to elevation -409 feet,

[2]Microcomputer-Aided Cost Engineering System

N.G.V.D. A minimum of one tunnel diameter of sound rock above the crown of the tunnel was allowed to ensure that there will be an adequate thickness of sound rock over the tunnel crown. To facilitate dewatering, a low point was provided at work shaft 2C. Four separate contracts will be required for the construction of the tunnel by three tunnel boring machines, as follows:

Contract A	From the outlet to workshaft 2B
Contract B	From workshaft 2B to hook hole shaft 5
Contract C	Between workshaft 5 and hook hole, workshaft 3
Contract D	From Pompton Inlet to Workshaft 3

The spur tunnel will be built under a separate Contract E. Its alignment is the shortest distance between the Passaic Inlet and the main tunnel that will accommodate the construction of a work shaft.

7.7.2 Shafts. Cost engineering performed for each shaft reflects the specific conditions and requirements at each location, such as tunnel boring machine access, clearing of trees, switchyard to facilitate rail transportation of muck, security fencing, and protection of drainage courses. Work shaft 2, will be provided with facilities consistent with its use as a master control center for the entire tunnel system.

7.7.3 Inlet and Outlet Structures. The Pompton Inlet will be used as work shaft for muck removal during the tunnel construction period. The Passaic Inlet will be used to remove the tunnel boring machine after the tunnel excavation. The Newark Bay Outlet will be a single purpose structure having no additional use during the tunnel construction period.

7.7.4 Tunnel Boring Machine. The use of tunnel boring machines for tunnel excavation was selected because of their high production, low level of required temporary support, and reduced concrete lining as the result of reduced overbreak.

7.7.5 Materials. An investigation was performed to determine commercial sources of materials required for construction including concrete tunnel lining, inlet and outlet structures, weirs, floodwalls, levees and embankments. The purpose of the investigation was to determine probable availability and cost of: ready-mix concrete, portland cement, concrete aggregates, fly ash, riprap, graded stone, earth borrow and clay, steel, sheet piling, H-piles and reinforcing steel. Estimated required quantities are about 950,000 cubic yards of ready-mixed concrete, 300,000 cubic yards of earth fill, 200,000 lineal feet of steel H-piles, 900,000 square feet of steel sheet piles, 90,000 cubic yards of riprap and graded stone and 50,000 tons of reinforcing steel. All materials were found to be locally available over the construction period. Appendix E - Geotechnical, summarizes the results of the study.

7.7.6 Disposal of Excavated Materials. Construction of the project will produce significant quantities of soil and rock that require disposal. A study was made on the character, transportation and disposal of material excavated during construction of the main tunnel, spur tunnel, shafts, inlet and outlet structures and channel excavations. Considered were quantity and nature of the materials, possible means of on-site disposal, potential disposal sites, HTRW factors and the economics of disposal. The total amount of material excavated for these works is about 10,000,000 cubic yards (loose measure) of rock and 2,000,000 cubic yards (loose measure) of soil.

The following conclusions and recommendations resulted from the study:

- Adequate capacity exists for the disposal of anticipated quantities of excavated materials at sites generally within 10 miles of the production shafts.

- Highway, rail and water routes are available within the project area. Highways, however, appear to have the lowest capital costs of the three modes of transportation.

- Prospective recipients have been found who are willing to accept excavated materials at no cost, but not to compensate for it.

- Environmentally, it might be more acceptable to use railway transportation to minimize effects on air, noise and transportation.

- There is a strong likelihood of HTRW contamination at shafts 2B, 2C, and 3 and that contaminated sediment may be encountered during construction of the outlet. In accordance with NJDEP guidelines, some contaminated materials that are excavated may be reused on site.

7.8 PROJECT SECURITY

Although the project involves no classified information or related facilities, the design calls for security measures to protect against vandalism and terrorist acts. Structures will be secured by the use of fencing, signs, lighting and alarm systems. Equipment will be set up to prevent unauthorized operation of the gates. Specific measures will be presented in the plans and specifications. Provisions will also be made to provide safety features protecting the general public from potentially unsafe or dangerous conditions.

MAIN REPORT

SECTION 8

ENVIRONMENTAL ANALYSIS

8. ENVIRONMENTAL ANALYSIS

8.1 OVERVIEW

This section covers environmental effects and environmental design aspects. Extensive studies of environmental resources in the basin were conducted for the Phase I General Design Memorandum. Because that document was prepared to establish feasibility it did not comprehensively treat environmental design factors. For implementation purposes, additional studies have been done to assure that each aspect of the project responds to the principles of good environmental design. Additional effort has also been applied to identifying and addressing the environmental impacts of the project and mitigating them as fully as possible. Full details are described in Appendix B - Environmental Resources. In addition, the Final Supplemental Environmental Impact Statement (SEIS) accompanies this report.

8.2 ENVIRONMENTAL EFFECTS

The natural environment affected by the project is limited to the Central Basin and the tunnel outlet area. As noted in Section 4, there are three distinct hydrologic regions, the Highland Area, the Central Basin and the Lower Valley. At present about 14% of the Central basin is recognized as wetlands, but the basin continues to develop although it remains basically suburban. The project's effects on fish and wildlife are related to aquatic and terrestrial changes. Most of the impacts are associated with construction and will be temporary, but some effects of a more enduring nature will occur and will be mitigated. Environmental effects of the project are comprehensively addressed in the Supplemental Environmental Impact Statement; summarized below are those impacts that are of most significance.

8.2.1 Newark Bay The freshwater outflows from the tunnel will be received by Newark Bay, which is about 5.7 miles long, 0.75 mile wide, and 3,200 acres in area. It has two distinct depths; shallows ranging from 0.5 to 11 feet at mean low water, and dredged ship channels of depths ranging up to 30 feet and covering an area of about 750 acres. Newark Bay is surrounded primarily by industrial and commercial development but some residential development as well. Virtually all of the shoreline has been impacted by bulkheading or riprap so that the extent of natural shore line is limited. Some of the industries located on the bay produce or handle materials that are suspected of being toxic. Biological sampling was performed as a result of agreement between the Corps of Engineers and the National Marine Fisheries Service. Positive as well as negative effects will result from the project based on the following facts.

- The amount of water entering Newark Bay will be the same but the timing of its entry will be different. This condition is expected to create minor short term changes in the Bay's water quality in the immediate vicinity of the outlet.

- The floodwaters entering Newark Bay will be cleaner than at present or in the future without the project. This condition is expected to reduce pollution entering the Bay.

- The tunnel will be mostly full of water between flood events. Discharge of this stored water is expected to create temporary degradation of dissolved oxygen levels in the immediate vicinity of the tunnel outlet due to the fact that stored tunnel water would become anoxic with time.

The total impact is expected to be insignificant. The resulting drop in salinity due to the rapid inflow of fresh water, will rarely exceed 24 hours in duration and will be similar in effect to what occurs in the without project conditions. Other impacts may occur as a result of: Changes in the chemical and physical properties of the floodwaters; the extent to which floodwaters remain in the tunnel before the next flood; disturbances of bottom sediment; and changes in water temperature.

Positive effects of the tunnel include reduction of pollutants entering the river during floods. The tunnel relieves this problem for all but the most severe flood events.

8.2.2 Wetlands. The loss of habitat near the remaining freshwater wetlands in the Central Basin is expected to continue with the project in place. However the project includes features to mitigate project-related losses.

The Central Basin contains about 24,000 acres of wetlands of which 13,700 are within the project area. The project will cause direct loss of 95 acres of wetlands as a result of levees and sideslopes associated with channel modifications.

The basic means used to quantify wetland impacts and to formulate a mitigation plan was the Habitat Evaluation Procedure (HEP) developed by the United States Fish and Wildlife Service, (USFWS). The species guilding concept was employed with HEP to choose species to be used. Other species, not chosen for HEP, but within the same habitat, were also considered during mitigation planning. The goal of mitigation was to offset all adverse impacts where they cannot be avoided. Where possible, alternative mitigation measures were considered at the areas directly affected by the project works. If that could not be done, off-site alternatives were considered such as wetlands creation and land restoration, regrading of land, restoration and habitat improvement.

8.2.3 Aquatic Resources Aquatic impacts will vary within specific reaches on the individual streams. Impacts will include some loss of shade, increased water temperatures and decreased dissolved oxygen. Effects on the aquatic biota will be greatest in areas where the physical measures will be placed. The Pequannock, Wanaque, and Ramapo River complex, where channel modifications and a levee/floodwall system will be provided, will be the resources most affected by the tunnel system. These areas contain the highest diversities of fish and benthic invertebrate species. The combination of greatest instream and bank manipulation in the area of the greatest diversity will cause the greatest impact on the aquatic environment.

The types of effects include: (1) reconfiguration of the stream morphology; (2) elimination of substantial tree shade and, therefore, an increase in water temperature coupled with a decrease in dissolved oxygen; (3) removal of aquatic flora and fauna during construction; and (4) entrainment increases as a result of adaption of the Pequannock Weir to direct flows to the main inlet and; (5) loss of riffle/run species.

Anadromous fish are found in limited numbers in Newark Bay and the Lower Passaic River. Generally, they spawn in April and May, seeking low salinity or fresh waters. Offspring reside in the river from May until September. They will not be affected by the project for the majority of the year. The effects of tunnel operation in April and May are expected to be minimal because operations mimic natural conditions.

8.2.4 Wildlife. The project's primary impacts on wildlife will be due to the loss of wetland habitat mostly by the placement of levees in the Central Basin. Some of these areas have already declined in value because of activities of man. A total of 95 acres of wetland habitat will be adversely affected or lost by project construction.

8.2.5 Endangered Species. A review of the project area was conducted in consultation with the USFWS, NMFS, and their state counterparts, in accord with the requirements of the Endangered Species Act. No species on the Federal endangered list will be adversely affected by the project based on the latest consultation with the Federal agencies concerned, as reported by Federal law (Section 7). Most species on the state list, especially those in the Great Piece Meadows, are likely to be beneficially affected due to lowering of maximum floodwater depth. Continued monitoring and sighting will alert the Corps to any need for follow-up action that may be required as part of the project. The National Marine Fisheries Service advised that the project will not affect endangered species under its jurisdiction. Recent sightings of endangered species were indicated in the summer of 1995, raising a concern to be addressed in future studies.

8.2.6 Groundwater. It is not expected that construction or operation of the tunnel or other project features will have a significant impact on groundwater quality. During construction, slurry trenches or freeze walls will be used to prevent seepage from the overburden soils into the excavations for shafts and surface structures. If deep groundwater contamination is encountered during tunnel excavation, the dewatering effluent will have to treated prior to discharge.

During operation, water will be maintained in the tunnel to elevation 0.0. This will, in effect, balance internal with external pressures and significantly reduce seepage of groundwater into the tunnel. Groundwater inflow into the tunnel will be limited by grouting of the rock and placement of a concrete tunnel liner.

Through the use of engineering controls during construction and operation, it is not anticipated that the tunnel will have any significant impact on groundwater quantity. Seepage into the completed tunnel, after grouting and liner installation, is estimated to be in the range of 1,000 to 2,000 gallons per minute (gpm). This flow for the entire 20.4 mile tunnel length is about equal to the output of a single high capacity municipal or commercial well. Since drawdowns in the overburden aquifer are estimated to be minimal, no significant impact on shallow wells is expected.

8.2.7 Water Quality. Instead of flowing into Newark Bay and gradually diluting the salinity of the water, floodwaters will enter Newark Bay as a freshwater plume that would drop salinity rapidly in the immediate vicinity of the tunnel outlet. At the 100 year event this effect essentially replicates natural conditions during a flood. Thus, the operation of the tunnel does not increase stress to the resident organisms. Nor are there expected to be any significant adverse effects in water temperature or dissolved oxygen in Newark Bay.

8.2.8 Air Quality. The project is within the State of New Jersey's Implementation Plan in accordance with the Clean Air Act National Ambient Air Quality Standards (NAAQS) for the majority of constituents. The evaluation of air quality impacts will depend upon the final determinations of significant factors such as construction schedule, construction equipment and hours of operation. If the expected air emissions exceed any of the NAAQS rates established for non-attainment areas, a full scale conformity analysis will be completed and subjected to the established Federal review process.

8.2.9 Aesthetics. The main inlet and shafts will be placed in industrial zones so as to avoid significant aesthetic impacts. Aesthetic treatments will be applied to levees and floodwalls as a standard feature if they are located in residential areas, parks or within view of parks. Levees will be beautified with plantings that are native to the area. In residential yards, turf grass will be planted and shrubs will be provided along the lower edges of levees.

8.2.10 Noise. Short-term construction related noise generated by the project includes blasting associated with the tunnel inlets, outlet, and shafts and use of heavy equipment associated with the movement of soil and rock. The blasting will take place deep underground (a minimum of 100 feet below the surface), thereby providing a buffer to surface noise and vibrations and preventing damage to structures in the area. Soil and rock will be moved via mechanical means such as bulldozers or crane. The tunnel boring machine will not generate any noise or vibrations at the surface as it cuts through rock since it will be from 150 to 500 feet below the surface.

The construction related noise at the tunnel inlets, shafts and at the tidal area levee/floodwalls will be in areas that already experience noises from highways and industrial activities. For example, the Pompton Inlet site is currently used for a commercial soil separation operation that utilizes areas with few structures nearby. The residential areas in the Central Basin will experience short-term noise increases during the construction of levees, floodwalls, and channel modifications. This noise will be heard by those who directly benefit from the project. The specific construction equipment to be sued and the duration of use will be addressed in the plans and specifications phase.

8.2.11 Cultural Resources. The Corps is party to a Programmatic Memorandum of Agreement with the New Jersey State Historic Preservation Office (NJSHPO)and the Advisory Council on Historic Preservation. In accordance with that agreement, cultural resource investigations were performed for several project elements, to identify properties within or adjacent to the project area that are listed, or potentially eligible for inclusion, in the National Register of Historic Places. All phases of the investigation and the review process have been coordinated with the NJSHPO.

8.3 ENVIRONMENTAL DESIGN

Environmentally sound objectives were pursued throughout the entire design effort. Opportunities for environmental enhancement were considered, as well as for mitigation of unavoidable project impacts to the extent possible. Environmental preservation has been incorporated as a standard feature into the design of each element, including the channel modifications, levees, floodwalls and other structures. In addition, specific fish and wildlife measures, separate from the project components, were included in the design specifically to mitigate unavoidable project impacts.

8.3.1 Mitigation of Estuarine Impacts An intensive sampling, strategy, provided the baseline conditions supported by extensive experimentation and model studies of water quality with which to compare project impacts. This allowed a mitigation needs of the plan to be developed that considered the following measures:

- Re-aeration of tunnel water

- Creation of estuarine marsh habitat

- Creation of fish habitat in Newark Bay away from the outlet

These efforts indicate the Bay would function with little or no change between a with project or with-out project condition.

8.3.2 Mitigation of Wetlands Impacts. The mitigation plan includes maintenance of wetlands in pending areas by use of pumps, sluice gates and flap gates to control site hydrology, which are integral to the function of the levees and are minimum facilities associated with the project features. Hence, their maintenance, operation and upkeep are required for the various structural project elements. The pumps, sluice gates, etc. will help to maintain wetlands since they can be used to manipulate water levels. The wetland mitigation incremental cost, if any, for these procedures is considered negligible. The ponding areas will not require additional maintenance beyond that necessary for minimum facility purposes. Maintaining and operating minimum facilities have been included the annual cost. To offset unavoidable wetland losses, techniques to be used include such measures as creation of wetlands from burrow areas, restoration of disturbed to wetlands, construction of blind ditching and earthen banks to create emergent scrub communities, and maintaining wetlands hydrology according to a planned program planned program. In addition, mitigation measures will be used at sites apart from the project elements including: restoring disturbed areas of the Lincoln Park gravel pits.

8.3.3 **Mitigation of Aquatic Impacts.** A plan was developed to mitigate changes in stream morphology, and the loss of tree shade, leading to increased water temperature and decreased dissolved oxygen. The measures include: maintaining shade on southern and western banks to the maximum extent possible; using stockpiled stream material and tunnel cobble material to restore existing stream substrate; using instream structures, as well as offstream velocity refuge embankments, to increase habitat in tributaries upstream of the tunnel inlet and in the Pompton River. Maintenance costs for dredging of the velocity refuges will be addressed in the FDM phase when additional sedimentation studies allow more specific estimates of dredging needs. Wing-dams and other instream structures will be used to replace riffle/run pool morphology. The maintenance of the wing-dams has already been included in the overall operation and maintenance costs for the channel modifications.

8.3.4 Mitigation of Wildlife Impacts. All project elements affecting wildlife resources were examined in detail to minimize their impacts, mainly limited to wetlands. Wetland mitigation incorporate wildlife concerns in addressing functional equivalency of mandated ratios for impacted acreage.

8.3.5 Great Piece Weir. The weir location and design was coordinated with the USFWS. To assure that this weir, as well as the Pequannock weir, effectively protect upstream wetlands, the USFWS Habitat evaluation Procedure and a plant recessional model were used. Wetlands within the 2-year floodplain will be thus protected.

8.3.6 Pompton River. The reach downstream of the Pompton Inlet provides opportunities to mitigate the upstream impacts on the Pequannock, Wanaque and Ramapo Rivers. Habitat mitigation techniques will be used to offset the upstream losses. Also, flow in this reach will be allowed at bankfull capacity of 4,300 cfs to increase the flushing of the bottom during flood events. This flow will also allow continued natural sediment transport and scouring, while helping to reduce contaminants in the river from overland sources.

8.3.7 Recreation and Aesthetic Enhancement Each project element was considered for the addition of recreational facilities and aesthetic treatment. These measures are described in Section 5 - Project Description.

8.3.8 Recreational Mitigation. Land that is part of the New Jersey Green Acres Program and diverted from recreational use to flood damage reduction purposes requires replacement with land of equal or greater value. Lands included in the easements for the project are considered to be diverted from recreational purposes. All the land in this project, so affected, consists of undeveloped woodland in the floodplain and could be replaced by similar passive recreation sites. These include Passaic County Park Department lands in Wayne Township and the Borough of Pompton Lakes, and Essex County Park Department lands in the

Borough of Fairfield and Livingston Township. It is expected that by the time project construction begins, the Town of Harrison, which has applied for the Green Acres Program, will have lands affected as part of the South 1st Street System.

In all areas where recreational land or open space is taken, either for narrow strips lost to channel widening, or where levees will cover parks or open space, the areal extent of the taking was calculated and will be offset with either direct land purchases or replaced with cash payment as mitigation for the loss.

8.3.9 Beneficial use of Excavated Materials The estimated quantity of rock excavation from tunnel construction is over 10 million cubic yards, loose. Soil materials will be excavated in the construction of shafts, channel modifications, inlets and outlet structures comprising an estimated quantity of 2 million cubic yards, loose. Potential uses of these excavated materials vary. Granular soils will provide excellent materials for both compacted and uncompacted fills and embankments. Some of the granular material may be adequate for processing into fine aggregate for concrete. The clays may be used for embankments and levees or for cover on landfills. Basalt rock could be processed into coarse aggregate for concrete or asphalt and used as stone base for roadways or for compacted embankments. The shale/sandstone material could be used for compacted embankments and levees, uncompacted embankments and underwater fills. Refer to Sections 15 and 16, Appendix E, for a detailed description of how excavated materials may be reused or disposed of.

8.3.10 Preservation of Natural Flood Storage The environmental effects of this project element were documented in the EIS which was filed with the Environmental Protection Agency on January 17, 1989 and are summarized below.

The preservation of natural flood storage element includes the acquisition of 5,350 acres of floodplain storage in the Central Passaic Basin, 5,200 acres of which are wetlands. The acquisition consists of large portions of major wetlands which are listed in Table 10. These areas are included in the project primarily for their significance for natural flood storage, but also for their high environmental values. Preservation of these areas will prevent increases in flood flows and corresponding flood damages caused by the loss of such areas to development. In addition to the beneficial flood protection, the preservation of these wetlands would conserve many positive wetland attributes and effects. It would preserve large refuges for wildlife, providing wildlife with food, escape and reproductive cover. Wetlands also provide a unique gene pool repository. From one-third to one-half of all the State's endangered, threatened and declining species are wetland dependent. Preservation of these wetlands would maintain an important stop over for migratory bird species on the Atlantic Flyway. If implemented as a separable element, the acquired acreage would be preserved intact as wetlands. Acquisitions within Troy Meadows would help preserve this National Natural Landmark, and land preserved within Great Piece Meadows lies within a reach listed on the Nationwide River Inventory, a list notable for its recreational attributes.

The preservation of natural flood storage would also serve to maintain areas that recharge both groundwater supplies and base flow to surface water supplies. The preservation of these wetlands from development would conserve the landscape diversity and aesthetics which are reflected in the satisfaction derived from recreational experiences such as canoeing, bird watching, or hiking.

MAIN REPORT

SECTION 9

REAL ESTATE REQUIREMENTS

9. REAL ESTATE REQUIREMENTS

9.1 OVERVIEW

A gross appraisal was completed to estimate the cost of acquiring the lands and easements for the construction of each element of the Flood Damage Reduction Project. The estimates were based on determining for each element the type of real estate interest required and applying the fair market values of properties as determined by surveys of market conditions and recent real estate transactions.

9.2 BASIS FOR LAND REQUIREMENTS

For those project elements that preclude any other use, acquisition in fee simple, which signifies ownership of all the rights in a parcel of real property, is required.

For those lands required for project elements that may be used by the property owner other purposes, permanent easements will be acquired. This will allow the government to construct, maintain and operate the project facilities and allow the owners to use the property as long as such use does not interfere with the project purpose.

Temporary easements will be acquired to allow for use of property needed only for the construction of the project including staging areas and transportation of supplies and equipment.

Fair market value is the amount in cash, or terms reasonably equivalent to cash, for which the property would be sold by a knowledgeable owner willing but not obligated to sell to a knowledgeable purchaser who desires but is not obligated to buy.

9.3 REAL ESTATE REQUIREMENTS FOR PROJECT ELEMENTS

The total acreage required for the project is 5,378 acres in fee simple, 468 acres in permanent easement and 123 acres in temporary. Table 14 displays these needs by project element.

Table 14 - Real Estate Requirements
(In acres)

Category	Fee simple	Permanent easement	Temporary easement
TUNNEL SYSTEM			
Main inlet	4.10	0.40	6.50
Passaic Inlet	5.60	0.80	6.37
Tunnel	0.00	218.00	0.00
Pequannock-Ramapo	0.00	4.06	2.96
Work shaft #2	1.02	0.48	2.50
Work shaft #2B	0.52	0.00	3.80
Work shaft #2C	1.50	1.37	1.13
Work shaft #3	0.18	0.08	0.38
Work shaft #4	0.14	0.41	2.50
Vent/hook hole shaft #5	0.02	0.10	0.35
Vent shaft #6	0.12	0.08	0.50
Newark Bay Outlet	1.70	0.00	2.00
Fairfield Road Bridge	0.00	0.20	0.23
Pequannock Channel	0.00	41.50	11.48
Wanaque Channel	0.00	14.30	5.20
Ramapo Channel	0.00	24.84	6.08
Pompton Bypass Channel	0.00	16.32	2.60
Passaic Channel	0.00	26.90	5.08
Great Piece Weir	0.77	1.00	7.75
Pequannock Weir	2.25	0.00	3.76
CENTRAL BASIN PROTECTION			
Passaic #2A	0.00	9.41	6.04
Passaic #10	0.00	27.81	1.76
Deepavaal Brook		15.98	6.72
Rockaway #1	0.00	5.47	2.70
Rockaway #2 (2)	0.00	4.98	2.05

Rockaway #3	0.00	3.47	7.15
Pinch Brook	0.00	2.95	1.97
TIDAL AREA PROTECTION			
Kearny Point	0.00	21.48	13.35
Lister/Turnpike/Doremus	0.00	21.48	6.02
South 1st Street	10.0	4.49	1.43
PRESERVATION OF LAND			
Land acquisition	5,350.00	0.00	0.00
Total	5,377.92	467.56	123.35

(1) 3 single-family homes (1 used as a business office).
(2) 4 multi-family structures - 1 single-family home.
(3) 2 Business properties, parking lot and storage yard.

MAIN REPORT

SECTION 10

COORDINATION

10. COORDINATION

10.1 OVERVIEW

Throughout the development of the project an active program has been pursued to obtain the views of all interests external to the Corps, including the other Federal agencies, state and local governments and their resource agencies, groups and individuals. Issues have been surfaced and steps have been taken toward resolution. Full details are provided in Appendix A - Public Involvement.

10.2 PUBLIC INVOLVEMENT PROGRAM

The public involvement program pursued the following objectives:

- To build public confidence and trust in the project implementation process.

- To reflect the needs and preferences of the people of the Passaic River Basin within the bounds of Federal, state, county and local programs, laws, regulations and authorities.

- To resolve issues and solve problems through public involvement.

These objectives were met by:

- Developing an information programs to make the public knowledgeable about the region's water resource problems, needs, objectives, alternatives and priorities.

- Creating a mechanism by which the public could express its views on any aspect of the process.

- Providing opportunities for the public to participate directly in reaching decisions pertinent to project implementation.

- Actively promoting effective coordination among federal, state, county and local agencies.

Three scoping meetings for the Supplemental Environmental Impact Statement (SEIS) were held in June, 1993 to provide a forum for the broad range of public and political views to be aired. The meetings permitted an open exchange of ideas, information and opinions particularly with respect to the revisions in the project as authorized by the water Resources Development Act of 1990. The chief purpose of the scoping meetings was to gather and document information on issues identified by the various interests so they could be properly reflected in this General Design Memorandum and the SEIS.

10.3 OTHER FEDERAL AGENCIES

Federal agencies with resource management responsibilities have provided opportunities to participate in the formulation and implementation of the project at every stage of the process. They have contributed their expertise and cooperated in the resolution of issues of significance to their missions.

10.3.1 In November 1988, the Environmental Protection Agency and the Corps of Engineers signed a Memorandum of Agreement for the Development of a Comprehensive Wetlands Mitigation Plan for the Mainstem Passaic River Flood Protection Feasibility Project. The agreement provided the EPA with a review and decision-making role in the development of the wetlands mitigation plan documented in this GDM. EPA also applied its expertise in the areas of air and water quality, and hazardous, toxic and radioactive wastes.

10.3.2 The National Marine Fisheries Service provided research and sampling data from Newark Bay needed to determine potential impacts due to the construction and operation of the tunnel outlet.

10.3.3 The Geological Survey collected data and created groundwater models for both tunnel inlets. These models were integrated with a model of the entire tunnel to replicate existing conditions and forecast project impacts on groundwater resources and hazardous, toxic and radioactive wastes.

10.3.4 The Fish and Wildlife Service provided extensive assistance regarding projection of future conditions with and without the project and inventories of the various fish and wildlife resources. It assisted in the establishment of baseline conditions for the proper application of the Habitat Evaluation Procedure. Over 50 technical reports discussed qualitative impact assessments that enabled the Corps to identify adverse impacts on fish and wildlife and minimize them by means of appropriate mitigation measures.

The goal of the Fish and Wildlife Service was to assure that the adverse environmental effects of the project are minimized to the maximum extent possible are incorporated. The Service provided the following recommendations toward that end.

1. In accordance with the Endangered Species Act of 1973, as amended, the Corps must continue consultation with the Service throughout the next study phase regarding potential project-related effects to the Indiana bat. The Corps should coordinate with the the Service regarding any studies necessary to determine the suitability of the project area for Indiana bats.

2. In accordance with the Endangered Species Act of 1973, as amended, the Corps must coordinate with the National Marine Fisheries Service regarding potential project-related effects to the Federally-listed threatened or endangered marine species.

3. The Corps should coordinate with the New Jersey Natural Heritage Program for current information regarding candidate species in the project area.

4. The Corps should coordinate with the New Jersey Division of Fish, Game and Wildlife, Endangered and Nongame Species Program regarding potential project-related effects to any state-listed speices.

5. The Corps should coordinate with the Service to develop site specific plans to offset unavoidable adverse impacts to palustrine forested wetlands through the restoration of former wetlands within the Passaic River Basin.

6. The Corps should coordinate with the Service to develop site specific plans to offset unavoidable adverse impacts to palustrine scrub-shrub wetlands throughthe restoration of former wetlands within the Passaic River Basin.

7. The Corps should coordinate with the Service to develop site specific plans to offset unavoidable adverse impacts to palustrine emergent wetlands through th eimprovement of existing emergent wetlands within the Passaic River Basin.

8. The Corps should incorporate the in-stram structure recommended by Garline et al (1995) into the selected plan to offset the adverse impacts of the proposed channel modifications.

9. The Corps should coordinate with the Service to develop plans for off-channel velocity refuges along the river reaches to be affected by the proposed channel modifications.

10. The Corps should coordinate with the Service to develop plans for additional studies to examine the effects of the

proposed project on water temperature regimes in the river reaches affected by channel modifications.

11. The Corps should take necessary steps to minimize the disturbance of contaminated sediments during construction of the tunnel outlet.

12. The Corps should identify suitable upland sites for the isposal of any contaminated sediments excavated uring the constuction of the tunnel outlet.

13. The Corps should coordinate with the Service, and the New Jersey Division of Fish, Game and Wildlife regarding the development of comprehensive management of pla ns for the proposed acaquisition areas, Great Piece Meadows Weir, and the wetlands mitigation areas.

Corps responses to these recommendations are as follows:

Recommendation 1. Concur. The Corps will maintain informal consultation with the Service regarding project-related effects on the Indiana bat. Should continuing informal consultation indicate biological assessments are necessary, one will be prepared in accordance with the 50 CFR Part 42. Studies required to support the biological assessment will be coordinated with the Service.

Recommendations 2 through 4. Concur. Similar consultation will be initiated with the National Marine Fisheries Service.

Recommendations 5 through 7. Concur. Ongoing consultation will be maintained regarding these resources.

Recommendations 8 and 9. Concur. The Corps New York District will actively pursue incorporation of these features into the selected plan.

Recommendation 10. Concur. Additional temperature studies regarding reaction of fishery species to increasing water temperatures will be conducted in final design stages.

Recommendation 11. Concur. Engineer controls for sediment disposal are incorporated in project plans.

Recommendation 12. Concur. Upland disposal will be considered consistent with regulatory controls regarding on-site re-use of sediments, ocean disposal and other options designed to meet regulatory criteria and state agreements for the disposal of contaminated sediments.

Recommendation 13. Concur. Resource management plans developed for proposed acquisition areas will be coordinated with the Service and the New Jersey Department of Fish, Game and Wildlife to ensure any plan development meets Service and state management criteria, goals and objectives.

10.4 STATE AND LOCAL AGENCIES

The staff of the non-Federal sponsor, the New Jersey department of Environmental Protection provided consultation, data collection, and assistance in mitigation planning.

MAIN REPORT

SECTION 11

COST ESTIMATE

11. COST ESTIMATE

11.1 OVERVIEW

This section provides information on the cost of building the project, including construction labor, equipment and materials, and real estate acquisition. Also discussed are the costs of operation and maintenance over the project life. The cost estimate is broken down with respect to the various elements of the project.

11.2 MANAGING THE COST ESTIMATE.

The total authorized project cost estimate as stated in Appendix D - Cost Engineering set the target for managing and controlling costs during implementation. The estimate has been and will continue to be updated as necessary. As the design is refined the cost of each feature becomes more accurate with fewer uncertainties. The estimate is made current for each major milestone in the implementation process.

11.3 FIRST COST OF CONSTRUCTION

First cost includes charges arising from the construction of the project including engineering and design, construction management and contingencies. The estimated project cost of the authorized plan of improvement is $1,420,000,000, of which $1,055,000,000 is Federal and $365,000,000 is non-Federal. The cost is estimated at October 1994 price levels. The Federal and non-Federal costs are summarized in Table 15. A detailed cost estimate of the plan of improvement is contained in Appendix D, Cost Engineering. Also shown are the estimated fully funded costs, which are the funds needed for the project accounting for price escalations due to inflation over the construction period.

Table 15 - Cost Estimates
(October, 1994 price level)

Project element	First cost	Fully funded
TUNNEL SYSTEM		
Tunnels (including shafts)	$1,094,254,301	$1,455,677,769
Inlets	$73,172,046	$102,438,457
Outlet	$32,791,234	$44,270,224
Weirs	$23,384,185	$32,231,518
Levees, walls, channels	$35,139,731	$51,659,126
Subtotal	$1,258,741,497	$1,686,277,094
CENTRAL BASIN PROTECTION		
Passaic #2A	$8,771,911	$10,929,191
Passaic #10	$2,811,135	$3,150,807
Deepavaal Brook	$3,196,402	$3,952,144
Rockaway System		
Rockaway #1	$3,856,781	$4,713,121
Rockaway #2	$3,667,121	$4,460,402
Rockaway #3	$13,546,094	$16,651,354
Pinch Brook	$1,850,156	$2,251,185
Subtotal	$37,699,600	$46,109,204
TIDAL AREA PROTECTION		
Kearny Point	$46,472,848	$59,510,892
Lister/Turnpike/Doremus	$36,668,234	$45,686,266
South First Street	$12,739,377	$15,628,931
Subtotal	$95,880,459	$120,826,320
PRESERVATION OF NATURAL STORAGE		
Land acquisition	$16,983,588	$19,705,395
FISH AND WILDLIFE		
Mitigation	$9,654,266	$13,137,405
Total cost of project	$1,420,000,000	$1,890,000,000

cutting of grass along the channel banks, levees and ponding areas; repair of concrete structures and painting of metal parts.

Fish and wildlife mitigation features have been designed to be self-maintaining, as recommended by the United States Fish and Wildlife Service and the New Jersey Bureau of Freshwater Fisheries. The wetlands will be self-perpetuating once established. Nesting boxes designed to replace the loss of reproductive cover from trees are expected to degenerate over time; they are not scheduled to be maintained or replaced since new trees and nesting niches will become available as the riparian corridor becomes reestablished.

The major activities required for tunnel operation and maintenance are as follows:

- Periodic pump-out. The tunnel will have to be pumped out to make a visual inspection and allow sediment to be removed. Pump-outs will be scheduled periodically and after each major flood event.

- Responsibilities of on-site personnel. Qualified personnel will receive flood warning messages and operate the gates when flood events are expected. Other personnel will perform routine daily tasks such as general inspecting and guarding against vandalism to the inlets, outlet, and gates. They will also ensure proper working order of the related electrical components and hydraulic machinery. An annual testing program of the entire system should be initiated along with a training program to provide for additional qualified operational personnel in case of a flood emergency.

- Mechanical maintenance. A yearly maintenance program will be initiated for the gates at the Pompton Inlet, the gates at the Passaic inlet and the gates at the outlet.

- Maintenance of inlet and outlet structures. An annually scheduled maintenance program will be established for inlets and the outlet.

- Cleaning of tunnel. Clean outs of the tunnel will occur at least ten times during the 100 year life of the structure, though others may occur after major flood events.

Average annual operation and maintenance costs, as shown in **Table 16** are estimated to be $3,150,000.

11.4 COMPARISON WITH PREVIOUSLY APPROVED ESTIMATE

Differences between the current cost estimate and the current approved Project Cost Estimate (DA form PB-3 effective 1 October 1994) are presented in detail in Appendix D. The basis of the PB-3 estimate is the cost contained in the authorizing legislation, updated to current price levels using the Office of Management and Budget inflation factors.

The current fully funded approved Project Cost Estimate (with allowance for inflation through construction) is $1,870,000,000. The fully funded estimate as developed for this General Design Memorandum, is $1,890,000,000.

11.5 OPERATION AND MAINTENANCE COSTS

The operation and maintenance (O&M) costs are the estimated average annual economic costs necessary to maintain the project at full operating efficiency to obtain the intended benefits.

In accordance with Section 101(a)(18)(A)(iv) of the Water Resources Development Act of 1990 (Public Law 101-640), upon completion of construction the Federal Government will be responsible for performing all measures to ensure the integrity of the tunnel, including staffing of operation centers, cleaning and periodically inspecting the tunnel structure, and testing and assuring the effectiveness of mechanical equipment at gated structures and pump stations. The non-Federal sponsor will be responsible for: operating, maintaining, repairing, rehabilitating and replacing the remaining project features, including existing highway and railroad embankments used as levees and tie-outs for levees; and recreational and environmental mitigation features.

Operation and maintenance costs are based on experience that provided information on actual practices for various types of projects. The only project facilities that will require continuous operation will be the pump stations. However, test operation of the gates at the inlet and outlet structures together with periodic maintenance will be required.

The major task associated with the project will be the annual maintenance required for the channels, levees and floodwalls. These tasks will include but not be limited to: inspection, maintenance, repair and replacement of riprap; clearing of debris from the channel and bridges, sediment removal as needed; shoal removal, brush and tree control; trash pickup

Table 16 - Operation and Maintenance Costs

	ANNUAL COSTS	
PLAN FEATURE	FEDERAL	NON-FEDERAL
Tunnel System		
Tunnels	$1,415,000	
Passaic Channel	$49,310	
Great Piece Weir	$58,000	
Ramapo Channel	$71,214	
Pequannock Channel	$145,665	
Pequannock Bypass Channel	$17,264	
Pequannock Weir	$58,000	
Pequannock/Ramapo Levee	$39,676	
Wanaque Channel	$52,871	
Central Basin Protection		
Passaic #2A Levee		$341,769
Deepavaal Channel		$80,386
Rockaway #1 Levee		$67,597
Rockaway #2 Levee		$49,353
Rockaway #3 Levee		$15,395
Passaic #10 Levee		$47,144
Pinch Brook		$20,374
Tidal Area Protection		
Kearny Point Levee		$201,582
Lister/Turnpike/Doremus Levee		$150,000
South First St. Levee		$69,637
Preservtion of Natural Storage		$200,000
Total	$1,907,000	$1,243,237

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SECTION 12

ECONOMIC ANALYSIS

12. ECONOMIC ANALYSIS

12.1 OVERVIEW

Federal participation in the project requires a demonstration of economic feasibility, which is established by determining whether the benefits exceed the annual economic charges. Benefits were determined based on detailed investigations of the economic impacts of flooding in the basin. Annual charges were based on the application of economic principles to all the costs of constructing, operation and maintenance of the project. The economic analysis is summarized in Table 17 and discussed in detail in Appendix I - Economics.

12.2 ANNUAL ECONOMIC CHARGES

The annual charges as summarized in Table 17 were computed on the basis of the following factors:

- Interest and amortization were determined using a discount rate of 7-3/4% and a project economic life of 100 years, which is the period of time over which the project is expected to yield its benefits.

- Interest during construction is the cost of construction money invested before benefits are derived from the project. It is added to the construction cost to determine the total investment in the project. Interest during construction is determined by adding compound interest at the applicable project discount rate from the date the expenditures begin to the beginning of the year in which benefits begin to accrue. Construction of this project is estimated to take 10 years 10 months as discussed in Section 14 - Implementation and Appendix - D, Cost Engineering.

- Costs for the operation and maintenance are discussed in Section 11 - Cost Estimate.

12.3 BENEFITS

Flood control benefits are based primarily on the damages that will be prevented by the project and averaged over the 100 year project life. Damage reduction estimates were based on studies of historical floods, projections of development in flood plain areas and statistical analyses relating damage potential to the hydrologic characteristics of the basin with and without the project.

Historical data on flood damages in the Passaic River basin have been compiled since the 1903 flood and researched in newspaper and Federal post-flood reports. To the extent possible the data were analyzed as specifically as to the stream, location and category of damage. While the flood of record is the event of 1903, major floods have occurred frequently since then. Ten major floods have occurred since in 1968.

Interviews were conducted to obtain first-hand data on damages resulting from actual flood events. This process has been ongoing since 1980. Over 3,000 interviews have been conducted to obtain information on residential, commercial, industrial, utility and public damage in the 214 damage reaches that were identified. This information, brought up to date by means of new surveys and interviews, permitted firm relationships to be established between depth of flooding and resulting damage. Extensive assessments of land use have also recently been performed to assure the validity of damage estimates.

Only tangible damages are used in the estimate of benefits for this project. Estimates were made for: Residential, commercial, industrial, and public property (schools, recreation areas); municipal facilities (streets, highways, utility lines); and municipal emergency costs. Where applicable, damages were categorized as to structures and contents.

All the benefits accruing to the flood damage reduction project are shown in Table 17. The total equivalent annual benefits over the period of analysis are estimated at $173,194,300. This is the value of flood damage reduction resulting from the tunnels, channels, levees and floodwalls including benefits in advance of the base year. Benefits are also credited to greater investment in existing properties due to the project (future affluence), reduction in delays to vehicular traffic and railroads, reductions in Federal Flood Insurance Administration costs, more beneficial use of residences (intensification) and growth in industrial contents. These latter two benefit categories refer to more intense utilization of an existing structure as a result of less frequent flooding. For instance residents may intensify the use of their homes by finishing the basement if the flood hazard is reduced.

Detailed information on the benefits is contained in Appendix I, Economics.

12.4 ECONOMIC JUSTIFICATION

Total annual benefits for the plan of improvement are $173,163,100. Total annual charges are $130,194,000 (October 1994 price level). Any costs already incurred on flood damage reduction efforts are excluded from the annual charges. A comparison of average annual benefits and annual charges results in net benefits of $42,969,100 and a benefit-to-cost ratio of 1.3 to 1.0 for the Passaic River Flood Damage Reduction Project.

Table 17 - Economic Justification
October, 1994 price level, 7-3/4% interest rate,
100 year project life

ANNUAL CHARGES	
First cost, interest and amortization	$110,032,000
Interest during construction	$20,036,000
Total investment	$130,068,000
Operation and maintenance	$3,150,000
(Minus GDM cost)	$(3,024,000)
Total annual charges	$130,194,000
BENEFITS	
Flood damage reduction	$117,640,800
Affluence	$3,551,600
Reduction of traffic delays	$1,666,700
Advance of base year	$38,745,900
Reduction in flood insurance costs	$890,900
Residential intensification	$520,400
Growth in industrial contents	$8,634,300
Recreation	$1,764,800
(Minus Residual induced damages)	($252,300)
Total benefits	$173,163,100

FEASIBILITY	
Net benefits	**$42,969,100**
Benefit-cost ratio	**1.3**

A breakdown of this benefit/cost analysis by separable project elements is presented in Table 17A. Separable elements are those components that can function independently without the presence of other project elements to reduce flood damages. These are economically justified elements of the authorized project that have been incorporated into the overall project design to augment the flood damage reduction provided by the primary project element, the tunnel, beyond its area of beneficial influence.

The benefits and costs of those elements that are integral to the functional role of the tunnel are included in the tunnel element. They include the 7 miles of channel work, pilot channels, Pequnnock and Great Piece Meadow Weirs, and the Pequannock-Ramapo Levee floodwall system. In addition, the benefits and costs of the Passaic #2A levee/floodwall and the Deepavaal Brook channel modifiction are included in the tunnel element since their design is hyraulically linked to the tunnel as described below.

Passaic #2A and Deepavaal Brook Channel Improvements

The Passaic #2A levee/floodwall system and the Deepavaal Brook channel modification work are both designed to be supplemental to the tunnel. These features provide additional protection to areas where water level (flood stage) reductions, as a result of tunnel diversion, do no provide the complete solution. It should be noted that these features are not integral to the tunnel (not required for the tunnel to operate properly) but as currently designed are dependent on the beneficial effects of the tunnel stage reductions. Should the tunnel element not be constructed, these features would need to be reanalyzed in terms of both physical layout of the feature and project economics.

As currently designed, the Passaic #2A levee/floodwall system provides protection to the heavily urbanized area in Fairfield that exists behind the Interstate I-80 embankment. The levee also prevents the Passaic River (near Station 2355+75) from crossing over into the Deepavaal Brook channel when the water level exceeds 171.1 NGVD. Without the tunnel this feature would have to be altered to most likely include a levee/floodwall system and pump station. These new proposed segments could be located near the confluence of the Passaic River and Deepavaal Brook.

Channel modifications along Deepavaal Brook also assume tunnel diversion and hence low Passaic River backwater stages. Without the tunnel, channel modification work would have to be carefully examined to determine project justification. Beneficial results could occur for localized rainfall/flood events on Deepavaal Brook if the Passaic River does not flood.

Should these two features be considered together in absence of the tunnel, additional hydrology and hydraulic analysis would be required to properly size the height of the new downstream levee/floodwall and pump station. An interior flood damage reduction analysis would also be required.

Rockaway Levee/Floodwall System

The Rockaway #1, #2 and #3 levee/floodwall elements are treated as a system due to the interaction of the individual features with each other and the desire to maintain a constant level of protection throughout the study area. This will be further explained below.

All of the levee units on the Rockaway River are located downstream of the Boonton Reservoir. These units will provide up to 100-year level of protection. On the right bank, Rockaway Levee units #1 and #3 provide protection to Parsippany Troy-Hills while on the left bank, the Rockaway #2 Levee provides protection to a section of Montville.

The design of the most downstream unit (Rockaway #1) is dependent upon the raising of the existing locally constructed Lake Hiawatha Flood Control Project. The raising of the existing upstream levee is the proposed Rockaway #3 system. The configuration of Rockaway #1 unit would need to be altered to prevent upstream flanking should the existing Lake Hiawatha levee not be raised. These two levee units (Rockaway #1 and Rockaway #3) therefore protect the same area behind the proposed Rockaway #1 unit and are physically and hydraulically connected.

For the left bank, protection was found to be justified for the section of Montville where Hatfield Brook enters the Rockaway River. Although the levees on the right bank are generally set back, water levels are slightly increased (for most floods less than 0.2 feet) in this area as a result of the proposed levees. However, since providing a comprehensive basin-wide level of protection was a goal, the Rockaway #2 levee was included to further enhance protection to basin residents and commercial areas where little to no stage reductions would occur as a result of the tunnel elements.

Table 17a - Incremental Benefits Of
Preservation of Natural Storage Project Element
(October 1994 price levels, 7 -3/4% interest rate,
100 year project life)

	LAST ADDED	FIRST ADDED
Annual Benefits	$5,008,800	$1,869,700
Annual Costs	$2,978,600	$1,604,400
Benefit-Cost Ratio	1.7	1.2
Net Benefits	$2,030,200	$265,300

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SECTION 13

COST SHARING

13. COST SHARING

13.1 OVERVIEW

The project is a joint undertaking of the Federal government and the State of New Jersey, the non-Federal local sponsor. Federal law requires that the costs be apportioned in accordance with the benefits to be realized. The sponsor's percentage varies with the type of benefit. Since the project serves the multiple purposes of flood damage reduction, hurricane damage reduction and recreation, the costs were allocated to each purpose to provide the basis for approtioning cost.

13.2 APPORTIONMENT OF COSTS.

The apportionment of Federal and non-Federal costs, based on the Water Resources Development Act of 1986, is given in **Table 18.** The Federal share of the project's fully funded construction costs is $1,405,000,000. The non-Federal costs are estimated at $485,000,000, of which lands, damages, rights-of-way and relocations are estimated at $66,000,000, and the required minimum 5% cash contribution is estimated at $87,200,000. The remaining estimated non-Federal cost of $331,800,000 can be paid in cash or credits as stated in the authorizing legislation. The apportionment of costs for the Preservation of Natural Flood Storage separable element is given in **Table 18a.**

13.3 CREDIT PROVISIONS

The Water Resources Development Act of 1990 authorizes credits for the non-Federal sponsor against its share of the project cost. Credits are allowed for real estate purchased for the wetlands bank and additional watershed lands as well as for the costs of activities that contribute to flood damage reduction. Such activities must meet the criteria stated in Section 104 of The Water Resource Development Act of 1986. These measures may include any flood damage structures, reduction or conversion of acquired lands to wetlands, compatible acquisition of floodplain properties and lands, easements and right-of-way.

Table 18 - Cost Apportionment
(Fully funded amounts)

	Federal	Non-Federal	Total
Flood damage reduction	$1,326,050,000	$422,250	$1,768,300,000
% share	75%	25%	
Hurricane protection	$78,600,000	$42,400,000	$121,000,000
% share	65%	35%	
Recreation	$350,000	$350,000	$700,000
% share	50%	50%	
Total	$1,405,000,000	$485,000,000	$1,890,000,000

Table 18a - Cost Apportionment for Preservation of Natural Flood Storage Separable Element (Fully Funded Amounts)

Federal	$14,782,500
Non-Federal	$ 4,927,500
TOTAL	$19,710,000

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SECTION 14

IMPLEMENTATION

14. IMPLEMENTATION

14.1 OVERVIEW

The implementation process will carry the project through the remaining design phase. This includes preparation of a real estate design memorandum for the Preservation of Natural Flood Storage Areas element. Funds must be budgeted by the Federal government and non-Federal sponsor to support construction activities, which include the execution of a Project Cooperation Agreement. A schedule has been developed to identify the steps and financial requirements.

14.2 SCHEDULE

Actual construction activities will begin in October 1997 and be completed in 1999 or 2000 depending on funding. Figure 135 shows the planned construction sequence of the project elements. The Preservation of Natural Flood Storage Areas is currently the only element scheduled to proceed.

14.3 FINANCIAL REQUIREMENTS

Initiation and completion of the project on schedule will require annual budgeting and commitment of funds by the Federal government and the local sponsor in accordance with the Financial Plan developed as part of the Project Cooperation Agreement process. Table 19 displays the estimated annual financial requirements over the construction period. A range of annual non-Federal expenditures is shown reflecting potential credits as discussed in Section 13, and the 5% cash contribution required by law for flood damage reduction projects. If the State of New Jersey were to take full advantage of credit provisions, the financial cost to the State would be the cash contribution.

TABLE 19 - Financial Requirements for Construction
(in millions of dollars)

		NON-FEDERAL		
FISCAL YEAR	TOTAL FUNDING	WRDA 1986	WRDA 1990 POTENTIAL CREDITS	REQUIRED CASH
1998	$ 5.3M	1.3	1	0.3
1999	14.4	3.6	2.9	0.7
TOTAL	$19.7M	$4.9M	$3.9M	$1M

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SECTION 15

ITEMS OF LOCAL COOPERATION

15. ITEMS OF LOCAL COOPERATION

15.1 NON-FEDERAL SPONSOR OBLIGATIONS

The Non-Federal sponsor, the State of New Jersey, has certain obligations which must be met for this project. The major obligations are presented below:

- Provide, to the United States, all lands, easements, and rights-of-way, including all borrow, ponding, and disposal areas, including lands required for fish and wildlife mitigation, determined suitable by the Chief of Engineers and necessary for construction, operation, and maintenance of the project;

- Provide cash payment equivalent to 5 percent of the cost assigned to structural flood control elements, to be paid during construction, or expend cash for lands during construction to offset the 5 percent non-Federal cash contribution requirement.

- Provide additional cash contributions or credits for lands as are necessary so that the non-Federal contribution for structural flood control is not less than 25 percent nor more than 50 percent of the cost of structural flood control, to be paid during construction;

- Provide additional cash contributions or credits for lands as are necessary so that the non-Federal contribution for nonstructural flood control is not less than 25 percent of the cost of nonstructural flood control;

- Provide additional cash contributions or credits for lands as are necessary so that the non-Federal contribution for hurricane and storm damage reduction is not less than 35 percent of the cost of hurricane and storm damage reduction, to be paid during construction;

- Share the cost of separable fish and wildlife mitigation features in the same proportion as the non-Federal share of the costs of project features which require mitigation;

- Provide fifty percent of the cost of separable recreation facilities for which there would be Federal participation, to be paid during construction;

- Provide a Financial Plan to the Government. The Financial Plan is to be prepared by the sponsor and submitted to the Corps at the earliest possible date. The Plan will define how the sponsor will finance its share of the costs of the project and must demonstrate the sponsor's ability to meet its obligations. The Plan will be reviewed by the Government with the PCA before construction funds are appropriated.

- Perform all necessary design and construction activities relating to alterations and relocations of buildings, highways, railroads, bridges (except railroad bridges and approaches), and utilities including storm drains, water supply lines, and sanitary sewers, other than those portions which pass under or through the project's structures, and other structures and improvements made necessary by construction, operation, and maintenance of the project;

- Hold and save the United States free from damages due to the construction, operation, maintenance, and replacement of the project, except where such damages are due to the fault or negligence of the United States or its contractors. This clause may result in an indemnification which compromises New Jersey sovereign immunity.

- Upon completion of each project feature, operate and maintain, replace and rehabilitate the works, including existing highway and railroad embankments used as levees and tie-outs for levees, and recreation and environmental mitigation features, in accordance with regulations prescribed by the Secretary of the Army; except for operation, maintenance, repair, rehabilitation and replacement of the tunnel works, as noted in paragraph 15.2 above.

- At least annually, inform affected interests regarding the limitations of the protection afforded by the project. Limitations, affected interests and procedures for informing affected interests will be as defined in the operation and maintenance manual.

- Publicize floodplain information in the areas concerned and provide this information to zoning and other regulatory agencies for their guidance and leadership in preventing unwise future development in the floodplain and in adopting such regulations as may be necessary to insure compatibility between future development and protection levels provided by the project;

- Prior to initiation of construction, prescribe and enforce regulations to maintain existing pre-project New Jersey Department of Environmental Protection Central Basin floodway delineations in the areas of natural flood storage acquisition;

- Prior to initiation of construction, prescribe and enforce regulations or other floodplain management techniques to prevent obstructions or encroachments on lands acquired for natural flood storage, floodplain storage, channels, interior drainage and ponding areas, and rights-of-way, which would reduce their flood-carrying and flood storage capacity, or would interfere with the operation and maintenance of the project, and control development in the project area to prevent increases in flood damage potential;

- Pay all investigatory and construction costs incurred due to the presence of regulated contaminated materials encountered on project sites, and hold and save the United States free from any future clean-up of hazardous waste sites on which project features are constructed.

- Administer and assure access to the recreation facilities and other project lands to all on an equal basis;

- Comply with all applicable Federal and state laws and regulations, including Section 601 of Title VI of the Civil Rights Act of 1964 (PL 88-352) and Department of Defense Directive 5500.II issued pursuant thereto and published in Part 300 of Title 32, Code of Federal regulations, as well as Army Regulation 600-7, entitled "Non- Discrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army; and

- Comply with the applicable provisions of the Uniform Relocations Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, 84 Stat 1894, approved January 2, 1971, in acquiring lands, easements, and rights-of-way for construction and subsequent operation and maintenance of the project, and inform all affected persons of applicable benefits, policies, and procedures in connection with said Act.

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SECTION 16

RECOMMENDATIONS

16. RECOMMENDATIONS

16.1 RECOMMENDATIONS

This General Design Memorandum describes an authorized project that meets the economic and environmental criteria for Federal participation. At this time, the non-Federal sponsor has expressed continued support for the Preservation of Natural Flood Storage separable element. This element is, therefore, recommended for implementation. The report identifies Federal and non-Federal responsibilities based on the flood damage reduction cost sharing policy established by Public Law 99-662. The Administration has proposed changes to that policy which would preclude Federal participation in the identified project. Congress took exception to that proposal and the Administration is reconsidering the policy. Consequently, National flood damage reduction policy is uncertain until agreement is reached between the Administration and Congress. However, the final report will be submitted for Washington level review and determination of consistency with policy will be made based on the flood damage reduction policy in effect at that time.

GARY THOMAS
Colonel, Corps of Engineers
District Engineer