# Delaware River Basin Comprehensive Flood Risk Management Interim Feasibility Study and Integrated Environmental Assessment for New Jersey

*Flooding in the Study Area, April 2005*

June 2015

DRAFT FEASIBILITY REPORT

U.S. ARMY CORPS OF ENGINEERS
PHILADELPHIA DISTRICT

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION

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**FINDING OF NO SIGNIFICANT IMPACT**
**DELAWARE RIVER BASIN COMPREHENSIVE**
**FLOOD RISK MANAGEMENT INTERIM FEASIBILITIY**
**STUDY AND INTEGRATED ENVIRONMENTAL ASSESSMENT**
**FOR NEW JERSEY**

## OVERVIEW

The United States Army Corps of Engineers (Corps), Philadelphia District (District), has evaluated flood risk management and associated ecosystem restoration projects for selected New Jersey communities that fall within the Delaware River basin. This evaluation provided a screening of structural and nonstructural measures that can be used to manage risks from riverine flooding, as well as an evaluation of potential associated ecosystem restoration opportunities along the river corridor.

## PURPOSE AND NEED

As mutually agreed to with the study sponsor, New Jersey Department of Environmental Protection (NJDEP), and based on knowledge of the areas of greatest flood damage from the main stem of the Delaware River, the purpose of the Delaware River Basin Comprehensive Flood Risk Management Interim Feasibility Study and Integrated Environmental Assessment for New Jersey was to evaluate the feasibility of Federal participation in implementing flood risk management along the Delaware River in the municipalities of Knowlton Township, Belvidere, White Township, Harmony Township, Philipsburg, Pohatcong Township, Holland Township, Frenchtown, Kingwood Township, Stockton, Lambertville, Hopewell Township, Ewing Township and Trenton, New Jersey. The study also investigated flooding and associated ecosystem restoration issues along the Delaware River in the Gibbstown area of Logan and Greenwich Townships. More specifically, the screening:

1) identified flooding problems in the communities listed above associated with major storm events in September 2004, April 2005 and June 2006;

2) identified potential flooding issues and associated ecosystem restoration opportunities along the Delaware River in Logan and Greenwich Townships in Gloucester County;

3) evaluated the technical, economic, environmental, and institutional feasibility of Federal participation in the implementation of identified projects; and

4) determined whether there is local support for implementation of the recommended plans.

## COORDINATION

The study was developed in partnership with NJDEP. A scoping letter soliciting input on the proposed study was also sent to appropriate state and Federal agencies as well as other potentially interested parties in January 2011. In addition, numerous meetings were held with local elected and appointed municipal officials, as well as with the general public.

The Draft Environmental Assessment (EA), as part of an integrated Draft Feasibility Study, was forwarded to the U.S. Environmental Protection Agency (EPA), Region II, the U.S. Fish and

Wildlife Service (USFWS), the National Marine Fisheries Service (NMFS), NJDEP, and all other known interested parties.

**ENDANGERED SPECIES**

Consultation with the USFWS and the NMFS has determined that the project is within the range of the federally listed Indiana bat (Myotis sodalist) and the proposed listed Northern long-eared bat (Myotis septentrionalis) . Through continued informal consultation with the USFWS, New Jersey Field Office, surveys to determine the presence or absence of roosting trees will be performed in the next phase of the study. In addition, if trees suitable for roosting are found in the project area, seasonal restrictions on tree removal activities will be instituted during construction to minimize any impacts on federally listed bats. Pursuant to Section 7 of the Endangered Species Act of 1973 as amended by P.L. 96-159 and SMART Planning Guidance, consultation with the USFWS and NMFS will be completed on this study prior to the Civil Works Review Board (CWRB) Milestone.

**WATER QUALITY COMPLIANCE**

Pursuant to Section 401 of the Clean Water Act, a 401 Water Quality Certificate will be obtained from NJDEP prior to project construction.

**WETLANDS**

There are wetlands found in the project area and the Tentatively Selected Plan will have an impact on those areas. The project team, in coordination with other state and Federal agencies, has attempted to avoid, minimize, and for unavoidable impacts, proposes appropriate mitigation for wetland impacts associated with this project. The estimated amount of wetland impacts is 11.5 acres and our mitigation plan (HEP-based and consistent with the National Wetland No Net Loss Policy) proposes the creation of 12.5 acres to compensate for this loss.

**COASTAL ZONE**

Based on the information gathered during the preparation of the Environmental Assessment, the project is not located in the area defined under the Coastal Zone Management Act of 1972. Therefore, the project will not need a federal consistency determination in regards to the Coastal Zone Management Program of New Jersey.

**CULTURAL RESOURCES**

The Phase IB shovel testing for the Lambertville alignment identified no archaeological sites; however, if the proposed Lambertville flood risk management structure is constructed on the current alignment, deep archaeological testing is recommended to test the Bw horizon at greater depth. The low artifact density in the Gibbstown area, lack of diagnostic artifacts and lack of stratigraphic integrity makes it unlikely that further work at the site would yield significant information pertaining to the region’s prehistory. No further work is recommended for the Gibbstown area. In addition, no Historic Structures analysis was conducted at this time for the Lambertville or Gibbstown Alternatives; however, several resources eligible for or listed on the National Register of Historic Places are within the project’s Area of Potential Effect. The Corps will negotiate a Programmatic Agreement (PA) with the New Jersey State Historic Preservation Office, the Tribes and other interested parties pursuant to 36 CFR 800.14(b)(1). The PA will stipulate the necessary actions to be completed in order for the Corps to comply with Section 106 of the National Historic Preservation Act during the Project Engineering and Design phase.

**RECOMMENDATION**

Because all significant impacts have been mitigated and the Environmental Assessment concludes that the work described is not a major Federal action significantly affecting the human environment, I have determined that an Environmental Impact Statement is not required.

___________________________________ __________________

Michael A. Bliss, P.E. Date
Lieutenant Colonel, Corps of Engineers
District Commander

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## Contributions to the US Army Corps of Engineers Campaign Plan

The US Army Corps of Engineers (Corps or USACE) is implementing focused and disciplined strategic change defined by the goals and objectives in the Fiscal Years (FY) 2015-19 USACE Campaign Plan (UCP).

Four goals define the strategic change the Corps will achieve with the FY15-19 UCP: (1) Support National Security; (2) Transform Civil Works; (3) Reduce Disaster Risks; and (4) Prepare for Tomorrow.

Transforming Civil Works will enable the Corps to deliver the best possible products and services to the Nation by modernizing the project planning program. The Delaware River Basin Comprehensive Flood Risk Management Interim Feasibility Study and Integrated Environmental Assessment for New Jersey (Interim Feasibility Study for New Jersey) contributes to that modernization through transition to an updated study process. Planning is being conducted with vertical coordination during the study process, with a goal of identifying and resolving policy, technical and legal issues early in the process. A full array of alternatives is being considered, but feasibility-level design work will focus on the agency recommended plan. In addition, the level of detail, data collection and modeling is based on what is necessary to conduct and deliver the feasibility study.

Reduction in Disaster Risk will be achieved through the reduction in flood risk offered by the recommended floodwall/levee systems and the accompanying nonstructural measures of acquisitions and ring structures. This will allow the municipalities to withstand the impacts of storms, be more resilient in their recovery from storms and, in the case of Greenwich and Logan Townships, be more robust in the face of future sea level rise.

Preparing for Tomorrow involves creating resilient people, teams, systems and processes to sustain a diverse culture of collaboration, innovation and participation to shape and deliver strategic solutions. The Interim Feasibility Study for New Jersey contributes to this effort through ongoing coordination with the Flood Risk Management Center of Expertise to learn from Corps-wide efforts, as well as sharing information with others within the Corps. The study team conducted an innovative public input process, which was then presented to flood risk management professionals within, and outside, the Corps. In addition, the study team maintains a robust website, including explanatory videos the team made to communicate technical concepts in laypersons' terms.

## Environmental Operating Principles

The US Army Corps of Engineers (Corps) Environmental Operating Principles (Principles) were developed to ensure that Corps missions include integrated and sustainable environmental practices. The Principles are listed below.

- Foster sustainability as a way of life throughout the organization.
- Proactively consider environmental consequences of all Corps activities and act accordingly.
- Create mutually supporting economic and environmentally sustainable solutions.
- Continue to meet our corporate responsibility and accountability under the law for activities undertaken by the Corps, which may impact human and natural environments.
- Consider the environment in employing a risk management and systems approach throughout life cycles of projects and programs.
- Leverage scientific, economic and social knowledge to understand the environmental context and effects of Corps actions in a collaborative manner.
- Employ an open, transparent process that respects views of individuals and groups interested in Corps activities.

Development of the Tentatively Selected Plan for the Delaware River Basin Comprehensive Flood Risk Management Interim Feasibility Study and Integrated Environmental Assessment for New Jersey (Interim Feasibility Study for New Jersey) **strived to achieve environmental sustainability** by examining all types of solutions (structural and non-structural) to flooding problems in the study area. The feasibility study team coordinated with the appropriate environmental agencies early in the study process in order to **proactively consider environmental consequences.** The project **created mutually supporting economic and environmentally sustainable solutions** by recommending both structural and non-structural measures to solve the needs of the local communities found within the study area. The Tentatively Selected Plan is consistent with all applicable laws and policies, and the Corps and its non-Federal sponsors **continue to meet corporate responsibility and accountability** for the project in accordance with those laws and policies. The study team used appropriate assessment methodologies to assess cumulative impacts to the environment through the National Environmental Policy Act and the use of engineering models, environmental surveys, and coordination with natural resource agencies. As a result of **employing a risk management and systems approach throughout the life cycle of the project,** the conceptual project design evolved to address as many concerns as possible and appropriate mitigation is proposed to address unavoidable adverse impacts**.** Study activities, including hydrologic, hydraulic, geotechnical, Hazardous, Toxic and Radioactive Waste, economic, cultural resource and biological surveys, **increased the integrated scientific knowledge base** for the Interim Feasibility Study for New Jersey and the **understanding of the environmental context and effects of Corps actions**. The feasibility study process included several public and agency meetings to interact with **individuals and groups interested in the study activities**. Through those meetings and written interactions, the study team **listened actively and respectfully** to project proponents and opponents alike in an effort to find innovative solutions to the flooding problems in the study area.

# Executive Summary

## Study Information

The intent of the Delaware River Basin Comprehensive Flood Risk Management Interim Feasibility Study and Integrated Environmental Assessment for New Jersey is to evaluate potential solutions to flooding problems and related environmental degradation within the Delaware River Basin for New Jersey. This report was prepared as an interim response to the latest project authorization, dated July 20, 2005, where the Secretary of the Army was requested to:

> *"review the report of the Chief of Engineers on the Delaware River and its tributaries, Pennsylvania, New Jersey, and New York, published as House Document 179, Seventy Third Congress, Second Session, with a view to determining whether any modifications of the recommendations contained therein are advisable in the interest of ecosystem restoration, floodplain management, flood control, water quality control, groundwater and subsidence management, comprehensive watershed management, recreation, and other allied purposes."*

This study was also included in the Second Interim Report to Congress pursuant to Disaster Relief Appropriations Act, 2013 (Public Law 113-2), resulting from Hurricane Sandy.

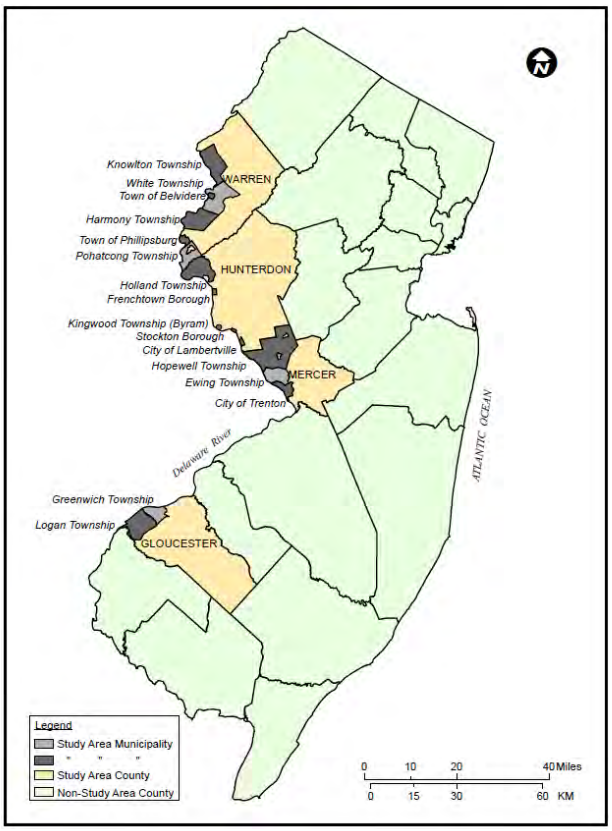


**Figure ES1: Study Area Map**

## Problem

The study area experiences significant flood related damages from two types of flooding events.

1. Riverine (fluvial) flooding from the Delaware River occurs in the study area during hurricanes, thunderstorms, northeasters, snowmelt, ice jams, or a combination of these events.

2. Tidal flooding from the Delaware River in the southern part of the study area also occurs and is caused by several factors: high flows from the upper river, high spring tides resulting from tidal fluctuations, and wind tides produced by hurricanes or other storm action.

## Plan Formulation

The goal of selecting a flood risk management plan is to decrease the study area's current risk from flooding.

In support of this goal, the planning objectives of this study are:

1) Reduce flood risk to life, safety and infrastructure associated with Delaware River fluvial conditions in the study area from 2015 to 2065. Provide associated ecosystem restoration, if feasible.

2) Reduce flood risk to life, safety and infrastructure associated with Delaware River tidal conditions and sea level rise within the study area from 2015 to 2065, where applicable. Provide associated ecosystem restoration, if feasible.

Several regional, structural, non-structural and ecological flood risk management measures were considered as part of a solution to address the planning objectives above. Each of the measures was initially evaluated on completeness, effectiveness, efficiency and acceptability in each municipality using specific screening criteria. Table ES1 shows how each measure would address the study objectives.

**Table ES1: How Management Measures Address Objectives**

| | Measure | Objective 1: Reduce risk from Riverine (Fluvial) Flooding | Objective 2: Reduce risk from Tidal Flooding |
|---|---|---|---|
| Regional Measures | Flood Warning System | Work together to reduce risk to life and property by lowering flood stages or providing advanced warning | If incorporated in tidal areas it may provide warning time for the residents |
| | Reservoir Management | | N/A |
| | Regional Dam | | |
| Structural Measures | Backflow Prevention Structures | Reduce Stages in Tributaries to the Delaware River | Reduce Stages in Tributaries to the Delaware River |
| | Levees and Floodwalls | Reduce flood stages behind levee/floodwall alignment | Reduce flood stages behind levee/floodwall alignment |
| | Channel Modification | Alters the magnitude, direction, or timing of flows to reduce stages along the Delaware River. | N/A |
| | Dam Removal | | |
| Nonstructural Measures | Land Use Regulations | Reduce risk to property damage and risk to life by modifying the structures that are subject to flood risk. | Reduce risk to property damage and risk to life by modifying the structures that are subject to flood risk. |
| | Building Retrofits | | |
| | Land Acquisition | | |
| | Easements and Deed Restrictions | | |
| Ecological | Floodplain Reclamation/Wetland Restoration | Alters the magnitude and timing of flows to reduce stages along the Delaware River. | Restore natural tidal flows |

The measures in Table ES1 are all generally feasible flood risk management solutions, but the level of effectiveness of each measure had to be evaluated to the specific, local conditions and constraints of this study. Several formulations of viable measures resulted in an array of Alternative Plans that were then evaluated individually based on economics, risks to life safety, implementation constraints, engineering feasibility, environmental impact, and agency and social acceptance.

## Alternative Plans Considered

After the evaluation process was complete, a focused array of feasible Alternatives were analyzed and compared to determine which Alternative resulted in the highest Net Excess Benefits. After a refined analysis of the Alternative Plans considered it became apparent that cost effective options remained feasible in Gibbstown (Logan and Greenwich Townships) and the northern portion of Lambertville. Table ES2 provides a brief description of each of the Alternative Plans that were subjected to a detailed comparison for the identification of the Tentatively Selected Plan (TSP).

**Table ES2: Focused Array of Alternatives**

| Alternative | Description |
|---|---|
| **Lambertville (Northern Part of City)** | |
| Alternative #1 | 500 LF of levee along Alexauken Creek with a maximum height of 12 feet, 1,409 LF of floodwall along D&R Canal with a maximum height of 7 feet, 1 property buy-out and demolition, and the construction of a 54 inch diameter gravity outlet in the area of Ely Creek. |
| **Gibbstown (Logan and Greenwich Townships)** | |
| Alternative #1 (Lowest Construction Cost Plan) | 7,386 LF of levee with a maximum height of 12 feet, 13,788 LF of floodwall with a maximum height of 10 feet (primarily concrete T-wall with piles), the construction of two swing closure gates, acquisition of 17 structures and nonstructural protection (ringwall) for 3 commercial properties outside line of protection, and interior drainage features. |
| Alternative #2 (Maximum Wetland Avoidance Plan) | This Alternative follows the same alignment as Alternative #1, but replaced levee sections with floodwalls to avoid impacts to the wetlands. |
| Alternative #3 (Intermediate Wetland Avoidance Plan) | This plan follows the same alignment as Alternative #1 and Alternative #2, but replaced fewer levee sections with floodwalls compared to Alternative #2 and was considered a balance between Alternative #1 and Alternative #2. |

## Tentatively Selected Plan (TSP)

The TSP for Lambertville is Alternative #1, which includes a system of levees and floodwalls with gravity drainage outlets and the buyout and demolition of one structure riverward of the proposed line of protection as shown in Figure ES2. Due to the limited size of the proposed project and a preliminary cost within the limits of the Corps' Continuing Authorities Program (CAP), it is anticipated that the Lambertville segment of the TSP will be converted to the CAP.

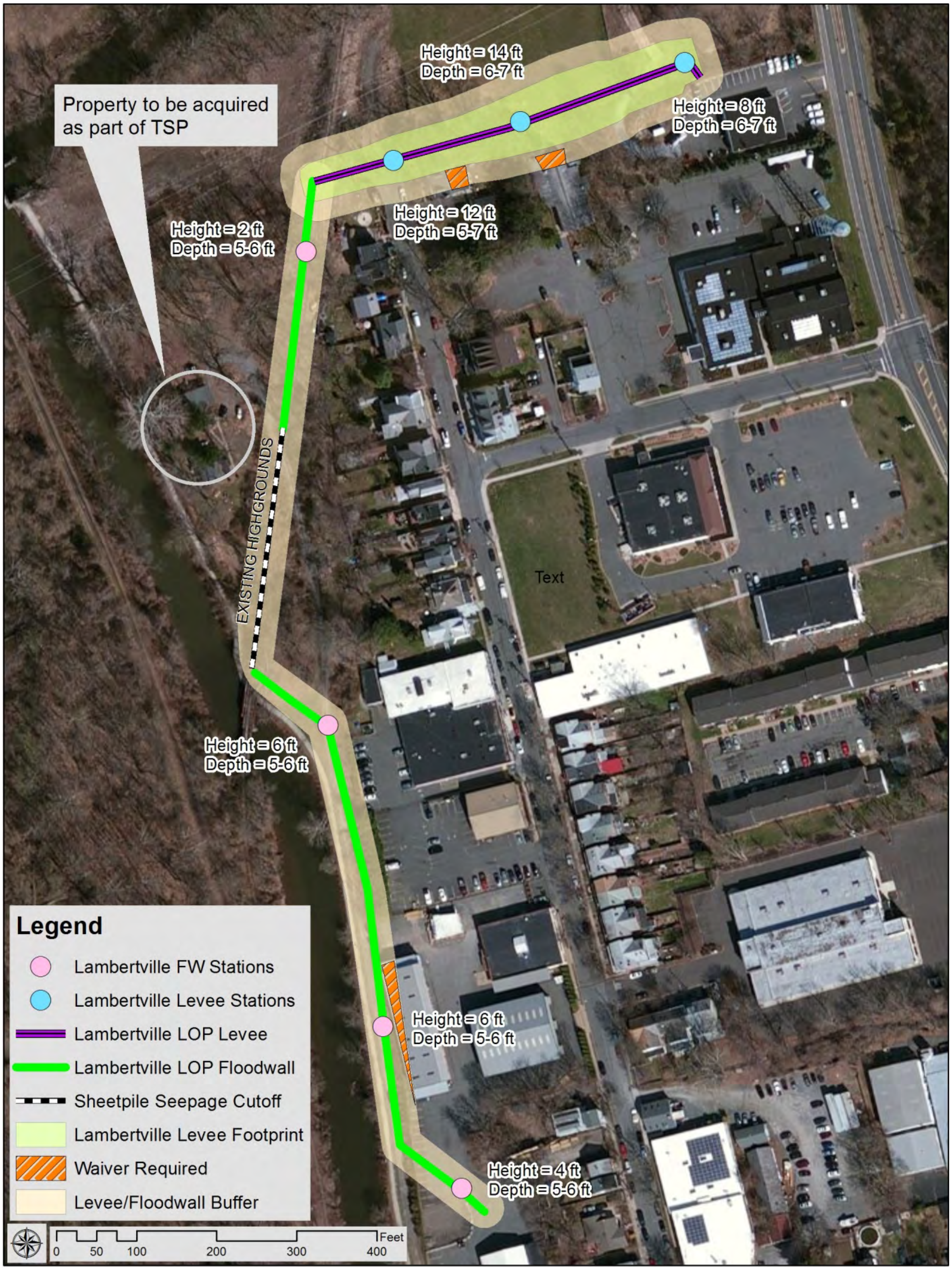


**Figure ES2: TSP Lambertville**

In Gibbstown the TSP is Alternative #1, presented in Figure ES3. Alternative #1 includes a system of levees and floodwalls with gravity drainage outlets and buyouts of 17 structures located outside of the levee system and construction of ring levees/floodwalls for three industrial facilities.

Approximately 11.5 acres of wetlands will be impacted by the Gibbstown levee/floodwall system and ringwalls. Approximately 12.5 acres of mitigation is planned. The flood risk management system will also have an impact on movement of fish in the Repaupo Creek watershed. The impact will be mitigated with "fish friendly" floodgates at the two largest creeks.

## First Cost of Construction

The estimated first cost of construction for the TSP is approximately $190.8 million. First cost of construction for Lambertville is approximately $8.9 million and the first cost for Gibbstown is approximately $181.9 million.

## Economic Feasibility

As presented in Table ES3, project benefits outweigh the project cost of the project. The benefit-to-cost ratio is estimated to be 1.8 to 1.

**Table ES3: TSP Economic Summary**

| | Gibbstown | Lambertville | **Total** |
|---|---|---|---|
| **Total Annual Benefits** | $14.9 million | $805,000 | **$15.7 million** |
| **Total Annual Costs** | $8.3 million | $432,000 | **$8.7 million** |
| **Net Benefits** | $6.6 million | $373,000 | **$7.0 million** |
| **BCR** | 1.8 | 1.9 | **1.8** |

Price Level: April 2014, Interest Rate: 3.50%, Period of Analysis: 50 Years

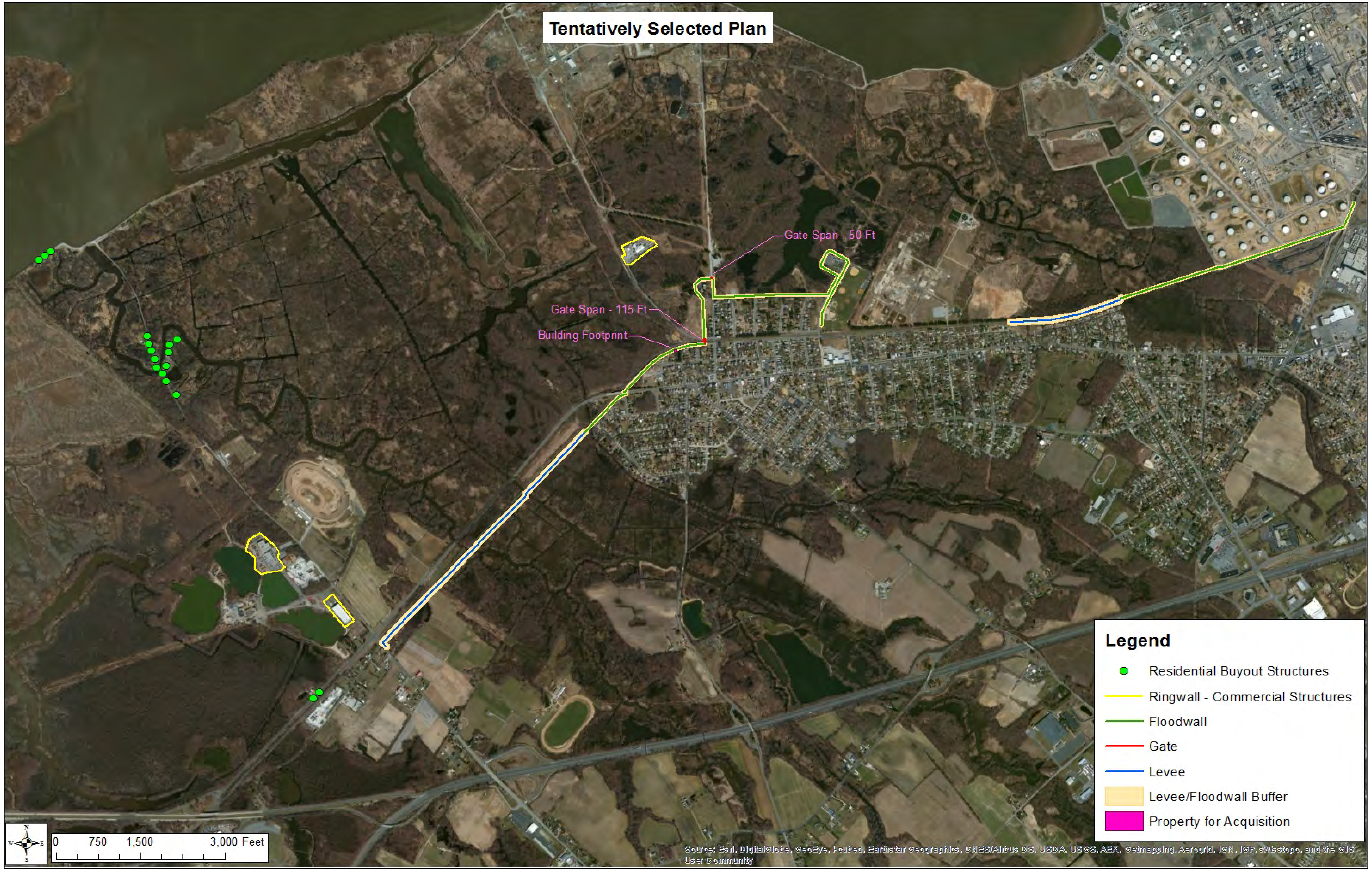


**Figure ES3: TSP Gibbstown**

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# 1 Introduction

The Delaware River Basin Comprehensive Flood Risk Management Interim Feasibility Study and Integrated Environmental Assessment for New Jersey (herein called "Interim Feasibility Study for New Jersey") is in the Feasibility Phase. This report is identified as an interim report because it partially responds to the authority (see full Study Authorization in Section 1.1). Its interim intent is to evaluate potential solutions to flooding problems and related environmental degradation within the Delaware River Basin for New Jersey alone.

This Interim Feasibility Study for New Jersey has been prepared by the Philadelphia District (District) of the U.S. Army Corps of Engineers (Corps) in accordance with the subject authority. Federal interest was established during the Reconnaissance Phase and a Feasibility Cost Sharing Agreement (FCSA) was signed between the District and the non-Federal sponsor, New Jersey Department of Environmental Protection (NJDEP), on July 27, 2006.

This Interim Study for New Jersey investigates the feasibility of alternative plans to address problems and opportunities along the Delaware River in the municipalities of Knowlton, Belvidere, White, Harmony, Phillipsburg, Pohatcong, Holland, Frenchtown, Kingwood, Stockton, Lambertville, Hopewell, Ewing and Trenton, New Jersey. These municipalities were found by the non-Federal sponsor to experience significant flooding from the Delaware River in 2004, 2005 and 2006 during intense storms snowmelt, ice jams and a combination of these events. The study also investigates flooding and associated ecosystem restoration issues along the Delaware River in Logan and Greenwich Townships, New Jersey caused by high upstream rainfall discharges and/or high ocean surge. Figure 1.1 presents a map of the study area.

## 1.1 Study Authority*

The Corps has been given the authority under Section 729 of the Water Resources Development Act (WRDA) of 1986, as amended by Section 202 of WRDA 2002, to conduct a Reconnaissance study and ensuing Feasibility level investigations in the Delaware River Basin.

In a more recent project authorization, dated July 20, 2005, the Secretary of the Army was requested to:

> *"review the report of the Chief of Engineers on the Delaware River and its tributaries, Pennsylvania, New Jersey, and New York, published as House Document 179, Seventy Third Congress, Second Session, with a view to determining whether any modifications of the recommendations contained therein are advisable in the interest of ecosystem restoration, floodplain management, flood control, water quality control, groundwater and subsidence management, comprehensive watershed management, recreation, and other allied purposes."*

The referenced 1984 Chief's Report concluded an analysis of flooding along the main stem Delaware River and an investigation into potential flood risk management measures. The study determined that local structural protective works could not be economically justified and that nonstructural measures could potentially be pursued further under the Corps'

Continuing Authorities Program. The Report recommended that flood risk be addressed both directly and indirectly on the local level.

### 1.1.1 Supplemental Authority

This study was also included in the Second Interim Report to Congress pursuant to Disaster Relief Appropriations Act, 2013 (Public Law 113-2). Public Law 113-2 was passed by Congress and signed into law by the President on January 29, 2013. The legislation provides supplemental appropriations to address damages caused by Hurricane Sandy and to reduce future flood risk in ways that will support the long-term sustainability of the ecosystem and communities and reduce the economic costs and risks associated with large-scale flood and storm events. The legislation provides funds to expedite and complete ongoing flood and storm damage protection in areas impacted by Hurricane Sandy within the boundaries of the Corps' North Atlantic Division. Feasibility studies that are already underway, such as this study, are eligible to be considered for initial construction funding under this provision. If PL 113-2 funding is not available for initial construction, then a separate authority will be pursued to authorize initial construction.

## 1.2 Study Area

The study area encompasses the 0.2% annual chance of exceedance (ACE) (500-year) floodplain of the Delaware River in New Jersey as identified by the Federal Emergency Management Agency's (FEMA) Q3 Shapefiles, a digital representation of the floodplain from the effective Flood Insurance Rate Maps (FIRMs). A general map of the study area is provided in Figure 1.1 below. Detailed figures showing the Q3 floodplains along with the building inventory utilized as part of this study effort are provided in Appendix H: Plan Formulation: Details of Phases 1 & 2.

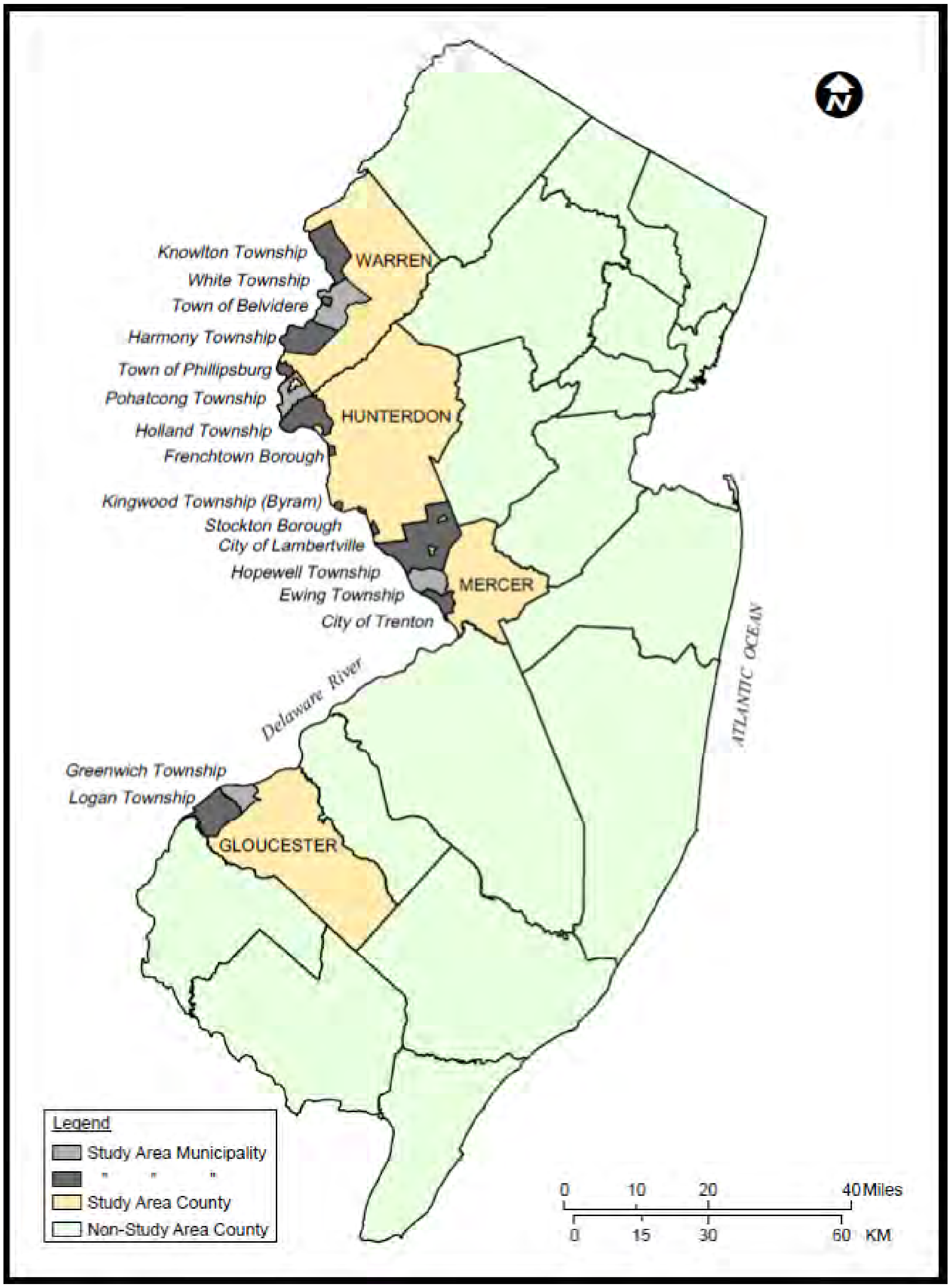


**Figure 1.1: Project Area Map**

## 1.3 Report Organization

This document has been organized in a manner consistent with USACE requirements for feasibility reports. The main report summarizes the results of feasibility studies, and the technical appendices present the details of the technical investigations conducted during the Interim Feasibility Study for New Jersey.

Chapter 2 of this study provides a summary of Federal and local participation in previous studies or projects within the bounds of the study area.

Chapter 3 of this study reviews the existing site conditions pertinent to quantifying the "with" and "without" project consequences.

Chapter 4 reviews the "without" project conditions along the study area.

Chapter 5 identifies the storm damage problems, opportunities and constraints along the study area. It also quantifies the without project damages for period-of-analysis (2015-2065). It then provides an overview of the step-by-step process leading up to the identification of the Tentatively Selected Plan.

Chapter 6 describes the components, impacts, economics, risks and uncertainties of the Selected Plan.

Chapter 7 reviews the implementation process, schedule and the cost-sharing agreement for the Selected Plan.

Chapter 8 includes information on the public review process.

Chapter 9 contains the outcome of this study recommended by the District Engineer.

Chapter 10 provides a comprehensive list of those involved in producing the analyses, documentation and decisions contained herein.

Chapter 11 lists the sources referenced throughout the report.

# 2 Prior Studies and Actions on the Delaware River

Prior studies and actions are described below for the overall Delaware River Basin and Greenwich and Logan Townships (known as “Gibbstown” or “Repaupo Watershed”).

## 2.1 Delaware River Basin in General

*Delaware River Basin Flood Analysis Model Project*, 2010, United States Geological Survey (USGS) and U.S. Army Corps of Engineers Hydrologic Engineering Center (HEC). The USGS-developed model provides flood hydrographs at existing National Weather Service (NWS) flood forecast points and reservoir stage, storage and discharge hydrographs. HEC developed a RES-SIM model which was used to evaluate effects of reservoir voids and release operations on downstream flood crests.

*Updated Flood Insurance Study & Flood Hazard Delineation for New Jersey*, 2010 and ongoing, FEMA. This study involved preparation of new floodplain delineations and associated mapping for 126 miles along the main stem of the Delaware River on the New Jersey side.

*Flood Warning Improvements in the Delaware River Basin*, 2010, NWS. The effort included evaluation and improvement of existing precipitation and stream gage networks, as well as creation of flood inundation maps.

*A Multi-Jurisdictional Flood Mitigation Plan for Municipalities in the Non-tidal, New Jersey portion of the Delaware River Basin*, 2008, DRBC. Provides local flood mitigation plans for 43 municipalities in Mercer, Hunterdon, Warren & Sussex Counties in NJ.

*Flood Magnitude and Frequency of the Delaware River in New Jersey, New York, and Pennsylvania*, 2008, USGS. This paper updates the flood magnitude and frequency figures for the eight active streamflow gaging stations along the main stem Delaware River in New Jersey, New York, and Pennsylvania.

*Lambertville – Swan Creek Watershed Preliminary Flood Damage and Mitigation Report*, 2007, USDA NRCS. Report studied the feasibility of an engineering solution to the Delaware River back-flooding into Swan Creek which impacts neighboring homes and businesses.

*Flexible Flow Management Program for the New York City Delaware Basin Reservoirs*, 2007, Decree Parties to the DRBC. The FFMP provides a comprehensive framework for addressing multiple flow management objectives.

*Delaware River Basin Interstate Flood Mitigation Task Force Action Agenda*, July 2007, Delaware River Basin Interstate Flood Mitigation Task Force. The action agenda provides a set of recommended measures for mitigating and alleviating flooding impacts along the Delaware River and its tributaries, using a watershed approach.

*Report on Delaware River Flood Mitigation*, August 2006, New Jersey Flood Mitigation Task Force. This report reviews causes for the April 2005 flooding, reviews responses of government agencies, and recommends measures to reduce impacts and likelihood of future flooding and improve communications and assistance to residents before, during and after a flood.

*Delaware River Basin Study Survey Report*, August 1984, Corps of Engineers. This report included an analysis of the economic justification of nonstructural flood risk management in 58 communities along the main stem Delaware River. Structural alternatives were also incorporated into the screening process.

*Delaware River Basin Comprehensive Study (Level B Study)*, May 1981, DRBC. This final report was prepared to provide a basis for updating a comprehensive plan of DRBC for development of water resources.

*Delaware River Basin Study Reconnaissance Report, Stage 1, Flood Damage Reduction Study,* August 1979, Corps of Engineers. The report concluded that for a study area along the main stem Delaware River from Tocks Island to Burlington, NJ, a flood damage reduction program composed of a mix of nonstructural measures would be viable.

*A Comprehensive Study of the Tocks Island Lake Project and Alternatives,* June 1975, URS/Madigan-Praeger, Inc. and Conklin & Rossant. The report considered the proposed dam across the Delaware River at Tocks Island, as well as alternatives. The report did not make recommendations.

*Delaware River Basin, NY, NJ, PA and DE,* August 1962, Corps of Engineers. This study provided a comprehensive plan for development of water resources of the Delaware River Basin.

*Report on the Comprehensive Survey of the Water Resources of the Delaware River Basin,* December 1960, Corps of Engineers. The purpose of this report was to project and plan for water resource requirements in the Delaware River Basin.

*Delaware River Basin, NY, NJ, PA and DE,* 1933, Corps of Engineers. The "308" Report provided preliminary study of water resources of the Basin as part of a national survey.

## 2.2 Flood Risk in Logan and Greenwich Townships

*South Jersey Levee Inventory,* 2010, USDA NRCS Assisting NJ Department of Environmental Protection. Field inventory and LiDAR mapping to identify and characterize the location, extent, and characteristics of existing levees/dikes in and along the Delaware Bay and lower Delaware River, including the Repaupo Levee.

*Floodgate Replacement and Partial Levee Elevation,* June 2009, Gloucester County Improvement Authority. This work was conducted with a grant from the State of New Jersey.

*2007 Inspection of Local Flood Damage Reduction Project, Gibbstown, New Jersey,* November 2007, Corps of Engineers. Inspection was conducted for Public Law 84-99 eligibility. The project was rated Unacceptable due to lack of a public sponsor for the entire levee.

*Preliminary Estimates of Costs and Benefits of Alternative Solutions for Flood Damage Reduction – Repaupo Creek Watershed, Gloucester County, New Jersey*, 1996, USDA NRCS in cooperation with Gloucester County Soil Conservation District. Report reviewed available data on the watershed, provided preliminary estimates of benefits and costs of flood risk management, considered environmental and cultural resources concerns for each alternative, and identified potential funding sources.

*Gibbstown Levee Rehabilitation Report,* June 1962, Corps of Engineers. Resulted in rehabilitation to the portion of the dike within Greenwich Township. No repairs were made to the Repaupo Floodgates.

## 2.3 Existing Flood Risk Management Programs

Existing Federal, bi-State, State and local programs for the management of floodplains and stormwater run-off include:

- FEMA's National Flood Insurance Program
- Delaware River Basin Commission (DRBC)
- New Jersey State Programs
- Local Programs

### 2.3.1 National Flood Insurance Program

FEMA, through its Mitigation Directorate, manages the National Flood Insurance Program (NFIP). The three components of the NFIP are: flood insurance, floodplain management, and flood hazard mapping.

### 2.3.2 Delaware River Basin Commission (DRBC)

This interstate commission was created to manage the water resources of the Delaware River. The DRBC develops and implements programs and policies that promote sustainable watershed management, watershed education, and water conservation. The Commission also collects and disseminates hydrologic, water quality, Geographical Information System (GIS), and regulatory information via its website at http://www.state.nj.us/drbc/. The hydrologic information includes reservoir storage levels, daily flows, drought information, floods, and weather and tide predictions.

In 2008, the DRBC published the first *State of the Delaware River Basin Report*, which described current environmental conditions and serves as a benchmark with which to compare future conditions. The DRBC also published a *Draft Flood Profile and Mitigation Action Plan by Jurisdiction* in 2008.

### 2.3.3 New Jersey State Programs

NJDEP is responsible for floodplain management in the State of New Jersey. The state regulates work in flood hazard areas and riparian zones to ensure that buildings are placed in safe areas, and are constructed to withstand high water, and also, to preserve and protect riverine habitat and the water quality of the State's surface waters.

The NJDEP has adopted revised Flood Hazard Area Control Act rules (N.J.A.C. 7:13, date November 5, 2007), as well as related amendments to the Coastal Permit Program rules (N.J.A.C. 7:7, date September 7, 2010) and the Coastal Zone Management rules (N.J.A.C. 7:7E, date September 7, 2010), in order to incorporate more stringent standards for development in flood hazard areas and riparian zones adjacent to surface waters throughout the State. The Department has adopted these new rules in order to better protect the public from the hazards of flooding, preserve the quality of surface waters, and protect the wildlife and vegetation that exist within and depend upon such areas for sustenance and habitat. A 0% net-fill requirement (which was previously implemented only in the Highlands Preservation Area and Central Passaic Basin) now applies to all non-tidal flood hazard areas of the State.

The revised rules also expand the preservation of near-stream vegetation by implementing new riparian zones that are 50, 150 or 300 feet in width along each side of surface waters throughout the State.

The Department has incorporated the new flood hazard area and riparian zone standards into the review of all Coastal Area Facility Review Act (CAFRA) and Waterfront Development permits, thereby eliminating a gap in the previous rules under which development in tidal areas was not reviewed under the same standards that applied to non-tidal areas

### 2.3.4 Local Programs

The communities within the study area, through their participation in the NFIP, have adopted and implemented local flood management ordinances and most have prepared flood hazard plans, which qualify the communities to apply for hazard mitigation funds from FEMA.

# 3 Flood History and Character in Study Area

This Interim Feasibility Study for New Jersey covers two distinct study areas. For the northern, non-tidal area, from Trenton and North, the report focuses on the towns impacted from the flooding that occurred in 2004, 2005 and 2006. For the southern tidal areas in Logan and Greenwich Townships, the report focuses on flood risk and flooding as a result of Hurricane Sandy (October 29-30, 2012).

The Delaware River has a long history of flooding dating back to the late 1800s. Most flooding is due to severe storms associated with tropical storms (e.g. hurricanes) or extra-tropical storms, such as thunderstorms and northeasters. Other floods are caused by combinations of storms, snowmelt, ice jams and tidal action. Further information on flooding history can be found in Appendix A: Engineering Technical Appendix, Section 2: Hydrology and Hydraulics. Further information on historical damages can be found in Appendix C: Economic Analysis.

## 3.1 Flooding in Trenton and North

The flood of record in the Delaware Basin was the 1955 storm that caused $2.8 billion in damages in current dollars.

There were three major floods on the Delaware between September 2004 and June 2006 that resulted in close to $745 million worth of damage in the states of New York, New Jersey and Pennsylvania.

<u>September 17-19, 2004</u>: The remnants of Tropical Storm Ivan, interacting with a cold front that dropped into the northeastern United States late Friday, September 17, 2004, produced tremendous rainfall amounts across northeast Pennsylvania and southern New York. Most of the Delaware River Basin upstream of Trenton received three- to five-inches of rain in a 12-hour period, with some isolated areas receiving as much as seven or eight inches, while many areas in the southern half of the watershed received an inch or less. This rain fell on soils already saturated by a wet summer, including Tropical Storm Frances just a week before.

<u>April 2-4, 2005</u>: Rainfall totaling as much as 5 inches, combined with wet antecedent conditions caused by more than 2 inches of rain that fell less than a week earlier (March 28-29), and snow cover in the northern part of the Basin set the stage for the worst flooding in 50 years along the main stem of the Delaware River. Along the main stem, the flood crests exceeded those reached in Tropical Storm Ivan only six-and-a-half months earlier, and again caused evacuations, bridge and road closures, and extensive damage. Reservoirs in the Upper Basin were at capacity and spilling during the storm. The Cannonsville and Neversink Reservoirs were spilling prior to the March 28-29 storm, and the Pepacton Reservoir began spilling after the March 28-29 storm. Lake Wallenpaupack in Pennsylvania began spilling for only the eighth time in 80 years during this storm.

<u>June 24-29, 2006:</u> Extremely heavy rainfall over the Basin during the June 24-28 period caused flash flooding and record to near-record flood crests along many streams and rivers throughout the Basin, including the main stem Delaware River. Total rainfall ranged from 3 to 6.5 inches across the New Jersey part of the Basin and 7 to 15 inches in northeastern Pennsylvania. The New York part of the Basin received 6 to 14 inches during the same period. Heavy rainfall during June 24-26 saturated the ground and produced bank full and

minor flooding conditions by early Tuesday, June 27. Most flooding in New Jersey occurred along the main stem of the Delaware River.

## 3.2 Flood Risk in Tidal Area, Greenwich and Logan Townships (Gibbstown)

Flood risk in the Gibbstown area of Greenwich and Logan Townships is closely associated with its location near the Delaware River and its extremely low elevation of 13 feet. Additionally, flood risk and flooding to date is related to the condition of an existing dike, or levee, along the river bank.

In the early 1800's the Repaupo Meadow Company (RMC) was chartered. The purpose was to reclaim marshlands in Greenwich and Logan Townships. A 4.5 mile long dike (sometimes referred to as the Gibbstown Levee or Repaupo Levee) was built to keep out waters from the Delaware River and five tide gates were constructed on the five interior creeks (Repaupo Creek, White Sluice Creek, Race Still Run/Sand Ditch, an unnamed stream, and Clonmell Creek) to drain the meadows at low tide. Salt hay was then harvested as a commercial product and some development, including industry, occurred behind the levee. In the early 20th century, as the area industrialized and the market for salt hay dried up, the RMC became little more than an entity on paper, and the infrastructure fell into disrepair.

Sundry stop-gap repairs and flood fighting efforts have been made over the years, but the structural decay has not been addressed in a comprehensive fashion. For instance, during Hurricane Floyd in 1999 the Corps provided 15,000 sandbags and did post-storm floodgate repairs. In 2000 the Corps again provided flood fighting assistance in the form of six 12-inch pumps. In 2001 Greenwich Township replaced damaged gaskets on a floodgate. During Hurricane Isabel in 2003, sandbags were placed across low spots in the structure, but a leak developed. In 2006 emergency repairs were made to a floodgate and in 2009 it was replaced. In preparation for Hurricane Sandy in 2012, local crews created berms along Floodgate Road to contain floodwaters. See Section 4.4.3.1 about the reliability of the dike as it relates to Corps Policy Guidance Letter 26 and plan formulation.

Without a comprehensive plan in place to address the high risk of flooding, the development of this area will continue to be at risk, require patchwork flood fighting during storm events and incur flood related damages during high flow events from the upper river, high spring tide events, and wind tides (storm surge) produced by hurricanes or other storm action.

# 4 Baseline Conditions/Affected Environment*

Due to the geographical separation of the northern and southern sections of the study area, where appropriate below, discussions are organized by these sections. The Northern Section encompasses parts of Warren, Hunterdon, and Mercer Counties, while the Southern Section encompasses parts of Gloucester County.

## 4.1 Physical Setting

### 4.1.1 Geomorphology, Physiography, and Geology

New Jersey has four distinct physiographic provinces, as shown in Figure 4.1. Three of these comprise the northern hilly, mountainous portion of the state. These include, from north to south, the Valley and Ridge, Highlands and Piedmont Physiographic Provinces, and together these three provinces encompass the northern two-fifths of the state. The Valley and Ridge Province is generally represented by high and steep ridges with relatively flat valley bottoms. The Highlands Province is dominated by a high mountainous plateau. The Piedmont Province has a gently rolling hilly terrain.

The southern larger portion of the state is in the Coastal Plain Physiographic Province, and exhibits a generally low flat topography. In New Jersey, the Coastal Plain Province extends from the southeastern terminus of the Piedmont Physiographic Province southeastward for approximately 155 miles to the edge of the Continental Shelf.

### 4.1.2 Topographic Variations in the Physiographic Provinces

The Valley and Ridge Province is generally the highest area of the state. The highest elevations range from around 1,600 to 1,800 feet in elevation (NAVD). Valley floor elevations range from around 400 to 600 feet.

The Highlands Province in general has a rugged topography. The highest elevations in the Highlands range from around 800 to 1,500 feet in elevation. The valley elevations range from 400 to 800 feet with the lowest elevation located along the Delaware River.

The Piedmont Province is primarily a low rolling plain separated by a series of higher ridges. On the foot of the Piedmont, the elevation of the Piedmont ranges from around 300 to 400 feet.

More than half of the land area in the Coastal Plain is below an elevation of 50 feet. The Coastal Plain area is largely surrounded by salty or brackish water. The eastern boundary of the Coastal Plain includes many barrier bars, bays, estuaries, marshes and meadowlands along the Atlantic coast extending from Sandy Hook in the north to Cape May Point at the southern tip of New Jersey. The southern portion of the study area is situated on the western side of the Coastal Plain Physiographic Province extending from Trenton south.

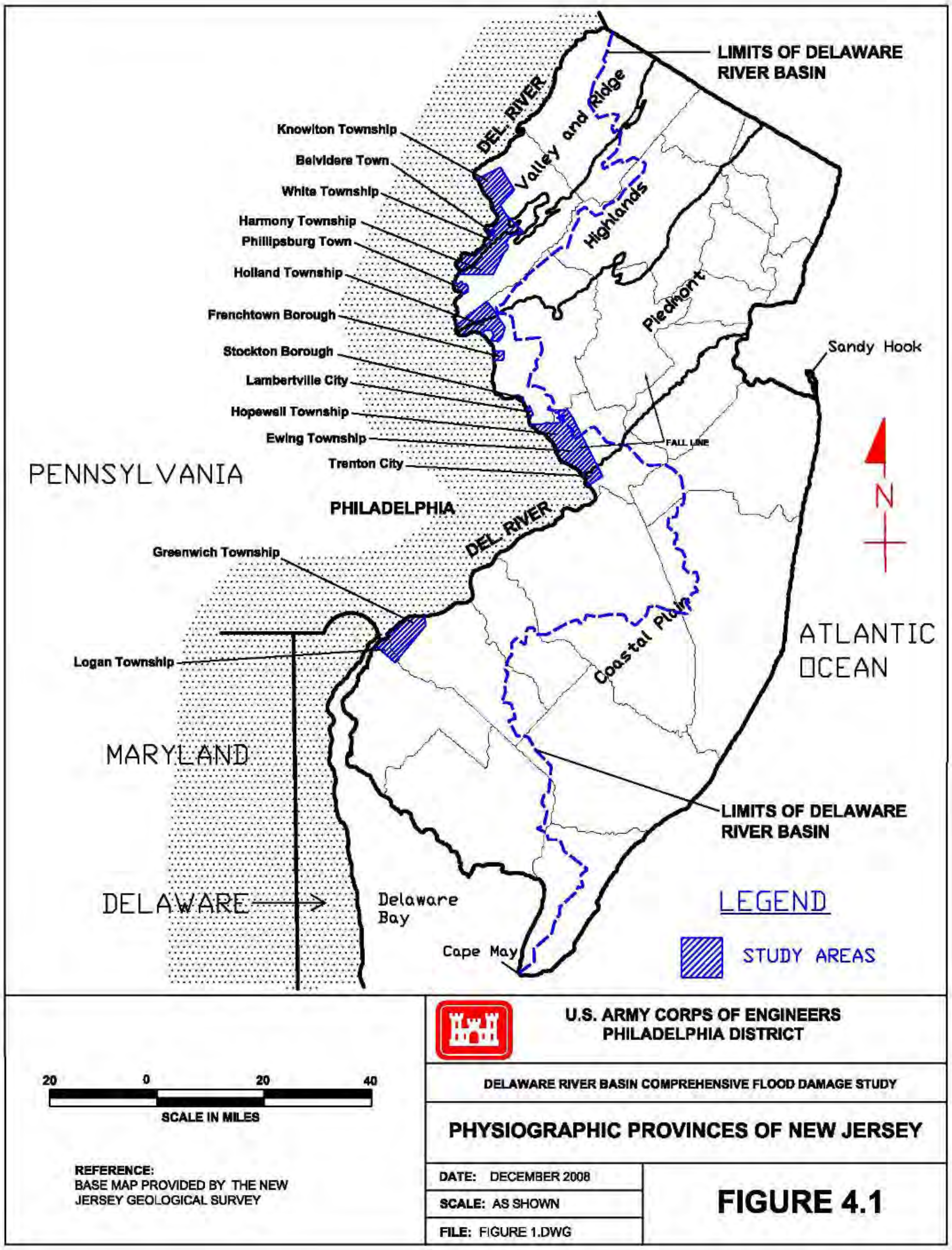


**Figure 4.1: Physiographic Provinces of New Jersey**

### 4.1.3 Drainage

The Delaware River Basin encompasses an area of over 12,700 square miles and includes parts of New York, Pennsylvania, New Jersey and Delaware. The location of the eastern perimeter of the Basin in New Jersey is shown on the Physiographic Provinces Map in Figure 4.1.

The drainage in the Valley and Ridge, Highland and Piedmont Physiographic Provinces is generally controlled by the terrain. The Valley and Ridge Province is drained by tributaries of the Delaware and Hudson Rivers, and Newark and Raritan Bays. The western part of the Highlands Province is drained by tributaries leading to the Delaware River, while the drainage in the remainder of the Highlands is directed by geologically controlled topographic features through tributaries of the Raritan and Passaic Rivers that drain into the Raritan and Newark Bays.

The land surface in the Coastal Plain in southern New Jersey is divided into drainage basins. A major drainage divide in the Coastal Plain separates streams flowing to the Delaware River on the west and to the Atlantic Ocean on the east and southeast.

The surficial drainage system of the New Jersey Coastal Plain was developed at a time when sea level was lower than at present. The subsequent rise in sea level has drowned the mouth of coastal streams where tidal action takes place. Currently, tidal effects extend up the Delaware River to Trenton, New Jersey, a distance of 139 miles.

### 4.1.4 Topography and Land Use

The study area encompasses four counties (see Figure 1.1). Warren County covers 363 square miles and is comprised of approximately 30% agricultural land and nearly 50% forested areas, 12% urban land, 7% wetlands, and about 1% barren land (rock). Hunterdon County has a total area of 438 square miles, of which less than 2% is water. Much of the county is hilly, with the ground rising up slowly from the Delaware River. Mercer County has a total area of 229 square miles with less than 2% water coverage. The county is generally flat and low-lying on the inner coastal plain. Approximately 41% of Mercer County is developed and 22% is agricultural lands. Gloucester County has a total area of 337 square miles, with less than 4% water. Gloucester County is largely composed of low-lying river and coastal plain.

## 4.2 Climate and Weather

The section entitled "Climatology of the Delaware River Basin" in Appendix A: Engineering Technical Appendix, Section 2: Hydrology and Hydraulics characterizes the existing climate and climate trends in the study area.

## 4.3 Air Quality

The Federal Clean Air Act (as amended 1990) requires the U.S. Environmental Protection Agency (EPA) to set National Ambient Air Quality Standards (NAAQS) (40 CFR part 50) for pollutants considered harmful to public health and the environment.

There are seven NAAQS: 1) 8-Hour Ozone; 2) Annual Particle Matter (PM) 2.5; 3) 24-Hour PM2.5; 4) PM10; 5) Sulfur Dioxide; 6) Carbon Monoxide; 7) Nitrogen Dioxide; and 8) Lead.

Within the study area, the counties of Hunterdon and Warren are within the New York-Northern New Jersey-Long Island NY-NJ-CT 8-hour ozone-nonattainment area (marginal), and the counties of Gloucester and Mercer are within the Philadelphia-Wilmington-Atlantic City, PA-NJ-MD-DE 8-hour ozone non-attainment area (marginal).

The 1990 Federal Clean Air Act Amendments directed EPA to develop two federal conformity rules. Those rules (promulgated as 40 CFR Parts 51 and 93) are designed to ensure that federal actions do not cause or contribute to air quality violations in areas that do not meet the NAAQS. The rules include transportation conformity, which applies to transportation plans, programs, and projects; and general conformity. This study falls under the general conformity rule.

## 4.4 Surface Water Resources

The study area is dominated by the Delaware River and its tributaries. The Delaware River is the longest un-dammed river east of the Mississippi River and extends 330 miles from the Catskill Mountains in New York to the mouth of the Delaware Bay. The river is fed by 216 substantial tributaries and is one of the largest rivers on the East Coast. The drainage area of the Delaware River Basin is 13,539 square miles, of which 2,969 square miles are in the State of New Jersey.

### 4.4.1 Existing Federal Water Control Structures

Federal water control projects impacting the study area are the General E. Jadwin Dam and Prompton Reservoir projects in the Lackawaxen River Basin of Pennsylvania, and the Beltzville Lake and Francis E. Walter Dam in the Lehigh River Basin of Pennsylvania (Figure 4.2).

#### 4.4.1.1 General E. Jadwin Dam

The Jadwin Dam project is located on Dyberry Creek, in Wayne County, Pennsylvania, about three miles above the confluence with the Lackawaxen River in Honesdale. The Lackawaxen River is a major tributary of the Delaware River. Jadwin Dam is a single-purpose flood risk management reservoir which, during normal flow conditions, is a "dry dam" providing complete release of flows within the stream channel limits. The reservoir was designed with an uncontrolled outlet works for short-term storage of water. Its primary purpose is to reduce flood stages in the Lackawaxen River at Honesdale and Hawley, Pennsylvania and secondarily in the Delaware River.

#### 4.4.1.2 Prompton Reservoir

The Prompton Reservoir project is located in Wayne County, Pennsylvania on the West Branch Lackawaxen River. The dam is located approximately 30 miles above the confluence of the Lackawaxen River with the Delaware River. Prompton Dam is an earth filled structure with uncontrolled outlet works and was designed primarily for flood risk management purposes. The dam is designed to hold flood water for a short period after a flood event. Its primary purpose is to reduce flood stages in the Lackawaxen River at Honesdale and Hawley, Pennsylvania, and secondarily in the Delaware River.

#### 4.4.1.3 Beltzville Lake

The dam is located on Pohopoco Creek in Pennsylvania four and half miles from its confluence with the Lehigh River. The existing project provides for multiple purpose development for water supply, flood risk management, and recreation. Its primary purpose is to reduce flood stages on the Lehigh River, which is a major tributary of the Delaware River, and secondarily to the main stem Delaware River. The project consists of an earth and rock filled dam, a spillway around the north end of the dam, and gate controlled outlet works discharging through a conduit on rock along the right abutment.

#### 4.4.1.4 Francis E. Walter Dam

The Walter Dam project is located on the Lehigh River in Carbon and Luzerne Counties, Pennsylvania, approximately 75 river miles above its confluence with the Delaware River. The dam is a rolled earth filled flood risk management structure with gate controlled outlet works. The existing dam is operated primarily for flood risk management, and secondarily for recreation and water quality purposes. Its primary purpose is to provide flood risk management along the entire Lehigh River and secondarily along the main stem Delaware River.

### 4.4.2 Existing Non-Federal Water Control Structures

Other major reservoirs in the Basin shown in Figure 4.2 include the New York City water supply reservoirs of Cannonsville, Pepacton and Neversink; the hydroelectric power generation reservoirs of the Mongaup System and Lake Wallenpaupack; and other major multipurpose reservoirs of Lake Nockamixon and Merrill Creek.

### 4.4.3 Existing Local Water Control Projects

There are no major protective works on the main stem Delaware River affecting the study area in the State of New Jersey. The City of Burlington, NJ did construct levees in the past which were designed to protect against a 1% ACE (100 year) event but they have fallen into such disrepair that they no longer can be considered as a flood risk management measure. In the 1800's a 4.5 mile long levee was constructed in what are now Logan and Greenwich Townships in Gloucester County, NJ (also known as Gibbstown). (See Figure 4.3.) The levee was originally constructed to support harvesting of salt hay, but has become locally perceived as providing a level of flood protection. The following sub-section discusses the structural reliability of the levee as it relates to the Corps Policy Guidance Letter 26 and the plan selection process for this study.

#### 4.4.3.1 Policy Guidance Letter 26: Benefit Determination Involving Existing Levees

The purpose of this section of the feasibility report is to provide information as to the current status of the existing Gibbstown Levee/Federally Uncertified Landform (FUL) and provide clarity as to what level of protection the existing structure provides with regard to the Corps plan formulation process. Because of the landform's history, previous damages, and the current state of disrepair, it is believed that the levee cannot be counted on for protection from storm events

The structure was constructed in the early 1800s by the Repaupo Meadow Company (RMC), a public corporation of landowners, and consisted of approximately 4.5 miles of earthen levees and floodgate structures. Its original purpose was to enhance agricultural resources; however, with residential and industrial development in Greenwich and Logan Townships, Gloucester County, the structure came to be depended upon for flood risk management. Despite the RMC being a state-sanctioned entity, by the 1960s it was unable to maintain the structure on its own, and was eventually assisted by the local municipalities and the DuPont Company, which had operated a large industrial plant behind the landform. (DuPont now conducts environmental remediation activities and leases a portion of the site to a carbon dioxide facility.)

In March 1962, a major storm event coupled with high tides severely damaged the landform, and dozens of residences behind the structure were inundated. The portion of the structure from Thompson Point to the downriver end of the structure was restored to pre-storm conditions later the same year by the U.S. Army Corps of Engineers (USACE) under Public Law 84-99 authority. The restoration authorization included wording to the effect that the local interests would operate and maintain the structure. Concurrently, the US Department of Agriculture (USDA) Soil Conservation Service [now Natural Resources Conservation Service (NRCS)] constructed a floodgate at White Sluice Race under Public Law 83-566 authority. Since the 1960s, the levee has continued to suffer sporadic damage, and the floodgate at the confluence of Repaupo Creek with the Delaware River was determined to be structurally inadequate by USACE during inspections in 1997. The RMC became operationally defunct during the 1970s. The townships, DuPont, and Ashland/Hercules, another industrial site behind the landform, have since performed limited levee repairs as necessary, and USACE performed a temporary rehabilitation of the Repaupo Creek Floodgate in 2000 under the Advance Measures authority of PL 84-99, Rehabilitation Inspection Program. USACE has studied the structure under the Continuing Authorities program; however, no current study is ongoing due to lack of sponsor participation.

Further anecdotal evidence from conversations with local emergency management officials indicated that seepage has been observed periodically throughout the levee history during high water events.

In 2007, a Continuing Eligibility Inspection was performed on the site and it was determined to be Unacceptable for eligibility in the PL 84-99 Program primarily due to a lack of a public sponsor, but also due to other deferred maintenance issues. Since that time, the project has been inactive in PL 84-99. Using county and state funding, Gloucester County replaced the Repaupo Creek Floodgate in 2009, and made improvements to the adjacent portions of the levee. Gloucester County also performed repairs to levee damage due to Hurricane Sandy in 2012.

The landform currently is depended on to protect the residential areas, industrial areas, railroad tracks, and roads upriver along Repaupo Creek, White Sluice Race, Sand Ditch, and Clonmell Creek from flooding due to high levels of the Delaware River.

The landform was last inspected by USACE personnel in 2012 while performing an Initial Eligibility Inspection for the PL 84-99 Rehabilitation and Inspection Program. (It was later determined that the landform continues to be ineligible for the Program.) The results of the inspection are detailed below. The DuPont Levee Segment was not inspected, therefore no observations are listed.

In the Logan Township section, unwanted vegetation covered both the landside and riverside slopes of the levee near the downriver tieback. Before Hurricane Sandy, Gloucester County officials removed excessive vegetation, added riprap and slushed concrete into the riprap on the riverside slope to armor it against wave erosion. Sod is missing on the levee, creating potential erosion pathways. There are also encroachments to the levee in this segment in the form of a house that has had additions built up the landside slope of the levee to its crest as well as debris. The 15 foot vegetation free zone on the landside of the levee also has small woody vegetation growing in it.

In the Greenwich Township section, unwanted vegetation and trees encroaching on the levee were observed throughout the section. Two locations were also noted to have sloughing occurring on the riverside. These areas are threatening the integrity of the landform. A few small ruts and depressions related to vehicular traffic were also observed. With the Repaupo Meadow Company no longer managing the levee system, the involvement of numerous entities degrades assurance that overall maintenance of the project is performed.

To better understand the nature of the levee embankment and foundation, USACE personnel obtained borings from a 2007 Melick-Tully Study on repairing the floodgates. The report provided several borings on and around the embankment. The borings indicated that the levee is composed of sands and gravel and the foundation has layers of organic clays, peats and silt. Both drilling areas, upstream and downstream of the Repaupo tide gate, had low blow counts in the borings, indicating that it is susceptible to uneven settlement, cracking of the embankment, through-seepage and under-seepage. The report only pertained to the southern end of the embankment on the Logan and Greenwich Township sections and no further information was available. Due to a high level of uncertainty and risk with the embankment and foundation, these ratings were found to be Unacceptable according to the PL 84-99 categorization of levees. There is no further boring data on the embankment, but the observations of sloughing, settlement, and sand boils would indicate that the remainder of the levee is composed of similar materials.

In conclusion, given the landform’s history, previous damages, and the current state of disrepair, it is believed that the levee cannot be counted on for protection from storm events. The 2007 Melick Tully report detailing the poor composition of the embankment and the foundation should also be considered as further evidence that the competency of the levee should be questioned. Due to the great amount of uncertainty in the entire levee embankment and considering the visual evidence of settlement, bank caving, unwanted vegetation growing on the levee, and the previous failures throughout the history of the embankment, no Probable Failure or Non-Failure points were able to be determined in response to PGL 26. Therefore, it was determined prudent to assume for plan formulation that the Gibbstown Levee System/Federally Uncertified Landform is offering no protection. An extensive boring program and geotechnical analysis was considered to obtain a more refined determination of benefits; however, a study at this level would be cost prohibitive considering the levee’s physical length and location on two hazardous waste sites.

### 4.4.4 Upstream Reservoirs’ Impact on Flooding

Major flooding occurred in the Delaware River Basin in September 2004, April 2005, and June 2006. The three New York City reservoirs of Cannonsville, Pepacton, and Neversink received a lot of attention after the three flood events because they were full prior to each of the events and spilled as a result of these events. Claims were made that the spills from these reservoirs contributed to the downstream floodwaters. A map showing the Reservoirs is presented in Figure 4.2.

The DRBC published the major findings of the Delaware River Flood Analysis Model conducted by the DRBC, USGS, USACE and NOAA in December 2009. The model indicated that spills from reservoirs (Cannonsville, Pepacton, and Neversink) are not the root cause of flooding along the Delaware River and that out-of-bank flooding would still have occurred at the locations it did during the 2004, 2005, and 2006 events even if none of the reservoirs spilled. Results of the model also indicated that reservoir operations that result in larger pre-event voids may potentially reduce peak flood crests at select locations, but the amount of reduction was highly dependent upon the characteristics (rainfall intensity, duration and timing) of the storm event itself, the distance downstream the select location was from the reservoir(s), and the local topography. Dedicated pre-event voids would not have eliminated the flooding.


**Figure 4.2: Delaware River Basin with Major Reservoirs (courtesy of DRBC).**

### 4.4.5 Water Quality

The Delaware River begins in the Catskill Mountains of southeast New York and flows over 280 miles (451 km) southward along the New York-Pennsylvania border and the Pennsylvania-New Jersey border to northern Delaware, where it widens as the Delaware Bay. The river meets tide-water at Trenton, New Jersey. It forms the Delaware Estuary from the falls at Trenton, New Jersey and Morrisville, Pennsylvania, south to the mouth of the bay between Cape May, New Jersey and Cape Henlopen, Delaware.

The DRBC is responsible for managing the water resources within the entire Delaware River Basin. Pursuant to Section 305 (b) of the Clean Water Act (33 U.S.C. 1251 *et seq.*), the DRBC prepares biennial assessments of water quality for the 339-mile long Delaware River and Bay. The DRBC divides the Basin into six water quality zones. The non-tidal portion of the Delaware River above the head of tide at Trenton, New Jersey is Zone 1. The bay is Zone 6, with Zones 2, 3, 4 and 5 moving south along the river. The study area encompasses water quality zones 1 - 4. According to the 2012 assessment, criteria to support drinking water were only met in Zones 1c and 3, with turbidity being the main problem in the other zones. Recreational activities were supported in all zones, although a portion of Zone 4 "had insufficient data", while fish consumption advisories still limit use in all zones.

In addition, The Partnership for the Delaware Estuary released its State of the Estuary Report and associated Technical Report in 2012. These reports track the nonprofit agency's progress towards the implementation of its long-term *Delaware Estuary Comprehensive Conservation and Management Plan*. With respect to water quality, results are mixed. Waterborne pollutants in some areas have been decreasing (suspended sediments, nutrients), while dissolved oxygen, an indicator of good water quality, has generally increased in recent decades. On the other hand, concentrations of many other contaminants are either remaining the same or increasing, and there are still many areas where fish consumption advisories remain in place mainly due to mercury and PCBs in the non-tidal areas of the estuary. Another recent issue in water quality is the prevalence of pharmaceutical and personal care product contamination.

## 4.5 Biological Resources

### 4.5.1 Vegetation

#### 4.5.1.1 Trenton and North

The vegetation type is predominantly riparian in the four counties, particularly along the Delaware River. Upland forests in this area are typically transitional and dominated by oak (*Quercus* spp.). Non-native flora include common reed (*Phragmites australis*), mile-a-minute vine (*Persicaria perfoliatum*), and purple loosestrife (*Lythrum salicaria*).

According to the U.S. Fish and Wildlife Service's National Wetland Inventory (2012), both forested and emergent wetlands are found intermittently from the northern project limit of Knowlton Township to the southern limit of Trenton, with some concentration of wetlands along the Delaware River in the Milford, Frenchtown, Stockton, and Lambertville areas.

Submerged freshwater aquatic vegetation (SAV), including water celery or American eel grass (*Vallisneria americana*) can be found in some areas of the Delaware River and its tributaries (north of Trenton, NJ).

#### 4.5.1.2 Tidal, Southern Section (Gibbstown)

The study area of Logan and Greenwich Townships in Gloucester County includes a combination of rural, urban, industrial, large transportation corridors, and open space. The vegetation inhabiting residential areas is typical of urban environments consisting of a maintained lawn of mixed mowed grasses and landscaping with planted hedges and shade trees. Because the area is rural with concentrated development in Gibbstown, wildlife resources are concentrated within riparian corridors, which includes riverbank, salt marsh, floodplain, forest, emergent and forested wetlands.

In addition, submerged aquatic vegetation (SAV), including American eel grass (*Vallisneria americana*) and horned pondweed (*Zannichellia palustris)* can be found in some areas of the Delaware River (Schuyler et. al, 1993).

In 2011, a preliminary ecological assessment of the Gibbstown Levee area was completed to understand the past, current and potential future changes in the natural resources within and around the vicinity of Gibbstown (Biohabitats, 2011). The 4,795 acre assessment was completed using current aerial imagery and mapping, as well as follow up site visits for ground-truthing. The land cover types/habitats represented on site are Emergent Wetland, Forested Wetland, Agriculture, Open Water, Upland/Herbaceous, and Urban Development.

### 4.5.2 Fish and Wildlife

#### 4.5.2.1 Fisheries

The Delaware River and its tributaries provide habitat for a variety of finfish, both residents and migrants. Some of the common fish species include largemouth bass (*Micropterus salmoides*), several species of sunfish (*Lepomis* spp.), pickerel (*Esox*, spp.), eastern mudminnow (*Umbra pygmaea*), brown bullhead (*Ameiurus nebulosus*), fallfish (*Semotilus corporalis*), white sucker (*Catostomus commersoni*), perch (*Aphredoderus* spp.) and margined madtom (*Noturus insignis*).

In addition, the Delaware River is host to several migratory fish including the American shad (*Alosa sapidissima*), river herring [blueback herring (*Alosa aestivalis*) and alewife (*Alosa pseudoharengus*)], and the American eel (*Anguilla rostrata*).

The study area encompasses the tidal freshwater areas of the Delaware River, and in most years is well below (<0.5 ppt) the salinities found within the mixing zone for which EFH has been identified. No essential fish habitat (EFH) has been designated within the study area (NMFS, 2012). However, the National Marine Fisheries Service (NMFS) recommends that activities that may potentially impact (directly or indirectly) prey items for EFH species identified within the mixing zone should be evaluated. Alosid species such as river herrings and American shad are prey items for juvenile bluefish (*Pomatomus saltatrix*), an EFH species identified in the mixing zone.

#### 4.5.2.2 Wildlife

The Delaware River is an important corridor for wildlife. In addition, it is part of a key migration route for birds since it is located along the Atlantic Flyway, one of four major waterfowl migratory routes in the United States. The Hamilton-Trenton Marsh area also provides stopover habitat for many migrating neo-tropical birds and this area supports more than 230 species of birds. In addition, the Delaware Bay estuarine system is an important wintering area for many waterfowl and seabirds.

Due to the developed nature of some parts of the study area, wildlife resources are concentrated mostly within riparian corridors, the riverbank, floodplain, upland forest, and emergent and forested freshwater wetlands. The undeveloped lands adjacent to the Delaware River offer habitat to birds such as finches, sparrows, swallow, blackbirds, mockingbirds, and warblers. Species include: northern cardinal (*Cardinalis cardinalis*), American goldfinch (*Carduelis tristis*), song sparrow (*Melospiza melodia*), barn swallow (*Hirundo rustica*), red-winged blackbird (*Agelaius phoeniceus*), brown-headed cowbird (*Molothrus ater*), and common grackle (*Quiscalus quiscula*). The study area also contains urban-suburban species tolerant of developed areas. Bird species likely include American robin (*Turdus migratorius*), black-capped chickadee (*Poecile atricapillus*), tufted titmouse (*Baeolphus bicolor*), and gray catbird (*Dumetella carolinensis*).

Mammals common to the study area include white-tailed deer (*Odocoileus virginianus*), eastern cottontail (*Sylvilagus floridanus*), river otter (*Lontra canadensis*), beaver (*Castor canadensis*), muskrat (*Ondatra* zibethicus), raccoon (*Procyon lotor*), gray squirrel (*Sciurus carolinensis*), northern long-eared bat (*Myotis septentrionalis*), big brown bat (*Eptesicus fuscus*) and little brown bat (*Myotis lucifugus*) are also likely to occur in the study area.

Reptile and amphibian species known to inhabit the study area include the painted turtle (*Chrysemys picta*), eastern box turtle (*Terrapene carolina*), Fowler's toad (*Bufo woodhousei fowleri*), New Jersey chorus frog (*Pseudacris triseriata kalmi*), common snapping turtle (*Chelydra serpentine*), black rat snake (*Elaphe obsolete*), and green frog (*Rana clamitans melanota).* Other species observed in the forested wetland habitats include northern water snake *(Nerodia sipedon)*, bullfrog *(Rana catesbeiana*), and northern leopard frog *(Rana pipiens*).

### 4.5.3 Threatened and Endangered Species

The Corps coordinated with the U.S. Fish and Wildlife Service (USFWS) on federally listed endangered and threatened species within the municipalities of the study area. The coordination is pursuant to the Endangered Species Act (ESA) of 1973 (87 Stat. 884, as amended; 16 U.S.C. 1531 *et seq)*.

Consultation with the USFWS has determined that the project is within the range of the federally listed Indiana bat (Myotis sodalist) and the proposed listed Northern long-eared bat (NLEB) (Myotis septentrionalis). NLEB is currently a proposed listed species and final determination of the status of this species will be made by FWS on April 2, 2015. There is the potential for roosting trees for both the Indiana bat and the NLEB to be in the project area. In addition, an historic occurrence of the endangered dwarf wedgemussel (*Alasmidonta heterodon*) is documented from the Delaware River in Warren County, within the City of Lambertville in Hunterdon County, and northern Mercer County.

Furthermore, the bald eagle (*Haliaeetus leucocephalus*) and the peregrine falcon (*Falco peregrinus*) may occur in the study area; however, the USFWS have removed both species from the Federal List of Endangered and Threatened Wildlife. The bald eagle continues to be protected under the Federal Bald and Golden Eagle Protection Act and Migratory Bird Treaty Act (MBTA). The peregrine falcon is also still protected under the MBTA. Both species are also State-listed species under the New Jersey Endangered and Nongame Species Conservation Act (N.J.S.A. 23:2A *et seq*.), which carries protections under the State Land Use Regulation Program.

Under the purview of the NMFS, the shortnose sturgeon (*Acipenser brevirostrum*) and the Atlantic sturgeon (*Acipenser oxyrinchus*) are federally listed endangered species of fish found within the Delaware Estuary. They are migratory species that inhabit marine and estuarine waters and spawn in freshwater. In addition, NMFS has listed river herring (alewife and blueback herring) as a "Species of Concern", which are those species about which NMFS has some concerns regarding status and threats; however, after a 12-month species review, they did not have enough compelling data to list alewife and blueback herring under the ESA in 2013.

## 4.6 Cultural Resources

A Phase IA cultural resources investigation was completed to assess the study area for possible impacts to existing resources as well as for archaeological resource probability (Bowen et. al, 2008). The following section provides the findings of literature review and archaeological potential assessment for the 16 municipalities that make up the Study Area within Warren, Hunterdon, Mercer, and Gloucester counties.

Examination of the New Jersey State Historic Preservation Office (SHPO) and the New Jersey State Museum (NJSM) cultural resource files indicated that over 400 resources, including 285 archaeological sites, 97 individual architectural resources, and 34 historic districts have been previously recorded within the 16 municipalities making up the study area. Archaeological sites include prehistoric, historic, and multi-component sites, and several sites with no documented cultural affiliation. Architectural resources consisted of individual structures and properties such as dwellings, bridges, farmsteads, and cemeteries. There are two primary types of historic districts within the project area: those that are composed of multiple properties and contributing elements that characterize a period of history or historical theme (e.g., Frenchtown historic districts); and transportation- related linear districts (e.g., D&R Canal historic districts) which are located within multiple municipalities.

### 4.6.1 Summary of Archeological Potential

On the basis of landform and the existing archaeological record, the study area exhibits high archaeological sensitivity throughout. Prehistoric site potential is typically considered high on landforms adjacent to or within 100-200 meters of perennial streams, particularly at stream and tributary confluences. These physiographic attributes characterize the entire project area. Historical site potential is higher in historically developed areas such as the banks of the Delaware River which have been the focus of historical activity for nearly 400 years. This activity is evident in the large number of previously documented historical properties located within the project area. See Appendix E: Cultural Resources for more details.

## 4.7 Socioeconomics

### 4.7.1 Population

Population for 2010 (U.S, Bureau of Census) for the four NJ study area counties was 907,865, an increase of 7.5% over the 2000 total for the counties of 829,860. All of the study area counties saw population growth from 2000 to 2010.

The major population center within the study area is the City of Trenton in Mercer County. The city’s population in 2010 was 84,913. There was a steady population decline recorded from 1950 to 2000. This decline was attributed to the reduction in the city’s manufacturing base, and the larger trend of urban depopulation and suburban expansion experienced throughout New Jersey and the region. However, this trend stabilized by 2010, with population gains being forecast through 2030.

### 4.7.2 Population Projections

Population projections were available to the year 2035 for all study area municipalities. According to this data, communities in the study area can expect to see population increases in the coming decades. Table 4.1 provides population totals and estimates for the four study area counties and the state of New Jersey overall.

**Table 4.1: State and County Population Totals**

| | 1950 | 1960 | 1970 | 1980 | 1990 | 2000 | 2010 | 2020 (est.) | 2030 (est.) | 2035 (est.) |
|---|---|---|---|---|---|---|---|---|---|---|
| **State of New Jersey** | 4,835,329 | 6,066,782 | 7,171,112 | 7,364,823 | 7,730,188 | 8,414,350 | 8,791,894 | 9,461,635 | 9,802,440 | 9,975,188 |
| **Warren County** | 54,374 | 63,220 | 73,960 | 84,429 | 91,607 | 102,437 | 108,692 | 126,798 | 133,422 | 134,204 |
| **Hunterdon County** | 42,736 | 54,107 | 69,718 | 87,361 | 107,776 | 121,989 | 128,349 | 152,889 | 146,546 | 147,825 |
| **Mercer County** | 229,781 | 266,392 | 304,116 | 307,863 | 325,824 | 350,761 | 366,513 | 370,543 | 384,309 | 388,385 |
| **Gloucester County** | 91,727 | 134,840 | 172,681 | 199,917 | 230,082 | 254,673 | 288,288 | 304,311 | 360,097 | 371,953 |

Source: U.S. Census Bureau, Population Estimates to year 2030, Census 2010. 2000, 1990 and 1980; Warren County Planning Department, Population Projections, 2005; Hunterdon County Planning Board Population Projections, 2002; Delaware Valley Regional Planning Commission, Mercer and Gloucester County, 2007

## 4.8 Wild and Scenic Rivers

The National Park Service (NPS) is responsible for administering the Wild and Scenic Rivers Act. The Act requires the NPS to protect and enhance a designated river's free-flowing condition, water quality and outstandingly remarkable values (NPS, 2012). For federal water resource projects that fall within the boundaries of Wild and Scenic Rivers, the NPS conducts an extensive review and evaluation to insure that they do not result in any "direct or adverse effects" to the values for which the river was added to the National System.

In 2000, the National Wild and Scenic River System incorporated key segments of the lower Delaware River, including a 65-mile section of the main stem linking the Delaware Water Gap and Washington Crossing, Pennsylvania, just upstream of Trenton, New Jersey. This reach extends into the study area. In addition, 24.2 miles of the Musconetcong River in Hunterdon and Warren Counties were added to the National Wild and Scenic Rivers system in 2006. The Musconetcong River drains a 157.6-square-mile watershed area in northern New Jersey, and is a major tributary to the Delaware River (NPS, 2012).

## 4.9 Prime and Unique Farmland

Under the Farmland Protection Policy Act (FPPA) of 1981, federal agencies need to coordinate potential projects that may convert important farmland to nonagricultural uses with the Natural Resource Conservation Service (NRCS). The proposed project area in Gibbstown, NJ overlaps with soils identified as potentially prime and / or unique. Using the Web Soil Survey maps found on NRCS' website, two types of soil types were identified that could be considered under the FPPA. Those two types are Mannington-Nanticoke-Udorthents complex (MamuAV) and Woodstown-Glassboro Complex (WokA). MamuAV has a rating of unique and WokA has a rating of prime.

## 4.10 Parks and Recreation

Because of its great beauty and many natural and historic resources, the Delaware River is an important recreational resource for millions of people (LDR Task Force, 1997). In the upstream reaches of the study area, riverside towns attract tourism with the development of riverfront biking and walking paths, restaurants, marinas, and shops and inns. Many access areas exist for boating, and fishing, as well as several outfitters that provide tubing, canoeing and kayaking in the region.

The Delaware River Water Trail by the Delaware River Greenway Partnership is a proposed 220 mile water trail from Trenton, NJ to Hancock, NY corresponding to the non-tidal segment of the river (Delaware River Greenway Partnership, 2006). This trail concept plan takes into account river access, camping facilities, public safety, and signage.

## 4.11 Hazardous, Toxic, and Radioactive Waste

A hazardous, toxic, and radioactive waste (HTRW) investigation was conducted to identify existing environmental conditions in the study area, in accordance with Engineering Regulation 1165-2-132. In 2008, an environmental record search was prepared by Environmental Data Resources, Inc. for the entire study area, which encompasses several municipalities along the Delaware River. Thousands of related environmental records were located and were reviewed by USACE. Following this preliminary assessment, two areas were selected for further study: Lambertville and Gibbstown. A detailed assessment of environmental conditions at these two sites is included in Appendix D of this document.

In Gibbstown, there are three large sites adjacent to the proposed project with significant environmental impacts: the Ashland/Hercules chemical manufacturing plant; the DuPont-Repauno chemical and explosives plant; and the Paulsboro oil refinery (See Figure 4.3). The Ashland/Hercules site has been identified as a priority cleanup under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also known as Superfund, and is currently on the National Priorities List. Remedial actions completed thus far have focused on a Solid Waste Disposal Area at the north end of the Ashland/Hercules property, approximately one mile north of the proposed floodwall. Of greater concern to the federal project is the Plant Process Area located at the south end of Ashland/Hercules' property. The State of New Jersey ordered remedial investigations and subsequent action for this area in 2009. As of March 2015, a remediation plan is being selected; remediation has not begun. Shallow groundwater samples collected in this area have exceeded NJDEP screening criteria, and a groundwater extraction and treatment system has operated since 1984 to prevent offsite migration of contaminated groundwater.

Corrective action activities are also underway at the DuPont property, under the Resource Conservation and Recovery Act (RCRA). Areas of Concern at the DuPont property are concentrated on the northern end of the site, along the Delaware River. Some soil and groundwater samples from southern parts of the site have exceeded screening criteria, but these impacts have been assessed as *deminimus* and no remediation has been recommended. A groundwater interceptor system has operated at the DuPont site since the 1980s, but the contaminated groundwater is confined to the lower aquifer and does not significantly impact the upper aquifers, which would be contacted during floodwall construction.

Soil, sediment and groundwater impacts have also been documented at the Paulsboro refinery, where soil and sediment remediation has been conducted to reduce loading of PCBs to the Delaware River. Hundreds of spills have been reported at the refinery and at the DuPont site.

The environmental database search identified several additional sites within 0.5 miles of the Gibbstown project that are enrolled in the State of New Jersey's Voluntary Cleanup Program, are listed as State Hazardous Waste Sites, or have Leaking Underground Storage Tanks.

Environmental records located near the Lambertville site are discussed in Appendix D, but none are expected to impact the proposed Lambertville area project.

**Figure 4.3: DuPont and Ashland/Hercules Area Map (Gibbstown)**


In addition, there are numerous sources of PCBs throughout the Delaware River. These sources include contaminated sites, non-point sources, industrial and municipal point sources in both the main stem Delaware River above Trenton and tributaries to the Delaware both above and below Trenton. The U.S. EPA, Region 2, leads remediation at eight sites undergoing cleanup for PCBs and four sites with ongoing PCB remediation are led by NJDEP. Of these sites, eight are located within Gloucester County. These include: Bridgeport Disposal, LLC, Bridgeport Rental Oil Services, Lail Property (Exxon/Mobil), Manchester Machinery and Salvage Site, Matteo & Sons, Inc., Monsanto, Welsbach and General Gas Mantle, Ashland/Hercules, and Former General Engines Company.

# 5 Plan Selection Process

The Federal objective in making investments in flood risk management is to contribute to the National Economic Development (NED) goal, consistent with protecting the Nation's environment, or to the National Ecosystem Restoration (NER) goal. Contribution to NED is achieved by increasing the net value of the nation's output of goods and services, expressed in monetary units. NED contributions must also consider the environmental effects of proposed changes on ecological, cultural, and aesthetic attributes of natural and cultural resources. Contribution to the NER is achieved by increasing the net value to the nation's output of significant habitat, expressed in habitat units. Plans formulated during this study were evaluated based on their contribution to NED, consistent with protection of the nation's environment, and their potential contribution to NER.

The relationship of benefits to costs is expressed in terms of a benefit-cost ratio (BCR). Flood risk management benefits are the monetary savings or benefits due to damages prevented, reduction in the cost of emergency services, and reduction of economic disruption. These project benefits are subsequently annualized to represent an annual benefit applicable for the period of analysis. To be economically feasible, a plan must ultimately have greater benefits than costs or, more specifically, a BCR greater than 1.0 based on the current applicable Federal interest rate (3.5% for FY 2014).

The NED objective is to maximize the economic worth of alternative plans. For flood risk management projects, this objective relates to a plan's capability to manage flood risk by comparing the plan's economic benefits with the project cost on an annualized basis. The amount that a project's economic benefits exceed the project cost is defined as net benefits. In the plan formulation process, the plan that reasonably yields the greatest net benefits meets the NED objective. After the tentative selection of the plan, an analysis to identify the optimum level of design will be included in Section 5.11. This analysis is ongoing but will be completed prior to the Agency Decision Milestone.

In order to determine the NER plan, alternative plans are considered, costs are developed and outputs/benefits are defined. Traditional benefit-cost analysis is not possible with non-monetary benefits or outputs. Therefore, cost-effectiveness/incremental cost analysis (CE/ICA) is used to determine the NER plan. The recommended NER Plan should be the alternative and scale having the maximum of monetary and non-monetary (habitat units) beneficial effects over monetary and non-monetary costs. (In other words, it is the plan that provides the most for the money). This plan occurs where the incremental beneficial effects just equal the incremental costs or, alternatively stated, where the extra environmental value is just worth the extra costs.

This Interim Feasibility Study for New Jersey follows the Corps' six-step, planning process:

1. Identification of Problems and Opportunities
2. Inventory and Forecast Conditions
3. Formulate Alternative Plans
4. Evaluate Alternative Plans
5. Compare Alternative Plans
6. Select Plan

The following sub-sections of Chapter 5 present the process that begins with the identification of the local flooding conditions, currently and in the future, through the formulation of flood risk management solutions, leading into a focused array of the feasible alternative plans to be evaluated and compared quantitatively and qualitatively, ultimately arriving at the identification of the NED Plan as defined above.

## 5.1 Basis for Planning Process

### 5.1.1 Problems and Opportunities*

Problem Statement: The study area represents a flood-prone, high risk area that repeatedly experiences severe flooding from the Delaware River. In general, the study area experiences flooding during hurricanes, thunderstorms, northeasters, snowmelt, and ice jams. The southernmost part of the study area is also at risk of tidal flooding from high ocean surges. For further description of the flooding issues, see Sections 3.1 and 3.2.

Opportunities: Implement flood risk management measures to reduce future storm-related damages and also to increase the life-safety of the residents within the study area.

### 5.1.2 Planning Goals and Objectives*

The goal of selecting a flood risk management plan is to decrease the study area's current risk from flooding.

In support of this goal, the planning objectives of this study are:

3) Reduce flood risk to life, safety and infrastructure associated with Delaware River fluvial conditions in the study area from 2015 to 2065. Provide associated ecosystem restoration, if feasible.

4) Reduce flood risk to life, safety and infrastructure associated with Delaware River tidal conditions and sea level rise within the study area from 2015 to 2065, where applicable. Provide associated ecosystem restoration, if feasible.

### 5.1.3 Planning Constraints

1) The study process must recognize that in much of the northern portion of the study area the Delaware River is categorized as a National Wild and Scenic River. Among other things, this status means that the river is to remain free flowing and water resource

projects cannot cause direct and adverse effects on the value of the river. The NPS will review federal water resource projects in Wild and Scenic Rivers and has approval authority over implementation of those projects. For example, any flood risk management structures cannot have a negative visual or hydrological effect on the Wild and Scenic River.

2) Much of the study area was developed in the colonial timeframe and, hence, it includes historic structures. This is especially true in Lambertville. Even when structures are not on the historic register, they are important to the character and property values of the area. The study process must make sure that plans recognize the presence and number of historic structures and avoid or minimize impacts to historic character through retrofit measures. Compliance with Section 106 of the National Historic Preservation Act must be assured.

3) The Delaware River holds the unique status of being the longest free-flowing river east of the Mississippi River. In the 1970's USACE studied the possibility of constructing a dam across the northern portion of the river at Tock's Island. The option was determined to be infeasible due to geotechnical, environmental and political reasons. The project was eventually de-authorized. In the 1980's USACE studied other flood risk management options in the area. The current planning process needs to take these past, as well as current, planning and management efforts into account in formulation of new flood risk management measures. Planning especially needs to recognize previously identified limitations on the feasibility and suitability of large structural water control projects, such as dams, on the Delaware River and within the New Jersey portion of the Basin.

4) A number of flood prone properties within the study area have been purchased and are now designated as open space. Because of this designation, the land is not available for construction of flood risk management measures.

### 5.1.4 Additional Planning Considerations

1) The potential for encountering contaminated sites in the development of flood risk management measures is a plan formulation constraint in many parts of New Jersey, including the study area. During the study and construction phases, it is essential that all regulations and procedures are followed to avoid disturbing or impacting any contaminated sites. This is especially important in the Gibbstown area where there will be close proximity to both CERCLA and RCRA designated sites. If flood risk management measures cannot be designed to completely avoid the contaminated areas, the non-Federal sponsor will need to make arrangements for remediation and provision of an uncontaminated project site. While this will address the contamination issue, it also has potential to delay construction.

2) Planning and design must avoid, minimize or mitigate any induced additional flooding.

3) Within the study area it will be necessary to identify existing wetlands and avoid, minimize and mitigate impacts. Wetlands will present a significant constraint in the Gibbstown area where there are hundreds of acres within the study area.

4) Within the entire study area there are various existing landforms that were neither constructed nor have been maintained as flood risk management measures, but are currently depended on to function in that capacity and have a history of often fulfilling that role. These landforms include road beds, railroad beds, canal walls and a levee built for salt hay farming. Plan formulation needs to recognize that, even though these structures are not taken into account in the without project conditions, they do have a history and meaning for the local residents.

5) Some people prefer to live adjacent to the river or along roads within wetlands, pursuing livelihoods and recreational activities within the natural resources. An example of this occurs along Floodgate Road in the Greenwich and Logan Townships area. Plan formulation should recognize on-going human activities and land-usage in identification of potential sites and measures for flood risk management-related ecosystem restoration.

6) The Delaware River is quite scenic through the study area, providing many recreational opportunities and, near Greenwich and Logan Townships, both commercial fishing and shipping. The river contributes to communities' identities and serves as a source of visual pleasure. Plan formulation needs to recognize the historic and current function of the Delaware River in the lives of the study area communities and avoid severing the communities' connections to the river. The Delaware River should be recognized as a visual, recreational, and economic resource to the communities.

7) Impacts to threatened and endangered species must be avoided.

## 5.2 Existing Conditions Hydrology and Hydraulic Analysis

An investigation of the hydrology of the main stem Delaware River in the northern part of the study area, from Trenton and North, was performed by the USGS and the Corps using the latest existing data. For the southern, tidally influenced portion of the study area (Gibbstown), an investigation of the estuary's stage frequency was also performed using the latest existing data provided to the Corps from NOAA and the latest storm surge modeling conducted for FEMA by the Corps.

### 5.2.1 Discharge Frequency Analysis for Trenton and North

A discharge frequency analysis was conducted in order to determine the magnitudes of flow associated with given ACE probabilities. The ACE probability is defined as that (level of) event that has a particular chance of occurring, or being exceeded, once in any year. It is the inverse of the return period—i.e., a flood with an ACE of 1% is the 100-year return-period flood.

Three HEC-1 rainfall-runoff hydraulic models that were previously developed by the Corps were used in the discharge frequency analysis (HEC, Special Projects Memo No 82-9, 1982). The three models were divided up by major basins. The Upper Delaware Basin model went from the headwaters to the USGS gage at Montague, NJ. The Lower Delaware Basin model went from the Montague to Trenton, NJ gage, and the third model was for the Lehigh River Basin in Pennsylvania. A summary of the discharge frequency data from the HEC-1 analysis are shown in Table 5.1.

**Table 5.1: Discharge Frequency Values for the Delaware River**

| USGS Station ID | Station Name | Annual Chance Exceedance/Recurrence Interval Discharges (cfs) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 50.0% (2-yr) | 20.0% (5-yr) | 10.0% (10-yr) | 4.0% (25-yr) | 2.0% (50-yr) | 1.0% (100-yr) | 0.4% (250-yr)[2] | NJFH AF[3] | 0.2% (500-yr) |
| 01438500 | Delaware River at Montague, N.J. | 65,200 | 101,000 | 127,000 | 164,000 | 194,000 | 226,000 | 270,000 | 282,000 | 308,000 |
| 01440200 | Delaware River near Delaware Water Gap, PA. | 71,800 | 110,000 | 139,000 | 178,000 | 210,000 | 244,000 | 291,000 | 305,000 | 332,000 |
| 01446500 | Delaware River at Belvidere, N.J. | 76,900 | 116,000 | 145,000 | 184,000 | 215,000 | 248,000 | 294,000 | 310,000 | 334,000 |
| 01457500 | Delaware River at Riegelsville, N.J. | 92,300 | 136,000 | 167,000 | 208,000 | 241,000 | 274,000 | 319,000 | 342,000 | 358,000 |
| 01463500 | Delaware River at Trenton, N.J. | 94,900 | 138,000 | 169,000 | 211,000 | 245,000 | 280,000 | 329,000 | 350,000 | 372,000 |

Additionally, exceedance probabilities and return periods were calculated by an analysis of historical annual peak discharge data at gage locations. Section A.3.1 in Appendix A: Engineering Technical Appendix, Section 2: Hydrology and Hydraulics presents the flow values from the gage analysis. The results were within 5% of the HEC-1 results, thus verifying the model.

### 5.2.2 Stage Frequency Analysis for Trenton and North

A hydraulic analysis using the computer program HEC-RAS 4.0 (River Analysis System) was conducted for FEMA by Medina Consultants in the wake of the record flooding caused by three major storms in three successive years in September 2004, April 2005, and June 2006. The hydraulic analysis was used to quantify the flood hazard risk along the Delaware River from the Sussex County, NJ/NY political boundary to the Mercer/Burlington County, NJ split. The hydraulic analysis resulted in FEMA delineating new flood hazard area work maps and subsequent publishing of updated DFIRMs for the Delaware River. Upon completion of the HEC-RAS model, USACE was requested by FEMA to review the hydraulic analysis done by Medina Consultants. During the review no major technical issues were found in the analysis, and it was approved by the Corps and subsequently adopted for this Study. The HEC-RAS program computation results at cross-section locations along the Delaware River for ACE values from 50% to 0.2% are presented in the Appendix A: Engineering Technical Appendix, Section 2: Hydrology and Hydraulics.

### 5.2.3 Stage Frequency Analysis for Tidal Area (Gibbstown)

The Delaware River in the southern part of the study area (Gibbstown) is tidally influenced and is a distinct hydraulic zone from the Delaware River at Trenton and North. The stage frequency adopted for the Delaware River at the Gibbstown Levee was based upon an analysis completed by NOAA of nearby long-term tide gages on the Delaware River at Lewes, DE; Reedy Point, DE; and Philadelphia, PA. Information from the 2010 Storm Surge Study on the Delaware and Chesapeake Bays (USACE) was used to complete the stage frequency curve because NOAA's analysis did not develop stage frequencies for the rare events beyond the 1% ACE (100-yr). Table 5.2 presents the stage frequency data used for the base year conditions in the tidally influenced part of the study area.

**Table 5.2: Delaware River Stage Frequency near Gibbstown**

| Event | ACE | Stage |
|---|---|---|
| 2-year | 50% | 5.50 |
| 5-year | 20% | 6.09 |
| 10-year | 10% | 6.44 |
| 25-year | 4% | 6.93 |
| 50-year | 2% | 7.25 |
| 100-year | 1% | 7.87 |
| 250-year | 0.4% | 9.35 |
| 500-year | 0.2% | 10.49 |

### 5.2.4 Interior Stage Frequencies Analysis for Tidal Area (Gibbstown)

To correctly depict flood risk within the Repaupo Creek watershed, the expected inundation areas that would result from various storm surges occurring on the Delaware River and/or the flooding that would result from interior drainage behind the existing levee system were analyzed.

An interior drainage analysis, using the computer program HEC-HMS 3.5 (Hydrologic Modeling System), was developed by the District. Precipitation over the watershed is independent of Delaware River tidal conditions. Interior rainfall could happen when the tides on the Delaware River are normal or when the tides are elevated due to storm conditions. A conservative estimate of tailwater conditions on the Delaware River corresponding to a 1% ACE storm (100-yr) condition was adopted for the interior ponding elevation stage frequency. The modeling choices to determine flow rates and interior ponding elevations are discussed in detail in Appendix A: Engineering Technical Appendix, Section 2: Hydrology and Hydraulics. Calibration of the interior drainage model was done by comparing results to previously published datasets for the watershed, comparison of parameters used to similar watersheds in southern New Jersey, and utilizing recent storm events within the watershed. The without project interior pond stages by frequency are presented in Table 5.3.

**Table 5.3: Without-Project Interior Pond Stage Frequency Data**

| Peak Interior Pond Elevation (feet NAVD 88) | | Repaupo Creek / White Sluice Race | Clonmell Creek |
|---|---|---|---|
| Repaupo Watershed Precipitation Event | 99% ACE (1-yr) | 0.35 | 1.00 |
| | 50% ACE (2-yr) | 0.58 | 1.47 |
| | 20% ACE (5-yr) | 1.10 | 2.18 |
| | 10% ACE (10-yr) | 1.44 | 2.65 |
| | 4% ACE (25-yr) | 1.86 | 3.23 |
| | 2% ACE (50-yr) | 2.16 | 3.64 |
| | 1% ACE (100-yr) | 2.46 | 4.06 |
| | 0.4% ACE (250-yr) | 2.87 | 4.61 |
| | 0.2% ACE (500-yr) | 3.16 | 5.04 |

### 5.2.5 Uncertainty in Stage Data

A risk and uncertainty analysis of the calculated stages examining discharge-probability function and the stage-discharge function were performed for the without project conditions using the HEC programs HEC-RAS and HEC-FDA. EM 1110-2-1619, "Risk-Based Analysis for Flood Damage Reduction Studies", dated 1 August 1996 and ER 1105-2-101, "Risk Analysis for Flood Damage Reduction Studies", dated 3 January 2006 were used as guidance. The uncertainty analysis is presented in Appendix A: Engineering Technical Appendix, Section 2: Hydrology and Hydraulics. Tables 5.4 and 5.5 present the results of the analysis. Table 5.4 summarizes the uncertainty of the calculated stage values by reach and frequency of event for the northern part of the study area not subject to tidal flooding and Table 5.5 summarizes the stage frequency uncertainty for the tidally influenced, southern part of the study area.

**Table 5.4: Stage Discharge Uncertainty of Fluvial Flooding**

| | Montague | | Water Gap | | Belvidere | | Riegelsville | | Trenton | |
|---|---|---|---|---|---|---|---|---|---|---|
| ACE | Discharge | Std. Dev. (ft) | Discharge | Std. Dev. (ft) | Discharge | Std. Dev. (ft) | Discharge | Std. Dev. (ft) | Discharge | Std. Dev. (ft) |
| 50% | 65,200 | 0.07 | 71,800 | 0.09 | 76,900 | 0.10 | 92,300 | 0.14 | 94,900 | 0.12 |
| 20% | 101,000 | 0.23 | 110,000 | 0.30 | 116,000 | 0.33 | 136,000 | 0.42 | 138,000 | 0.36 |
| 10% | 127,000 | 0.52 | 139,000 | 0.66 | 145,000 | 0.70 | 167,000 | 0.84 | 169,000 | 0.72 |
| 4% | 164,000 | 0.92 | 178,000 | 1.16 | 184,000 | 1.20 | 208,000 | 1.38 | 211,700 | 1.20 |
| 2% | 194,000 | 1.27 | 210,000 | 1.59 | 215,000 | 1.61 | 241,000 | 1.82 | 245,000 | 1.58 |
| 1% | 226,000 | 1.48 | 244,000 | 1.85 | 248,000 | 1.86 | 274,000 | 2.07 | 280,000 | 1.81 |
| 0.4% | 269,560 | 1.48 | 290,760 | 1.85 | 293,810 | 1.86 | 319,060 | 2.07 | 329,160 | 1.81 |
| 0.2% | 308,000 | 1.48 | 332,000 | 1.85 | 334,000 | 1.86 | 358,000 | 2.07 | 372,000 | 1.81 |

**Table 5.5: Stage Frequency Uncertainty of Tidal Flooding**

| ACE | Std. Dev. (ft) |
|---|---|
| 50% | 0.05 |
| 20% | 0.11 |
| 10% | 0.16 |
| 4% | 0.24 |
| 2% | 0.28 |
| 1% | 0.34 |
| 0.4% | 0.40 |
| 0.2% | 0.45 |

## 5.3 Future Without-Project Hydrology and Hydraulic Conditions*

The "future without- project" conditions analysis represents the changes to the probable flood stages from the base-year (2015) extended out 50 years to the future year (2065). This analysis is a projection of the future conditions based on the incorporation of any known projects planned to be completed within the study reach and any long term natural river or tidal processes that may affect future stages. This analysis produces the flood stages and damage values that represent the No-Action Plan. The No-Action (without project) Plan fails to meet any of the objectives or needs of this study but it provides the base against which project benefits are measured and is necessary for the National Environmental Policy Act (NEPA) evaluation. Additionally, this plan would be implemented if project costs for the selected plan were to exceed project benefits, thus indicating that risk management measures are not in the Federal interest under current NED guidelines.

### 5.3.1 Non-Tidal Area, Trenton and North

The hydrologic conditions along the Delaware River have historically been relatively static. This conclusion was based upon the work done by the Corps and USGS during the gage analysis of peak annual streamflows for several gages along the Delaware River, many of which have a period of record of over 100 years (Schopp & Firda, 2008). The work USGS performed showed no long-term trends in the annual peak streamflow data over the course of the past 100 years.

However, in order to account for future development in the Delaware River Basin and climate variability, an additional analysis was performed to examine the population projections into the future year, and any resulting land use (imperviousness) changes that could impact the hydrology of the Basin. The analysis also examined potential future climate variability according to the current state of knowledge in the scientific community. Based upon these two factors, which are described in detail in Appendix A: Engineering Technical Appendix, Section 2:Hydrology and Hydraulics, Sections A.5.6-A.5.8, the ACE streamflows for the "future without- project" conditions for year 2065 were increased by 10% from the base-year conditions. Table 5.6 summarizes the peak streamflows on the Delaware River used for the "future without- project" conditions.

**Table 5.6: Peak Delaware River Streamflows (cubic feet per second – cfs) for Future Without Project Conditions**

| Location | Annual Chance of Exceedance / Recurrence Interval | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 50% 2-year | 20% 5-year | 10% 10-year | 4% 25-year | 2% 50-year | 1% 100-yr | 0.40% 250-yr | 0.20% 500-yr |
| Montague, NJ | 71,720 | 111,100 | 139,700 | 180,400 | 213,400 | 248,600 | 296,516 | 338,800 |
| Water Gap, PA | 78,980 | 121,000 | 152,900 | 195,800 | 231,000 | 268,400 | 319,836 | 365,200 |
| Belvidere, NJ | 84,590 | 127,600 | 159,500 | 202,400 | 236,500 | 272,800 | 323,191 | 367,400 |
| Riegelsville, NJ | 101,530 | 149,600 | 183,700 | 228,800 | 265,100 | 301,400 | 350,966 | 393,800 |
| Trenton, NJ | 104,390 | 151,800 | 185,900 | 232,870 | 269,500 | 308,000 | 362,076 | 409,200 |

### 5.3.2 Tidal Area, Gibbstown

An analysis of future potential magnitudes of sea level change was conducted following the guidelines set forth in EC 1165-2-211, which was the most up to date guidance at the time of the analysis. The effects of higher relative sea level change rates on design alternatives, economic and environmental evaluation, and risk were considered for the Gibbstown area. Three different (low, intermediate and high) sea level projections, as set forth in EC 1165-2-211, were calculated at the Philadelphia, PA, Reedy Point, DE, and Lewes, DE tidal stations and were used in the sea level change analysis. The low rate was based on an extrapolation of the historical rate at each gage. The intermediate rate reflects a future acceleration of sea level change at each individual gage based upon the Modified NRC Curve I in the guidance. The high rate reflects a higher future acceleration of sea level change at each individual gage based upon the Modified NRC Curve III in the guidance.

Published historic sea level change rates recorded by NOAA at the nearby stations were used to derive the value of 2.87 mm/year at the Repaupo Creek confluence with the Delaware River in Gibbstown. The intermediate and high sea level change projections were then derived to be 5.41 mm/year and 13.71 mm/year, respectively. A graph of the three different projections is shown in Figure 5.1.

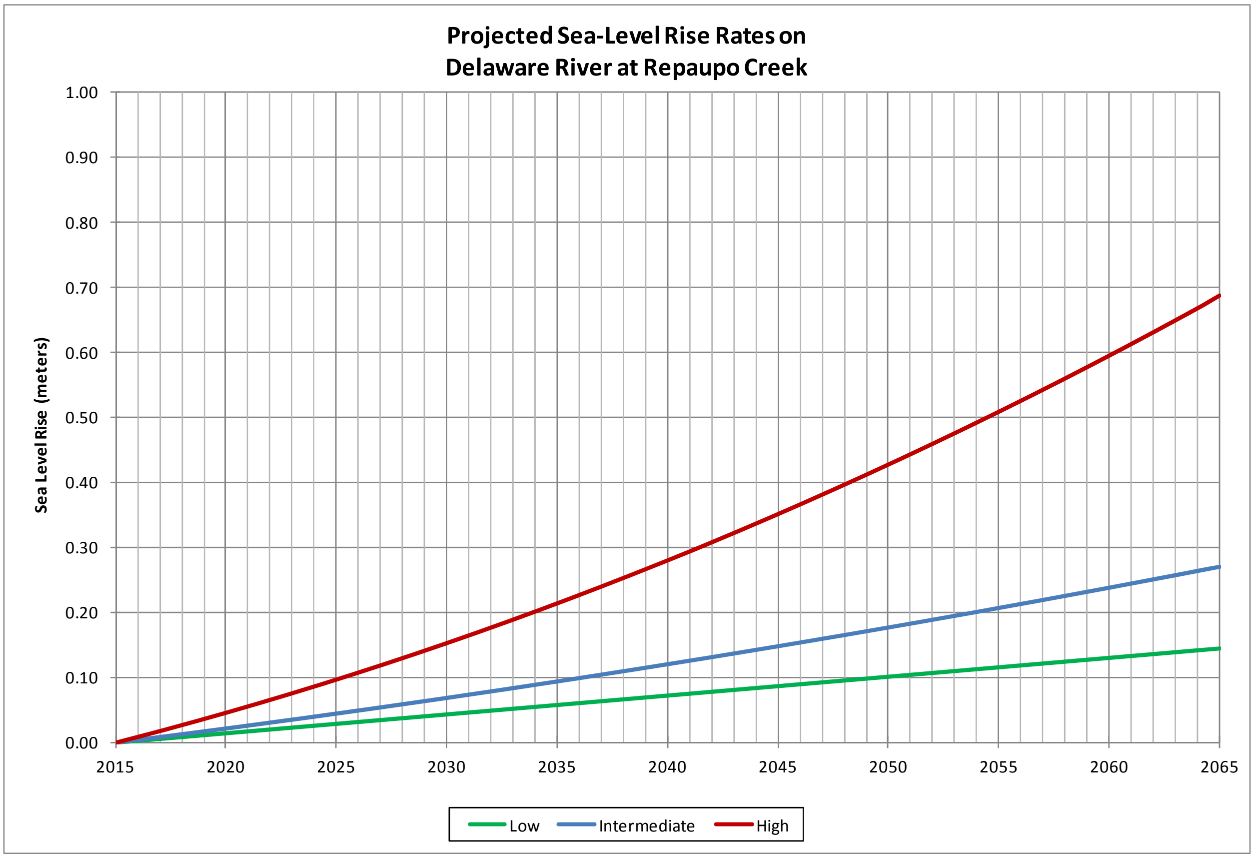


**Figure 5.1: Projected Sea Level Rise Rates on Delaware River at Repaupo Creek**

The stage frequency curves developed for existing conditions were modified accordingly based upon the annual sea level change estimates projected out 50 years from the base-year using the three different sea level trends. The historic rate or low projection is being used as the basis of design for the flood risk management structures in accordance with current USACE planning guidance (ER 1105-2-100). However, the three different projections for sea level trends have been examined in an economic and ecologic sensitivity analysis in Section 6.6. The future stage frequencies for the three different sea level projections along the Gibbstown area are shown in Table 5.7.

**Table 5.7: Stage Frequency with SLC at Gibbstown Area, Year 2065**

| Event | ACE | Low Rate | Intermediate Rate | High Rate |
|---|---|---|---|---|
| **2-year** | **50%** | 5.96 | 6.38 | 7.74 |
| **5-year** | **20%** | 6.54 | 6.96 | 8.32 |
| **10-year** | **10%** | 6.91 | 7.33 | 8.69 |
| **25-year** | **4%** | 7.38 | 7.80 | 9.16 |
| **50-year** | **2%** | 7.73 | 8.14 | 9.50 |
| **100-year** | **1%** | 8.34 | 8.76 | 10.12 |
| **250-year** | **0.40%** | 9.82 | 10.24 | 11.60 |
| **500-year** | **0.20%** | 10.96 | 11.38 | 12.74 |

Datum: feet NAVD 88

The interior ponding stage frequency curve for the future without project conditions was estimated utilizing similar assumptions as those developed for the base year without project hydrologic model. Under the future project condition, however, the three sea level change curves were incorporated into the analysis. Table 5.8 summarizes the future without project interior ponding stage frequency curves for the three estimates of sea level change.

**Table 5.8: Future Without Project Interior Stage Frequency Values**

| Peak Interior Pond Elevation (feet NAVD 88) | | Repaupo Creek / White Sluice Race | | | Clonmell Creek | | |
|---|---|---|---|---|---|---|---|
| | | **Low** | **Intermediate** | **High** | **Low** | **Intermediate** | **High** |
| **Repaupo Watershed Precipitation Event** | **99% ACE (1-yr)** | 1.07 | 1.36 | 2.18 | 1.24 | 1.30 | 1.38 |
| | **50% ACE (2-yr)** | 1.30 | 1.57 | 2.41 | 1.61 | 1.71 | 1.85 |
| | **20% ACE (5-yr)** | 2.15 | 2.45 | 3.28 | 2.31 | 2.44 | 2.73 |
| | **10% ACE (10-yr)** | 2.47 | 2.79 | 3.63 | 2.81 | 2.95 | 3.29 |
| | **4% ACE (25-yr)** | 2.86 | 3.18 | 4.05 | 3.39 | 3.51 | 3.92 |
| | **2% ACE (50-yr)** | 3.15 | 3.46 | 4.34 | 3.81 | 3.94 | 4.34 |
| | **1% ACE (100-yr)** | 3.43 | 3.75 | 4.65 | 4.22 | 4.35 | 4.76 |
| | **0.4% ACE (250-yr)** | 3.84 | 4.15 | 5.04 | 4.79 | 4.92 | 5.32 |
| | **0.2% ACE (500-yr)** | 4.13 | 4.44 | 5.30 | 5.21 | 5.35 | 5.75 |

## 5.4 Flood Damage Analysis

Economic flood damage analysis models for the existing and future without project conditions were developed for the structures in the 1% ACE (100-year) floodplain. The damage analysis interfaced with the hydrologic modeling as described in Section 5.2 and 5.3. Results of these analyses serve as a baseline for determining estimated reductions in damages resulting from the implementation of risk management measures.

### 5.4.1 Structure Inventory

Surveys were conducted to identify each residential and habitable commercial structure within the study area. Both the locations and first floor elevations of structures and their entryways were identified to determine potential impact by flood waters.

Data for each structure was entered into the Marshall & Swift (M&S) Residential or Commercial Software Programs to obtain the depreciated replacement cost. Depreciated replacement cost, as opposed to market value, is applied in the damage estimation process, since it measures directly damageable assets from flooding events and the cost to replace these assets. Market value includes additional factors, such as the value of land, which are not included in the assessment of damageable structure and content assets from flooding. Depreciated replacement cost was estimated by the M&S Software using the Life Cycle method. This method was used to assign a representative effective age, based on the M&S typical life cycle chart for a property and assumed that a structure can have a lower effective age regardless of an increasing chronological age if improvements typically made through the life cycle of a structure are completed. By consolidating the effective age, the Life-Cycle Method normalizes extremes and appropriately accounts for the effects condition has on effective age. Table 5.9 presents the number of structures inundated above ground level by municipality and flooding event. For the Gibbstown area the number of structures at risk will increase significantly as sea level rises. Table 5.10 includes the number of structures subject to inundation in areas affected by sea level rise. Details on the structural inventory are presented in Appendix C: Economic Analysis.

**Table 5.9: Total Number of Structures by Municipality and Exceedance Probability--Non-Tidal Area**

| | Trenton | Ewing | Hopewell | Lambertville | Stockton | Kingwood | Frenchtown |
|---|---|---|---|---|---|---|---|
| 50% ACE (2-year) | 0 | 0 | 0 | 3 | 0 | 1 | 0 |
| 20% ACE (5-year) | 20 | 0 | 1 | 8 | 1 | 8 | 1 |
| 10% ACE (10-year) | 100 | 9 | 6 | 18 | 2 | 15 | 7 |
| 4% ACE (25-year) | 153 | 66 | 12 | 50 | 51 | 30 | 20 |
| 2% ACE (50-year) | 195 | 98 | 20 | 83 | 71 | 33 | 32 |
| 1% ACE (100-year) | 255 | 127 | 25 | 100 | 98 | 36 | 45 |
| 0.4% ACE (250-year) | 313 | 153 | 27 | 130 | 115 | 40 | 72 |
| 0.2% ACE (500-year) | 344 | 164 | 28 | 154 | 121 | 41 | 100 |

**Table 5.9 (Continued): Total Number of Structures by Municipality and Exceedance Probability--Non-Tidal Area**

| | Holland | Pohatcong | Phillipsburg | Harmony | Belvidere | Knowlton | White | Totals |
|---|---|---|---|---|---|---|---|---|
| 50% ACE (2-year) | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 7 |
| 20% ACE (5-year) | 1 | 9 | 0 | 10 | 1 | 2 | 0 | 62 |
| 10% ACE (10-year) | 2 | 20 | 2 | 33 | 4 | 8 | 4 | 230 |
| 4% ACE (25-year) | 7 | 32 | 2 | 62 | 18 | 34 | 4 | 541 |
| 2% ACE (50-year) | 13 | 48 | 11 | 105 | 50 | 47 | 7 | 813 |
| 1% ACE (100-year) | 17 | 65 | 14 | 133 | 74 | 69 | 7 | 1065 |
| 0.4% ACE (250-year) | 23 | 74 | 17 | 144 | 89 | 92 | 8 | 1297 |
| 0.2% ACE (500-year) | 28 | 76 | 19 | 144 | 93 | 106 | 8 | 1426 |

**Table 5.10: Total Number of Structures by Municipality and Exceedance Probability--Tidal Area**

| | Greenwich | | Logan | | Greenwich and Logan (Gibbstown) Totals | |
|---|---|---|---|---|---|---|
| | Base Year | Future Year | Base Year | Future Year | Base Year | Future Year |
| 50% ACE (2-year) | 207 | 236 | 10 | 10 | 217 | 246 |
| 20% ACE (5-year) | 250 | 287 | 10 | 11 | 260 | 298 |
| 10% ACE (10-year) | 274 | 331 | 11 | 11 | 285 | 342 |
| 4% ACE (25-year) | 331 | 369 | 11 | 11 | 342 | 380 |
| 2% ACE (50-year) | 351 | 392 | 11 | 11 | 362 | 403 |
| 1% ACE (100-year) | 385 | 457 | 11 | 12 | 396 | 469 |
| 0.4% ACE (250-year) | 427 | 589 | 12 | 19 | 439 | 608 |
| 0.2% ACE (500-year) | 460 | 700 | 12 | 21 | 472 | 721 |

5.4.1.1 2014 Update to Inventory in Lambertville and Gibbstown

In 2014 a structure inventory update was needed in order to be consistent with Corps guidance and ensure that the data was current. By this time, further plan formulation screening had occurred, allowing for a focused inventory in Lambertville and Gibbstown, the two areas associated with the TSP. Details of the structure inventory can be found in Appendix C: Economic Analysis. The inventory of structures contributing to storm damages was updated to reflect the existing conditions via a review of publicly available aerial photographs and other pertinent information, and via a field survey of a randomly selected sample of structures for the purposes of developing an overall value update factor to be applied to the full inventory.

The sample set of structures for the 2014 field survey in Gibbstown was developed by randomly selecting 21 seed structures from the prior full inventory and adding the next nine structures following each seed to give a sample set of 210 structures in 21 clusters of 10, representing 25% of the overall inventory.

In Lambertville the inventory update only included all 60 structures that could possibly benefit from a levee or floodwall at the northern section of the City.

On completion of the field survey, depreciated structure replacement values at a July 2014 price level were calculated for all surveyed structures using RS Means Square Foot Costs 2014. Structure values from the prior inventory were compared to the values calculated at the 2014 price level to compute an overall value update factor of 1.45 for the Gibbstown inventory. This factor was then applied to all structures in the revised Gibbstown inventory which were not included in the field survey. An update factor was not developed for the Lambertville inventory, which was revised using structure values calculated directly using RS Means for all 60 structures surveyed.

### 5.4.2 Annual Damage Summary

Average Annual Damage (AAD) is the amount of damage that is predicted during a specific year. The AAD for the base year is an analysis of the existing conditions while the AAD for the future year takes into account any changes in hydrologic conditions anticipated to occur over the 50-year period, including sea level rise where applicable and changes to the structure values in the building inventory.

Equivalent Annual Damages (EAD) provide the basis for comparing the effectiveness of different flood risk management measures (i.e. the project benefits are principally the resulting reduction in the EAD). EAD was estimated for the entire project area for the screening of measures based on a price level of December 2010 and the FY13 federal discount rate of 3.75%. The without-project Equivalent Annual Damages prior to the 2014 update for selected areas are presented in Table 5.11 along with the average annual damages for the base year (2015) and future year (2065) conditions. The full without-project damage analysis is documented in Appendix C: Economic Analysis and the EAD for the 2014 update is presented in Table 5.12.

**Table 5.11: Annual Damage: Without-Project Conditions**

| Municipality | Base Year Average Annual Damage | Future Year Average Annual Damage | Equivalent Annual Damage |
|---|---|---|---|
| *Trenton and North* | | | |
| Trenton | $2,506,725 | $4,171,218 | $3,080,453 |
| Ewing | $754,374 | $1,195,766 | $906,516 |
| Hopewell | $72,970 | $111,710 | $86,323 |
| Lambertville | $1,738,000 | $2,651,000 | $2,053,659 |
| Stockton | $442,269 | $702,870 | $532,094 |
| Kingwood | $188,938 | $270,226 | $216,956 |
| Frenchtown | $255,528 | $445,925 | $321,155 |
| Holland | $297,883 | $492,740 | $365,047 |
| Pohatcong | $108,512 | $179,285 | $132,906 |
| Phillipsburg | $60,803 | $114,338 | $79,255 |
| Harmony | $610,852 | $930,138 | $720,906 |
| Belvidere | $261,462 | $386,329 | $304,501 |
| White | $115,736 | $156,855 | $129,909 |
| Knowlton | $114,337 | $171,542 | $134,054 |
| **Subtotal** | **$7,528,389** | **$11,979,942** | **$9,063,734** |
| *Tidal Area, Greenwich and Logan (Gibbstown)* | | | |
| Greenwich/Logan (Gibbstown) | **$10,260,911** | **$13,328,752** | **$11,318,349** |
| *Combined* | | | |
| **Total** | **$17,789,300** | **$25,308,694** | **$20,382,083** |

Price Level: August 2010, Interest Rate: 3.75%, Period of Analysis: 50 Years

5.4.2.1 Trenton and North

The economic model for the study area from Trenton and North predicted the highest annual damages in the City of Lambertville. It also predicted some of the higher values for damage per structure in Lambertville. Lambertville's EAD is higher than most communities because frequent storm events cause relatively large amounts of damage.

5.4.2.2 Tidal Area (Gibbstown)

The residential and commercial structures in this area experience damages at elevations close to or below normal stage conditions of the Delaware River and would experience damage during high frequency events. The Equivalent Annual Damages estimated were very significant as these structures may be subject to flooding on a relatively frequent basis.

5.4.2.3 Sensitivity Analysis for the Federally Uncertified Landform (FUL)

The damage model for the tidal part of the study area (Gibbstown) did not consider any flood risk management provided by the Gibbstown Levee as discussed in Section 4.4.3. The Federally Uncertified Landform (FUL) (Gibbstown Levee), however, may provide some unmeasured level of risk management not accounted for in the damage model.

An additional sensitivity analysis has been performed to quantify the changes to the damage results that would be experienced if the FUL was to be considered as providing some level of flood risk management.

To attempt to gage the possible effects of the FUL, a risk and uncertainty scenario for the Gibbstown Levee area was modeled, at an average structure height of seven feet (a representative height for the existing landform). Based on this height of performance, the model predicts that the communities would only receive damage in events greater than the 4% ACE (25 year).

The results of the analysis, presented in Appendix C: Economic Analysis, indicate a substantial reduction in Expected Annual Damage (EAD) for the base year. A substantial reduction in EAD was also observed for the low rate sea level rise and intermediate rate sea level rise future years. The future year using the high rate predicts that the two year storm would have tidal water surface elevations greater than 7 feet NAVD 88, and therefore, for the high rate, the FUL provides little-to-no protection.

5.4.2.4 2014 Update to Equivalent Annual Damage Values

The Equivalent Annual Damage (EAD) values were updated to reflect newly released stage frequency data in the tidal areas (Gibbstown) and the structural inventory revised in 2014 for Gibbstown and Lambertville. The EADs in Lambertville are significantly less than the initial EAD calculation because the inventory update only included the 60 structures that could possibly benefit from a levee or floodwall at the northern section of the City. The updated 2014 without project EAD are presented in Table 5.12 along with the average annual damages for the base year and future year conditions.

**Table 5.12: 2014 Update to Equivalent Annual Damage: Without-Project Conditions**

| Municipality | Average Annual Damages Base Year | Average Annual Damages Future Year | Total Equivalent Annual Damage |
|---|---|---|---|
| Lambertville (Northern part of City) | $953,000 | $1,503,000 | $1,147,000 |
| Gibbstown (Greenwich/Logan) | $13,818,000 | $17,835,000 | $15,237,000 |

Price Level: April 2014, Interest Rate: 3.50%, Period of Analysis: 50 Years

## 5.5 Plan Formulation Approach

The formulation approach used in this study is consistent with the national objectives as stated in the *Planning Guidance Notebook*, as well as the Corps *Planning Manual* and the Principles outlined in SMART planning guidance. In general, flood risk management plans must contribute to the National Economic Development (NED) account consistent with protecting the Nation's environment, pursuant to national environmental statutes, applicable executive orders and other Federal planning requirements. Plans to address the needs in the study area must be formulated to provide a complete, effective, efficient, and acceptable plan for flood risk management. These objectives impose general planning constraints within any study area.

**Completeness** is defined as *"the extent to which a given alternative plan provides and accounts for all necessary investments of other actions to ensure the realization of the planned effects. This may require relating the plan to other types of public or private plans if the other plans are crucial to realization of the contributions of the objective."*

**Effectiveness** is defined as *"the extent to which an alternative plan alleviates the specified problems and achieves the specified opportunities."*

**Efficiency** is defined as *"the extent to which an alternative plan is the most cost effective means of alleviating the specified problems and realizing the specified opportunities, consistent with protecting the Nation's environment."*

**Acceptability** is defined as *"the workability and viability of the alternative plan with respect to acceptance by State and local entities, and the public, and compatibility with existing laws, regulations, and public policies."*

Taken as a whole, the plan formulation approach recognizes the need to balance flood risk management and ecosystem restoration opportunities with other social and environmental needs within the study area. In addition to the no action alternative, as represented by the without project future condition (See Section 5.3), a broad range of alternative plans are presented below.

### 5.5.1 Floodplain Management Plan

It should also be acknowledged that in addition to identifying the NED plan for Federal participation, it is also possible to recommend elements that could be locally implemented and considered as part of a Floodplain Management Plan (FPMP) or an expanded FPMP. Currently, the minimum requirements necessary for a FPMP have been met in the area with the adoption of FEMA floodplain standards, and adoption of State Flood Hazard regulations. This study helps to identify elements that have local support that could comprise elements of an expanded FPMP, such as land development regulation or local storm water management practices. (See Appendix H: Plan Formulation: Details of Phases 1 & 2)

### 5.5.2 Iterative Approach

Formulation, evaluation and comparison steps have been repeated iteratively in each of the three Phases described below. Each phase of investigation developed alternative measures to an increased level of detail to determine whether the alternative measures should be considered further, or eliminated. The three phases of analysis include the following:

- Phase 1 – Screening of Measures
- Phase 2 – First Added Assessment of Alternatives
- Phase 3 – Incremental Alternative Plan Development and Assessment

The following sections provide a summary of the approach to this iterative process. Figure 5.2: Plan Formulation Process provides a schematic overview of the planning approach.

For the Interim Feasibility Study for New Jersey, a consistent terminology is used for describing alternatives, based upon the level of detail, and refinement. These terms generally are: 1) measures, 2) alternatives, and 3) alternative plans. The term “measure” is used in the screening process when describing the types of solutions that are available for flood risk management and are concept-level in detail. The term “alternative” represents a specific plan for an area, with specific design objectives, which represent a single risk management measure. The term “alternative plan” is defined as combinations of measures integrated together or varied by location to accomplish the desired objectives of flood risk management, and ecosystem restoration.

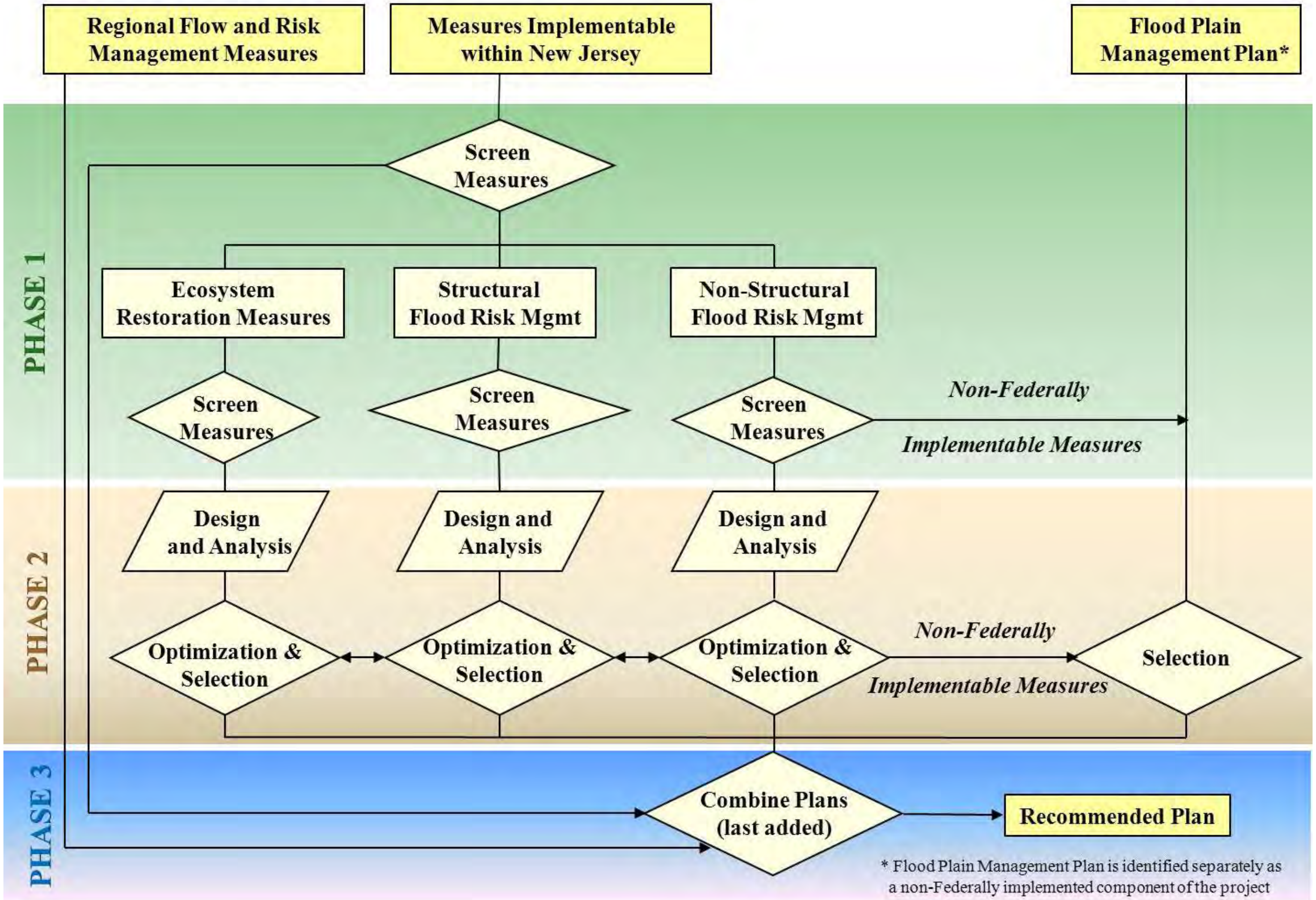


**Figure 5.2: Plan Formulation Process**

## 5.6 Description of Measures

A general description of the range of measures evaluated is provided in the section below. Further description can be found in Appendix H: Plan Formulation: Details of Phases 1 & 2. The approach to developing a comprehensive plan is to separately identify and evaluate the over-arching regional management measures, and the more localized measures necessary to address specific problems or opportunities. The regional measures and local measures will be identified for possible implementation for the study area, either separately or in combination with other alternatives.

Structural measures consist of structures designed to control, divert, or exclude the flow of water from the flood-prone areas to the extent necessary to reduce damages to property, hazards to life or public health, and general economic losses.

Nonstructural measures are those activities that can be undertaken to move what is being damaged out of harm's way, rather than attempting to alter the movement of water. Nonstructural measures include a variety of techniques, including land-use controls to limit future development in the flood hazard areas, acquisition or relocation of flood-prone development, and retrofit of existing structures.

Ecosystem restoration measures seek to restore the functional outputs of important habitats within the study area. Restoring wetlands can also provide localized flood risk management by slowing the speed of floodwaters, absorbing the force of flow, detaining floodwaters, and filtering out suspended solids. Through these actions, wetlands have the potential to lower flood heights and reduce the erosive potential of the water.

### 5.6.1 Regional Measures

#### 5.6.1.1 Flood Warning System

The process of notifying local residents of impending floods can be divided into flood forecasting, warning, and preparedness planning.

Forecasting and warning is primarily a program of the NWS. Along the Delaware River, the process includes use of gages owned by the USGS and the DRBC.

#### 5.6.1.2 Reservoir Management

This technique involves planned methods by which existing reservoirs can be used for multiple purposes, including flood risk management, water supply, recreation, and power generation, while achieving the primary purposes of those facilities. For example, volume in a water supply reservoir can be drawn down in anticipation of forecast spring flooding from snowmelt. The reduction in volume allows for greater retention of floodwaters, which in turn restore the reservoir to its target volume. If multiple reservoirs are present in a watershed, coordination must be used to identify and achieve the multi-use objectives.

#### 5.6.1.3 Regional Dams

Large-scale dams or impoundments designed to restrict the flow of water on the main stem and/or tributaries of the Delaware River could be constructed to provide flood risk management for the Basin. Such structures would have substantial footprints and would require the dedication of extensive lands for the retention of water. Dams or impoundments could operate with a permanent pool of retained water on the upstream side of the structure, or could operate as "dry dams" that do not retain water during non-flood periods.

### 5.6.2 Structural Measures

#### 5.6.2.1 Backflow Prevention Structures

Backflow prevention structures, such as flap valves and sluice gates, can prevent high stages in the main channel from backing up into tributaries and storm drains. The structures are typically used in combination with some form of levee or floodwall (which may also be a raised roadway or path), or natural topographic feature; otherwise, they are placed on storm drains and do not require a line of protection.

#### 5.6.2.2 Levees and Floodwalls

In general, floodwalls and levees function within the limits of their design to confine flood flows to the existing channel footprint, prevent breakout of floodwaters, and provide protection against flooding. Interior drainage facilities are often required to handle stormwater that ponds behind the barriers. Levees and floodwalls can be combined with closure structures, such as stoplog closures and gate closures. Levees are earthen embankments, whereas permanent floodwalls are usually built out of concrete or sheetpile, and temporary floodwalls can be constructed out of a variety of materials. Permanently installed, deployable flood barriers can also be used. These barriers can be constructed to deploy automatically when floodwaters reach the structure, using hydrostatic pressure to raise the barrier into place.

#### 5.6.2.3 Channel Modification

Channel modification involves widening, deepening or straightening of existing channels, creation of new channels, and the modification of highway and railroad bridges that constrict the channel.

#### 5.6.2.4 Dams or Flow Detention

Flood risk management dams can have a permanent pool of water behind them, or they may be designed to not retain a permanent pool. This second kind is known as a dry dam. Both types are designed to allow regular passage of water through them and to form a flood pool behind them during heavy rainfall events.

A typically smaller form of flow detention, known as detention basins, is used to attenuate the peak flow rate of run-off by temporarily storing large volumes of stormwater, then releasing them at a controlled rate of flow. This alternative was considered as a means to create flood storage areas in the floodplain by enclosing a large area with a dike. During floods, the floodwaters would overflow into the storage area.

#### 5.6.2.5 Dam Removal

Dam removal would remove controls on downstream flows from former impoundment areas. The technique is used to restore natural flow to rivers, potentially reduce flooding on tributaries and areas upstream of the dam. For ecosystem restoration purposes, it can be used to improve the ability of fish to travel upstream to spawning habitats.

### 5.6.3 Nonstructural Measures

An evaluation of nonstructural measures under the criteria of completeness, effectiveness, efficiency, and acceptability is provided in the following section, as well as a discussion of whether the measure should be further evaluated as part of a potential Federal flood risk management project. These measures are grouped into the categories of land use and regulatory measures, retrofit measures, and land acquisition measures.

5.6.3.1 Land Use and Regulatory Measures

Land use and regulatory measures are designed to direct the location and nature of new development and redevelopment to manage risks from flooding and other hazards. The measures include: zoning and land use controls, new infrastructure controls, and landform /habitat regulation, construction standards and practices, insurance program modifications, and tax incentives.

5.6.3.2 Building Retrofit Measures

Building retrofit measures are designed to protect damageable property from floodwaters by preventing the water from entering a structure, moving the structure out of floodprone areas, elevating the structure above flood elevations, or modifying the structure so that designated portions (e.g., lower floors or basements) are designed to flood without incurring damage. All exterior losses such as damage to grounds, utilities, roads, crops, etc., would be fully sustained in the future. Descriptions of the assorted techniques are included in Appendix H: Plan Formulation: Details of Phases 1 & 2.

5.6.3.3 Land or Structure Acquisition Measures

Purchase of property is the public acquisition of private developed or undeveloped lands vulnerable to flooding for long-term protection and preservation. Purchase of developed lands requires purchase and removal of buildings. A requirement is the preparation of a plan for the alternate use of the land, which may include recreation or open-space uses.

Easements allow owners to retain full ownership of property but can either restrict certain uses or permit the use of land by the public or particular entities for specified purposes. Easements are generally established as part of the deed restrictions. For purposes of flood risk management, easements may restrict development of floodprone portions of property, or could be used to create flowage areas where floodwaters are directed en route to waterbodies or detention basins.

### 5.6.4 Ecosystem Restoration Measures

5.6.4.1 Floodplain Reclamation/Wetland Restoration

For this study, ecosystem restoration measures must contribute to the primary goal of flood risk management. Reclaimed floodplains and wetlands can provide localized flood risk management by slowing the speed of floodwaters, absorbing the force of flow, and detaining floodwaters. Through these actions, floodplains and wetlands can lower flood heights and reduce the erosive potential of the water, thereby minimizing property damage. Floodplain reclamation can be achieved through removal of buildings and flood control structures to allow floodwaters to return. Wetland restoration can expand upon the ecosystem services of existing wetlands by improving hydrology to increase flows and expand flood storage capacity. Additional detail on specific techniques to achieve floodplain reclamation and wetland restoration is provided in Appendix H: Plan Formulation: Details of Phases 1 & 2.

Based on a series of site visits and trip reports, several sites were initially identified as possessing some of these restoration opportunities. Appendix H: Plan Formulation: Details of Phases 1 & 2 provides a summary of the identified sites and potential restoration measures.

While the option of wetlands restoration was considered for the whole study area, the nature of the geography and development indicates that it is most applicable in the tidal portion of the Study Area (Greenwich and Logan Townships).

## 5.7 Phase 1 - Screening of Measures

The Corps *Planning Guidance* Notebook calls for a detailed review under the criteria of completeness, effectiveness, efficiency and acceptability. This review of the measures was conducted for each of the study area communities. Description of these criteria and details of the evaluation are provided in Appendix H: Plan Formulation: Details of Phases 1 & 2. Structural and nonstructural measures to be eliminated from further evaluation were identified, as well as those measures that are recommended for further evaluation in the next stages of the planning process. As is evident in Appendix H, because of the very site specific nature of structural measures, Phases 1 and 2 overlapped in the assessment.

### 5.7.1 Evaluation Criteria

The evaluation of alternatives was structured to mirror the current Federal Principles and Guidelines for Water Resource Implementation Studies (P&G) assessment criteria that any plan must be complete, effective, efficient and acceptable. The following specific criteria were used to help establish completeness, effectiveness, efficiency and acceptability:

- Reductions in flood damages (qualitative and quantitative)
- Cost of implementation (qualitative and quantitative)
- Potential for induced flooding
- Unavoidable impacts and significant environmental mitigation requirements
- Opportunities to provide ecosystem restoration with the measure
- Potential impacts to Federally listed threatened and endangered species
- Compliance with Federal and State regulations

### 5.7.2 Outcome of the Screening - Regional Measures

Several measures that may be implemented and would have impacts beyond the limits of the Interim Feasibility Study for New Jersey area are discussed below.

#### 5.7.2.1 Flood Warning System

Flood warning system expansion that increases public receipt of warning information and advance knowledge of hazardous conditions (such as reverse 9-1-1 for floodplain areas) would provide benefits to all of the communities within the study area and is recommended for continued development through joint Federal and local actions. It is important to note that an effective flood warning system is an important element of other flood risk management measures, helping to protect human life and to ensure correct operation of gates, pumps and closure structures.

#### 5.7.2.2 Reservoir Management

Reservoir management improvement efforts are also recommended for continued development. Current joint efforts of the Corps, USGS, DRBC and others, such as the Flexible Flow Management Plan (FFMP), have the potential to further optimize the use of available reservoir storage for multiple purposes, including flood risk management.

5.7.2.3 Regional Dams

In 1962, after the 1955 flood of record, Congress authorized the Tocks Island Dam on the main stem Delaware River. Over a period of many years the project met with numerous major impediments, including local opposition, geologic issues, and financial limits. In 1975, the project was indefinitely delayed; in 1978, the project area became part of the National Wild and Scenic River system; in 1992, the project was re-reviewed and tabled for another 10 years; and in 2002 Congress officially de-authorized the Tocks Island Dam Project.

Any current project of the nature and magnitude of a dam on the main stem Delaware River would encounter at least as many issues, as well as significantly more rigorous environmental regulation. A structural project of this size, if it could be constructed, would also take many years to come to fruition, offering no flood risk management benefit in the interim. In consideration of these factors, construction of an impoundment on the main stem of the Delaware River has been eliminated as a viable alternative.

### 5.7.3 Outcome of the Screening - Structural Measures

5.7.3.1 Backflow Prevention Structures

In much of the study area, a primary concern is that the flow of Delaware River floodwaters may cause backflow up tributaries. There is a risk of flood damage between adjacent risk management measures where they do not tie-in to high ground. Tie-back structures in place of high ground may be a solution to avoid backflow flooding damages.

Backflow prevention devices are needed on many of the municipal stormwater systems; however, unless it is associated with a levee or other line of protection, this is a non-Corps responsibility and should be pursued by other Federal agencies, the State of New Jersey and the local communities.

5.7.3.2 Levees and Floodwalls

Levees and floodwalls are effective flood risk management measures in the following circumstances: *a.* damageable property is clustered geographically; *b.* a high degree of protection, with little residual damage, is desired; *c.* a variety of properties, including infrastructure, structures, contents, and agricultural property, are to be protected; *d.* sufficient real estate is available for levee construction at reasonable economic, environmental, and social costs; and *e.* the economic value of damageable property protected will justify the cost of constructing the new or enhanced levee and floodwalls. In addition, residents must be amenable to any visual effects associated with installation of a permanent levee or floodwall; these structures can block some, or all, of the view of the river, or otherwise reduce access.

Levees and floodwalls to provide a line of protection were evaluated for the following study area communities: Knowlton Township, Phillipsburg, Frenchtown, Stockton, Lambertville, Ewing Township, the Glen Afton and The Island sections of Trenton, downtown Trenton, and Greenwich and Logan Townships. In the other communities, a lack of density in the floodplain development or the presence of other constraints precluded consideration of a levee or floodwall system.

Prior to determining the actual benefits to buildings from the concept-level Line of Protection, a comparison was conducted between the estimated annual costs of the structural measures and the Equivalent Annual Damages of the buildings protected for the calculation of an initial screening BCR. The benefits were not calculated in the HEC-FDA computer program at this screening phase.

#### 5.7.3.3 Channel Modification

The Delaware River through the study area maintains a very mild slope throughout most of its length, limiting the effective flow carrying capacities of any channel modification or dredging. Because of the relatively flat stream gradient along the main stem, a significant reduction in flood levels would require extensive excavation, relocations, and acquisition of additional lands, all at high costs. In addition, channel modifications would violate other criteria regarding induced flooding, significant environmental impacts, and would likely violate the Wild and Scenic Rivers Act. Therefore, the approach was dropped from further consideration.

#### 5.7.3.4 Dams or Flow Detention

In 1984, the use of flood risk management projects including dry dams on Delaware River tributaries was investigated in a Delaware River Basin study. Potential multipurpose dam sites in the study area had been identified in the 1960s and had also been mentioned in the 1975 "Tocks Island Lake Project and Alternatives" Study. In 1984, it was established that other than possible sites on the Aquashicola Creek and Cherry Creek in Pennsylvania, which were still rejected for other reasons, those locations would not provide suitable sites for flood risk management. It should be noted that dry dams in these locations would probably not have provided significant benefits in the floods of 2004, 2005 and 2006.

Detention basins are used to attenuate the peak flow rate of run-off by temporarily storing large volumes of stormwater, then releasing them at a controlled rate of flow. Environmental impacts of this option would be significant. Potential downstream negative effects could include changes in the quality of water flowing out of the reservoir behind the dam and changes in downstream water temperatures. Downstream riparian areas that are dependent on overbank flows for recharge would probably experience reductions in size. Economic justification would be highly unlikely for alternatives that rely on detention basins.

Dams or flow detention within New Jersey have not been identified as an effective option to manage the risk of flooding on the main stem of the Delaware River in New Jersey. The potential detention sites within the state do not control a significant portion of the drainage area, and the tributary streams in New Jersey have typically contributed their peak runoff before the peak flows from the upper portions of the basin have reached the New Jersey damage sites. Delaying peak flows from smaller New Jersey tributaries may actually make their peak flows more coincident with peak flows on the Delaware River.

#### 5.7.3.5 Dam Removal

While there are no dams along the main stem of the Delaware River, there are, however, dams on some tributaries. The option of dam removal was considered for its viability in terms of flood risk management, especially on the Pequest River in Belvidere, NJ. It is thought by some local officials that removal of the Pequest dams would lower the upstream water surface and create some additional storage area during times of flooding. This position is supported by a 1985 report by the Soil Conservation Service (now NRCS). Site visits indicate that removal of the dams would have little or no impact on flooding from the Delaware River main stem, which was the focus of this study. Much of the flooding in the area is associated with the Pequest overtopping the right bank and flowing along a parallel Road (Water St.).

### 5.7.4 Outcome of the Screening - Nonstructural Measures

An evaluation of nonstructural measures is provided in the following section, as well as a discussion of whether the measure should be further evaluated as part of a potential Federal flood risk management project. These measures are grouped into the categories of land use and regulatory measures, building retrofit measures, and land acquisition measures.

#### 5.7.4.1 Land Use and Regulatory Measures

Land Use and Regulatory Measures are generally appropriate for reducing damage to future development. They may also be effective in reducing future damages by regulating redevelopment, expansion, or reconstruction of existing buildings. However, in areas that are near full development, these measures are not effective in managing the existing hazard. Some measures, such as tax incentives, may be effective in supporting other efforts, such as retrofitting existing properties to reduce flood damages. The following provides a brief review of the applicability of specific land use and regulatory measures:

**Zoning and Land Use Controls:** Because the Corps has no authority to control land use and zoning, this measure is only recommended for further assessment as part of the non-Federal Flood Risk Management Plan (FPMP), which is yet to be developed.

**New Infrastructure Controls and Landform/Habitat Regulations:** Because the Corps of Engineers has no authority to implement new infrastructure controls or landform/habitat regulations, these measures are only recommended for further assessment as part of the non-Federal FPMP.

**Construction Standards and Practices:** The Corps does not typically have authority to enact community-level regulations. Thus, these measures should be included in other Federal agencies risk management plans, and as part of the non-Federal FPMP.

**Insurance Program Modifications:** An assessment of the potential for insurance program modifications has not identified any authority to make changes as part of the study. Possible changes to the NFIP currently being considered include new initiatives to prevent repetitive losses, and the elimination of subsidies to all but primary residences. These and other changes should be addressed outside the Corps study.

**Tax Incentives:** changes in the Federal income tax code cannot be implemented as part of the current study. None of the additional tax-based measures are implementable by the Corps, and are therefore only recommended as part of the non-Federal FPMP.

#### 5.7.4.2 Building Retrofit Measures

Retrofit measures are effective in managing flood risks to existing development. While many of these measures, such as elevation, are also effective in managing risks to future development, these should be implemented for that purpose through regulatory programs and construction standards aimed at new construction. To provide a timely flood risk management for existing development requires physical changes or retrofits to the at-risk properties.

A screening algorithm of potential nonstructural retrofit measures was applied to identify an appropriate measure for buildings. For structures subject to flooding at an annual probability of occurrence of 1% or more, preliminary costs for the application of various nonstructural flood risk management measures were estimated. The algorithm used to identify and apply feasible and appropriate nonstructural measures was based upon numerous criteria, including building type, usage, size, configuration, construction material, and first floor elevation. The algorithm included nonstructural retrofit measures, such as: 1) dry floodproofing; 2) wet floodproofing; 3) elevation; 4) ringwall; 5) rebuilding; and 6) acquisition (see Structure Acquisition Measures). Details on the algorithm are available in Appendix H: Plan Formulation: Details of Phases 1 & 2.

Nine of the fifteen communities (White Township, Town of Belvidere, Harmony Township, Town of Phillipsburg, Byram, City of Lambertville, Hopewell Township, City of Trenton and Gibbstown) had BCRs identified that may be cost effective. The results included the plan for each municipality that resulted in the greatest number of structures as part of the plan while still remaining economically feasible.

5.7.4.3 Land or Structure Acquisition Measures

Land Acquisition may be used to purchase natural lands or flood-prone buildings. Land acquisition could be accomplished in a variety of ways, including donation with tax benefits, full fee acquisition, purchase of redevelopment rights, and combining acquisition with leases. The following provides a brief review of the applicability of specific land acquisition measures:

**Structure Acquisition:** Buyouts (acquisition) required as part of a structural plan are considered a part of what is known as Land, Easements, Rights-Of-Way, Relocation, and Disposal Areas (LERRD) and must be paid 100% by the non-Federal sponsor, with cost credit toward their share of the overall project cost. The use of structure acquisition as a non-structural measure must be cost justified and is recommended for continued consideration as part of the Federally cost-shared plan and the non-Federal FPMP.

**Purchase of Property:** There would be no immediate NED benefit to the Corps in purchasing undeveloped lands. Thus, this technique is eliminated from further evaluation as part of the Federal flood risk management plan. However, it may be appropriate for inclusion in the non-Federal FPMP or local plans, particularly if a suitable alternate use of the land could be identified.

**Easements and Deed Restrictions:** Easements and deed restrictions, according to the Corps regulations, typically require the non-Federal sponsor to obtain minimum easements for structural projects to ensure access to and maintenance of the risk management features.

**Exchange of Property and Transfer of Development Rights:** Exchange of property and transfer of development rights measures were eliminated from further evaluation as part of the Federal flood risk management plan due to a lack of Federal authority. However, if local communities or the non-Federal sponsor were to acquire lands needed for the Federal project through the use of such measures, they could potentially receive credit for the value of the property to offset their required cost-sharing obligations. These techniques would be appropriate for inclusion in the non-Federal FPMP.

### 5.7.5 Outcome of the Screening - Ecosystem Restoration

The study considered ecosystem restoration opportunities associated with the primary goal of flood risk management.

Potential sites were identified in White, Belvidere, Harmony, Phillipsburg, Frenchtown, and Greenwich and Logan Townships. The sites were evaluated for their completeness, effectiveness, efficiency, acceptability and significance. Because only a limited number of restoration opportunities were identified, the evaluation was conducted for sites, rather than for specific restoration measures at those sites.

While all the identified measures would provide benefits to the environment, it appeared that only the site in Greenwich and Logan Townships would meet the significance requirement.

### 5.7.6 Summary of the Outcome of Phase 1 – Screening of Measures

No potential regional flood risk management measures were identified. Levees and floodwalls, along with associated interior drainage features, were identified as potential structural measures. (For clarity, screening of structural measures for individual municipalities is presented in Phase 2 of this main report, although there was necessary overlap between Phases 1 and 2, as is evident in Appendix H: Plan Formulation: Details of Phases 1 & 2.) Nonstructural building retrofits appeared to have potential in the following municipalities: White, Belvidere, Harmony, Phillipsburg, Byram (in Kingwood Township), Lambertville, Hopewell, Trenton and Gibbstown (Logan and Greenwich Townships). Another nonstructural measure, structure acquisition, appeared to have potential in Belvidere, Harmony, Phillipsburg and Gibbstown. Ecosystem restoration had potential in the Gibbstown area.

## 5.8 Phase 2 - First Added Assessment of Alternatives

The viable measures were combined as a system to create location specific Alternatives. The following subsections and tables present a quantitative and qualitative comparison of the Alternatives created by using the measures described previously in this section.

### 5.8.1 Outcome of the Screening - Structural Alternatives

Because of the extremely site-specific nature of the concept-level structural alternatives, the evaluation of these measures under the criteria of completeness, effectiveness, efficiency, and acceptability is provided in Appendix H: Plan Formulation: Details of Phases 1 & 2. A summary of the evaluation results and recommendations for further study (if warranted) is provided in the sections below. In cases where structural lines of protection (LOPs) may have been indicated, concept- level plans were developed to provide “order of magnitude” annual cost estimates. Table 5.13 provides a summary of structural alternatives, including construction cost and an initial screening benefit/cost ratio. The annual costs were compared to the average annual damages to determine the initial screening BCRs, assuming all flood risks are mitigated. The results were used to see whether further evaluation was warranted.

In Stockton, the initial assessment indicated the proposed Alternative (enhancements to the existing embankment of the D&R Canal) was potentially cost-effective and the cost and benefit comparisons will have to be further refined.

In Lambertville, a levee along Alexauken Creek combined with a floodwall segment along the D&R Canal appeared to be an effective solution to flooding in the northern section of the community.

In the Swan Creek area of Lambertville, floodgates coupled with a tie-back structure appeared to be a potentially cost effective means to inhibit backwater flooding from the Delaware River. The cost effectiveness appeared to be reliant on whether the existing canal wall can meet the USACE standards for tie-back structures because the additional costs for wall (tie-back) modification are likely to cause the total costs to exceed the benefits of the project. In addition to refining the costs of the floodgates, further investigations were needed to determine the availability of using the existing canal wall as a tie-back structure.

In the Glen Afton and The Island neighborhoods of Trenton, a range of structural alternatives were evaluated including floodwalls, floodwalls with removable sections, and deployable flood barriers. Further evaluation of the risk management these measures would provide and the level of residual damages was required before a decision could be reached on cost-effectiveness and suitability for Federal participation.

In Greenwich and Logan Townships, an extensive levee/floodwall line of protection appeared likely to provide cost-effective protection to 842 structures in Gibbstown, plus unquantified benefits to the community of Paulsboro. Nonstructural protection would be included for a number of residences outside the line of protection as well as a ringwall for a light industrial manufacturing facility. This measure required further evaluated for Federal participation.

The structural alternative evaluated for Knowlton Township, along the Lopatcong Creek in Frenchtown, Ewing Township, and downtown Trenton were not likely to be cost-effective, and no further evaluation for Corps participation was recommended. Further information may be found in Table 5.13 and in Appendix H: Plan Formulation: Details of Phases 1 & 2.

Regarding the municipal wastewater treatment plant in Phillipsburg (Site 2b in Table 5.13), additional evaluation was conducted to determine whether structural protection of the facility would be cost-effective. It was ascertained that a flood event at the plant would not affect water supply in the Delaware and Raritan Canal. Therefore, associated benefits would not be realized and a structural flood risk management measure would not be cost-effective.

**Table 5.13: Concept-Level Alternatives—Initial Economic Evaluation for Lines of Protection**

| Town | Site #(1) | Structural Alternative | Height Above Grade (2) | Figure # in Community Evaluations | Estimated LOP Construction Cost (rounded) | Estimated Annual Cost of LOP (rounded)(4) | HEC-FDA Reach and (# of Bldgs.) | # of Buildings Behind LOP | Equivalent Annual Damage (5)(6) | Initial Screening Benefit/Cost Ratio (BCR) | Notes/Assessment on Cost-Effectiveness |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Knowlton** | 1 | 4,000 LF T-wall floodwall with levee tie-off | 9 feet | Fig. 3.4 | $ 19,197,000 | $910,000 | DR-65 (31) | 31 | $57,000 | <0.1 | Unlikely to be cost-effective. No further evaluation recommended. |
| **Phillipsburg** | 2a | 700 LF T-wall floodwall at Lopatcong Creek | >15 feet | Fig. 3.15 | $ 7,194,000 | $340,000 | DR-41 (16) | 16 | $18,000 | <0.1 | Unlikely to be cost-effective. No further evaluation recommended. |
| | 2b | 1,725 LF ringwall (T-wall floodwall) at Wastewater Treatment Plant (WWTP) | > 10 feet | Fig. 3.15 | $ 13,234,000 | $630,000 | DR-41 (1) | 1 | -- | -- | A flood event at the plant would not affect water supply in the Delaware and Raritan Canal |
| **Frenchtown (all reaches)** | 3 | 7,000 LF floodwall along bike path (sheetpile-supported I-wall) | 6 feet | Fig. 3.22 | $ 17,044,000 | $810,000 | 131 | 117 | $141,000 | 0.2 | Unlikely to be cost-effective. No further evaluation recommended. |
| *Reach DR-28* | | -- | -- | -- | -- | -- | DR-28 (60) | 47 | $87,284 | | |
| *Reach DR-29* | | -- | -- | -- | -- | -- | DR-29 (71) | 69 | $53,252 | | |
| **Stockton (all reaches)** | 4 | Reinforce canal bank along 5,400 LF - Elevate bank height; assume 50% of a new levee | 9 feet above existing | Fig. 3.27 | $7,318,000 | $350,000 | | 115 | $359,000 | 1.03 | Potentially cost-effective. Refine damage/benefit assessment for concept-level Line of Protection (LOP) layout and costs. Refine damages to reflect impacts of D&R Canal embankment. |
| *Reach DR-21* | | -- | -- | -- | -- | -- | DR-21 (63) | 63 | $168,000 | | |
| *Reach DR-22* | | -- | -- | -- | -- | -- | DR-22 (65) | 52 | $191,000 | | |
| **Lambertville** | 5 | (a) 590 LF levee at Alexauken Creek (b) 810 LF floodwall along D&R Canal | (a) 12 feet (b) 5 feet | Fig. 3.30 | $4,427,000 | $210,000 | DR-19 (94) | 38 | $610,000 | 2.9 | Likely to be cost-effective. Refine damage/benefit assessment for LOP layout and costs. |
| | | Floodgates and tie-back structure for floodgates at Swan Creek | | -- | -- | $189,000 | DR-18A | 55 | $283,000 | 0.81 | Possibly cost effective, The addition of a tie-back structure for the floodgates may prevent the project from having a BCR above 1. |
| **Ewing** | 6 | 7,700 LF T-wall floodwall with levee tie-off | 9 feet | Fig. 3.35 | $30,519,000 | $1,450,000 | DR-9 (154) | 146 | $640,000 | 0.4 | Unlikely to be cost-effective. No further evaluation recommended. |

Price Level: October 2009, Discount Rate (FY2011): 4.125%, Period of Analysis: 50 years

**Table 5.13 (Continued): Concept-Level Alternatives—Initial Economic Evaluation for Lines of Protection**

| Town | Site #(1) | Structural Alternative | Height Above Grade (2) | Figure # in Community Evaluations | Estimated LOP Construction Cost (rounded) | Estimated Annual Cost of LOP (rounded)(4) | HEC-FDA Reach and (# of Bldgs.) | # of Buildings Behind LOP | Selected EAD Amount for Comparison (5)(6) | Initial Screening Benefit/Cost Ratio (BCR) | Notes/Assessment on Cost-Effectiveness |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Trenton** (Glen Afton/The Island) | 7a.1 | 7,280 LF T-wall floodwall | 13 feet | Fig. 3.40 | $59,233,000 | $2,820,000 | DR-7 (287) | 287 | $1,463,000 | 0.5 | Summary: Refine damage/benefit assessment and concept layout/costs. LOP is assumed to be less for 5 foot barrier vs. 13 foot barrier. The 13-foot high barrier with vehicle-load coating option (7a.5) is not likely to be cost-effective. |
| | 7a.2 | 7,280 LF T-wall floodwall (includes removable sections) | 13 feet | Fig. 3.40 | $88,788,000 | $4,220,000 | DR-7 (287) | 287 | $1,463,000 | 0.3 | |
| | 7a.3(3) | 7,280 LF 5 ft. high deployable FloodBreak barrier; vehicle-load coating | 5 feet | Fig. 3.40 | $29,000,000 | $1,380,000 | DR-7 (287) | 287 | $1,463,000 | 1.06 | These 5-ft high barriers would likely have high residual damages. |
| | 7a.4(3) | 7,280 LF 5 ft. high deployable FloodBreak barrier; pedestrian-load coating | 5 feet | Fig. 3.40 | $17,000,000 | $810,000 | DR-7 (287) | 287 | $1,463,000 | 1.8 | These 5-ft high barriers would likely have high residual damages. |
| | 7a.5(3) | 7,280 LF 13 ft. high deployable FloodBreak barrier; vehicle-load coating | 13 feet | Fig. 3.40 | $75,000,000 | $3,570,000 | DR-7 (287) | 287 | $1,463,000 | 0.4 | |
| **Trenton, cont.**(6)- Downtown: Bridge St. at US Route 1 and Rt. 29/South Warren St. | 7b.1 | 150 LF portable flood barrier along Route 1 and 375 LF portable flood barrier along Rt. 29/South Warren St. | 6 feet | Fig. 3.41 | $2,451,000 | $120,000 | DR-4 (158) | 158 | $2,400 | <0.1 | Summary: Unlikely to be cost-effective. Few buildings in downtown Trenton are below 100-year floodplain elevation. LOP layout was based on Q3 mapping; the updated extent of flooding using the DFIRM model shows a smaller 1% ACE floodplain. Majority of damage in reach occurs to buildings immediately on riverfront. |
| Downtown: Bridge St. at US Route 1 only(3) | 7b.2(3) | 150 LF deployable FloodBreak barrier; vehicle-load coating | 6 feet | Fig. 3.41 | $1,000,000 | $50,000 | DR-4 (158) | 158 | $2,400 | <0.1 | |
| Downtown: Rt. 29/South Warren St.(3) | 7c.1 | 400 LF single-section deployable FloodBreak barrier, vehicle-load coating | 6 feet | Fig. 3.41 | $2,300,000 | $110,000 | DR-4 (158) | 158 | $2,400 | <0.1 | |

Price Level: October 2009, Discount Rate (FY2011): 4.125%, Period of Analysis: 50 years

**Table 5.13 (Continued): Concept-Level Alternatives—Initial Economic Evaluation for Lines of Protection**

| Town | Site #(1) | Structural Alternative | Height Above Grade (2) | Figure # in Community Evaluations | Estimated LOP Construction Cost (rounded) | Estimated Annual Cost of LOP (rounded) | HEC-FDA Reach and (# of Bldgs.) | # of Buildings Behind LOP | Selected EAD Amount for Comparison (5) | Initial Screening Benefit/Cost Ratio (BCR) | Notes/Assessment on Cost-Effectiveness |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Trenton, cont.**(6)- Downtown: Rt. 29/South Warren St.(3) | 7c.2 | Two section (130 and 120 LF) deployable FloodBreak barrier, with berm in between; vehicle-load coating | 6 feet | Fig. 3.41 | $1,300,000 | $60,000 | DR-4 (158) | 158 | $2,400 | <0.1 | |
| **Greenwich and Logan Townships (Gibbstown)** | 8 | 25,000 LF Levee/floodwall; 40% T-wall floodwall | 9 feet | Fig. 3.46 | $78,432,000 | $3,730,000 | RL-3 (809) | 805 | $12,582,000 | 3.4 | Likely to be cost-effective. Refine damages to reflect protection from existing levee. |

Price Level: October 2009, Discount Rate (FY2011): 4.125%, Period of Analysis: 50 years

(1) Different design options (materials, height above grade) are presented for sites 7a and 7c. A number is added to the site designation to indicate the design option.
(2) Includes 3 feet freeboard. A risk and uncertainty analysis for actual additional design allowances has not been conducted at this stage.
(3) Estimated costs provided by FloodBreak, Inc. (www.floodbreak.com) These estimates do not include costs for lands and easements.
(4) Both the Probability-Weighted (PW) and Risk and Uncertainty (R&U) EAD estimation do not consider **protection** from existing uncertified features such as embankments or levees.
(5) PW EAD is shown for specific protected buildings; however, if all buildings in a given reach would be protected by LOP, the EAD including R&U from HEC-FDA model is shown.
(6) In downtown Trenton, if alt. 7b.1 is not chosen, then 7b.2 and either 7c.1 or 7c.2 would be selected.

### 5.8.2 Outcome of the Screening - Nonstructural Alternatives

As with the structural screening, the economic analysis assumes no protection from existing features such as levees, railroad beds or canal embankments. The annual costs were compared to the average annual damages to determine the initial screening BCRs, assuming all flood risks are mitigated. Potentially cost-effective treatments (equal to or greater than 0.7 BCR) for at least the 50% ACE (2-year) floodplain were identified in the following communities: White Township, Belvidere, Harmony Township, Phillipsburg, Pohatcong Township, Byram (in Kingwood Twp.), Stockton, Lambertville, Hopewell Township, and Trenton. However, the Corps cannot participate in the nonstructural retrofit of single private structures which was the case for Pohatcong Township and Stockton. In addition, initial screening BCRs for Knowlton Township, Holland Township, Frenchtown and Ewing Township did not meet the 0.7 BCR threshold.

For the non-tidal, Trenton and North, area as a whole, the nonstructural treatment of 28 buildings in the 50% ACE (2-year) floodplain has an initial screening BCR of 1.3, while the treatment of 136 buildings in the 20% ACE (5-year) floodplain has an initial screening BCR of 0.8. Optimization of costs and benefits would be required to identify a recommended plan. Table 5.14 presents a summary of the initial screening of nonstructural retrofit Alternatives by floodplain for Trenton and North.

**Table 5.14: Cost Summary of Nonstructural Alternatives by Floodplain: Trenton and North**

| Delaware River Basin: Trenton and North | Annual Chance Exceedance Floodplain | | | | | |
|---|---|---|---|---|---|---|
| | 50% | 20% | 10% | 4% | 2% | 1% |
| *Structures Treated* | *28* | *136* | *326* | *681* | *972* | *1,187* |
| Total Annual Damage | $382,000 | $1,334,000 | $2,525,000 | $4,406,000 | $5,511,000 | $6,044,000 |
| First Cost | $3,549,000 | $21,901,000 | $55,319,000 | $121,003,000 | $176,636,000 | $221,134,000 |
| Temp Relocation | $280,000 | $1,320,000 | $3,130,000 | $6,570,000 | $9,200,000 | $10,980,000 |
| Contingency | $1,149,000 | $6,966,000 | $17,535,000 | $38,272,000 | $55,751,000 | $69,634,000 |
| Construction Cost | $4,977,000 | $30,188,000 | $75,983,000 | $165,845,000 | $241,587,000 | $301,749,000 |
| Survey/Appraisal | $280,000 | $1,360,000 | $3,260,000 | $6,810,000 | $9,720,000 | $11,870,000 |
| E&D | $280,000 | $1,360,000 | $3,260,000 | $6,810,000 | $9,720,000 | $11,870,000 |
| S&A | $597,000 | $3,623,000 | $9,118,000 | $19,901,000 | $28,990,000 | $36,210,000 |
| Total Project Cost | $6,135,000 | $36,530,000 | $91,621,000 | $199,366,000 | $290,018,000 | $361,698,000 |
| Total Annual Cost | $292,000 | $1,737,000 | $4,357,000 | $9,480,000 | $13,791,000 | $17,199,000 |
| *Initial Screening BCR* | *1.3* | *0.8* | *0.6* | *0.5* | *0.4* | *0.4* |

Price Level: August 2010, Interest Rate: 4.125%, Period of Analysis: 50 years

In Greenwich and Logan Townships (Gibbstown), nonstructural Alternatives were also evaluated and assigned to buildings. The initial screening BCR of 3.9 is seen in the treatment of 254 buildings in the 50% ACE (2-year) floodplain. The treatment of the suitable buildings in the 1% ACE (100-year) floodplain would include 420 buildings with an initial screening BCR of 2.6. Table 5.15 presents summary information of the nonstructural retrofit costs by floodplain:

**Table 5.15: Cost Summary of Nonstructural Alternatives by Floodplain: Greenwich and Logan Townships (Gibbstown)**

| Greenwich and Logan Townships Total: | Annual Chance Exceedance Floodplain | | | | | |
|---|---|---|---|---|---|---|
| | 50% | 20% | 10% | 4% | 2% | 1% |
| *Structures Treated* | *254* | *299* | *325* | *380* | *396* | *420* |
| Total Annual Damage | $9,817,432 | $10,085,100 | $10,254,503 | $10,330,538 | $10,385,826 | $10,394,420 |
| First Cost | $30,281,644 | $35,109,430 | $38,342,640 | $43,876,825 | $45,390,012 | $47,781,744 |
| Temp Relocation | $2,430,000 | $2,810,000 | $3,030,000 | $3,420,000 | $3,500,000 | $3,580,000 |
| Contingency | $9,813,493 | $11,375,829 | $12,411,792 | $14,189,047 | $14,667,004 | $15,408,523 |
| Construction Cost | $42,525,137 | $49,295,259 | $53,784,432 | $61,485,872 | $63,557,015 | $66,770,267 |
| Survey/Appraisal | $2,540,000 | $2,990,000 | $3,250,000 | $3,800,000 | $3,960,000 | $4,200,000 |
| E&D | $2,540,000 | $2,990,000 | $3,250,000 | $3,800,000 | $3,960,000 | $4,200,000 |
| S&A | $5,103,016 | $5,915,431 | $6,454,132 | $7,378,305 | $7,626,842 | $8,012,432 |
| Total Project Cost | $52,708,153 | $61,190,690 | $66,738,563 | $76,464,177 | $79,103,857 | $83,182,699 |
| Total Annual Cost | $2,506,325 | $2,909,678 | $3,173,485 | $3,635,947 | $3,761,467 | $3,955,420 |
| *Initial Screening BCR* | *3.92* | *3.47* | *3.23* | *2.84* | *2.76* | *2.63* |

Price Level: August 2010, Interest Rate: 4.125%, Period of Analysis: 50 years

### 5.8.3 Outcome of the Screening - Ecosystem Restoration Alternatives

The potential for Corps participation in ecosystem restoration Alternatives appears to be limited due to the relatively small scale and limited regional or national significance of the potential restoration outputs. The most significant restoration opportunity for Corps involvement is restoration of historic tidal inundation and invasive species control in conjunction with a line of protection at Greenwich and Logan Townships. However, restoration of the marsh would not contribute significantly to flood risk management. Consequently and consistent with Public Law 113-2 (Hurricane Sandy response), restoration will need to be considered separately from this study under other project authorization.

### 5.8.4 Outcome of the Screening - Alternatives to be Assessed Outside of the Interim Feasibility Study for New Jersey

In addition to the alternatives identified for continued study as part of the Interim Feasibility Study for New Jersey, numerous alternatives such as installation of backflow prevention devices on stormwater systems have been identified as appropriate for continued assessment as part of other local and Federal programs. More information on Alternatives such as this one are provided in Appendix H: Plan Formulation: Details of Phases 1 & 2.

### 5.8.5 Additional Phase 2 Assessments

Additional investigation was performed to follow up on the outcome of the initial Phase 2 assessment. Plans with BCRs close to 1.0 were revisited. The purpose of the additional investigation was to assure that the most viable plans were carried forward into the detailed Phase 3 assessment.

Initial assessment of the potential to reinforce the canal bank in Stockton included an assumption that it would be necessary to rebuild half of the structure volume and elevate the height. After geotechnical boring information was obtained, the initial calculations were shown to be optimistic. The geotechnical information indicated a need to include a sheetpile wall in the design in order to cut off seepage. The cost increase caused the BCR to decline from 1.03 to less than the required 1.0. In addition, the NPS indicated that changing the visual presentation of the embankment could be in conflict with the Wild and Scenic River designation. The NPS has veto authority for federally assisted water resources projects within the purview of a designated Wild and Scenic River. As a result of the additional information, reinforcement of the canal bank in Stockton was eliminated as a potential flood risk management measure.

Further information was also obtained for the Swan Creek area of Lambertville. A conceptual plan and the accompanying preliminary cost estimate were updated to bring them in alignment with current Corps practice. The costs remained potentially viable, but did not take into consideration the likelihood of the canal wall not meeting Corps standards as a tie back structure. The probable need to create a tie back structure would increase the costs and likely prevent the BCR from reaching the required 1.0. In addition, as with Stockton, the NPS stated significant reservations about structural flood risk management solutions in the Lower Delaware Wild and Scenic River area. Therefore, Swan Creek was removed from further consideration.

Initial assessment for the Glen Afton and The Island neighborhoods of Trenton indicated that a relatively low level of protection might be feasible. However, the analysis considered total damages, but not residual risk. A residual risk analysis was completed, showing that most of the damages in the area would occur from extreme flood events. Thus it was determined that substantial risk would remain, significantly reducing benefits and causing the BCR to go below 1.0. Hence, further plan formulation was not conducted for Trenton.

Initial assessment also indicated that a comprehensive nonstructural plan for Gibbstown might provide cost effective flood risk management by reducing structure and content damages to a limited number of structures. Because the plan primarily consisted of elevating at-risk structures, the plan would not prevent flooding of roads, cars and outside properties and only partially addressed the flood risk. When comparing the non-structural and structural alternatives it became apparent that the structural plan would provide greater risk reduction to a larger number of structures at a similar or lower cost. Accordingly, the continued formulation focused on a plan using structural measures for the higher density areas, supplemented by non-structural measures for the remaining structures at risk of flooding.

### 5.8.6 Summary of the Outcome of Phase 2 – First Added Assessment of Alternatives

At the conclusion of the Phase 2 screening, structural plans for Gibbstown and the Alexauken Creek area in Lambertville remained feasible. Both implementation of nonstructural measures by individual municipalities [White Township, Belvidere, Harmony Township, Phillipsburg, Byram (in Kingwood Twp.), Lambertville, Hopewell Township, and Trenton] and a comprehensive nonstructural plan for Trenton and North also continued to be considered. This outcome was confirmed by NAD and HQUSACE at the Alternatives Milestone Meeting on November 15, 2013.

## 5.9 Phase 3 - Incremental Alternative Plan Development and Assessment*

As noted at the conclusion of Section 5.8, plans for Gibbstown and the Alexauken Creek area of Lambertville remained feasible. Therefore, more detailed alternative plans for design and implementation were considered. The following sections provide the descriptions of refinements and adjustments to the flood risk management features in both Gibbstown and Lambertville, plus the development and evaluation of additional features to address interior flooding. Together, the refined flood risk management features and optimized interior drainage features form the basis of the Tentatively Selected Plan (TSP).

### 5.9.1 Gibbstown (Logan and Greenwich Townships) Alternative Plans

The general plan identified for the communities of Logan and Greenwich was identified as a 21,339 foot line of protection (7,386 LF of levee, 13,788 LF of floodwall and two closure gates, all adjacent to Gibbstown) extending northward from high ground near Floodgate Road, along the west side of Gibbstown, until reaching high ground in Paulsboro. Alternative combinations of levees and floodwalls were evaluated as part of the final array. The plan included nonstructural treatment of 20 properties outside the alignment. Alternative features to address interior drainage trapped behind the levees and floodwalls were evaluated to develop a comprehensive plan.

5.9.1.1 Line of Protection

Flood risk management features of the project include the levees, floodwalls, closure gates, ringwalls and buyouts. In response to items identified in the project Risk Register, as well as to address the need to identify mitigation requirements, refinements were performed for the structural plan in the Gibbstown area. These updates included incorporating recently completed storm surge modeling results into the storm damage analysis and into the selection of a preliminary structure design elevation. The plan layouts were significantly revised using more detailed topographic mapping, detailed parcel mapping and current aerial photography. The new mapping identified where existing grade elevations are sufficient to meet the structure crests, providing an opportunity to reduce structure lengths. Whereas, the older mapping indicated that flooding from Mantua Creek in Paulsboro would enter Gibbstown, the new mapping and water surface elevations indicated that flooding from Mantua Creek will not be a problem in Gibbstown. Therefore, a line of protection along Mantua Creek was eliminated from consideration. The alignments were also revised to avoid properties owned by DuPont, Ashland/Hercules and Paulsboro refinery, where possible. Some properties owned by both companies have been identified as having significant HTRW concerns and are listed as RCRA or CERCLA sites. In addition, the alignment was revised to avoid piping systems at the Paulsboro Refinery.

One of the major technical concerns was the potential for poor soil conditions along the line of protection at Gibbstown. A limited geotechnical investigation was undertaken to identify the general nature of the soils and to develop more reliable design criteria. The investigation indicated the presence of non-continuous fibrous peat soils. (See Appendix A: Engineering Technical Appendix, Section 4: Geotechnical Investigation.) Based on this information the design sections and cost estimates have been updated to include additional excavation and disposal of poor quality material, geogrids, wick drains and surcharging to enhance levee stability, and additional pile length (50 ft) for stability of the flood wall sections.

The opportunities for alternative alignments or design features to provide enhanced risk management, to reduce impacts, or to reduce costs were also considered. The two additional alternative alignments, Alignment A and Alignment B are presented in Figure 5.3. After consideration of these alignments, it was found that neither alignment was viable, so the original alignment was used in the Alternative Plan comparison. Alternative Alignment A was rejected due the presence of contamination at the DuPont and Ashland/Hercules properties, as well as potential extensive environmental impacts to the river and wetlands. Alternative Alignment B was rejected due to concerns associated with the lack of safe evacuation routes during a storm. In addition, Alternative Alignment B lacked the availability of natural storage areas landward of the alignment, which would not facilitate the safe storage of interior precipitation runoff.

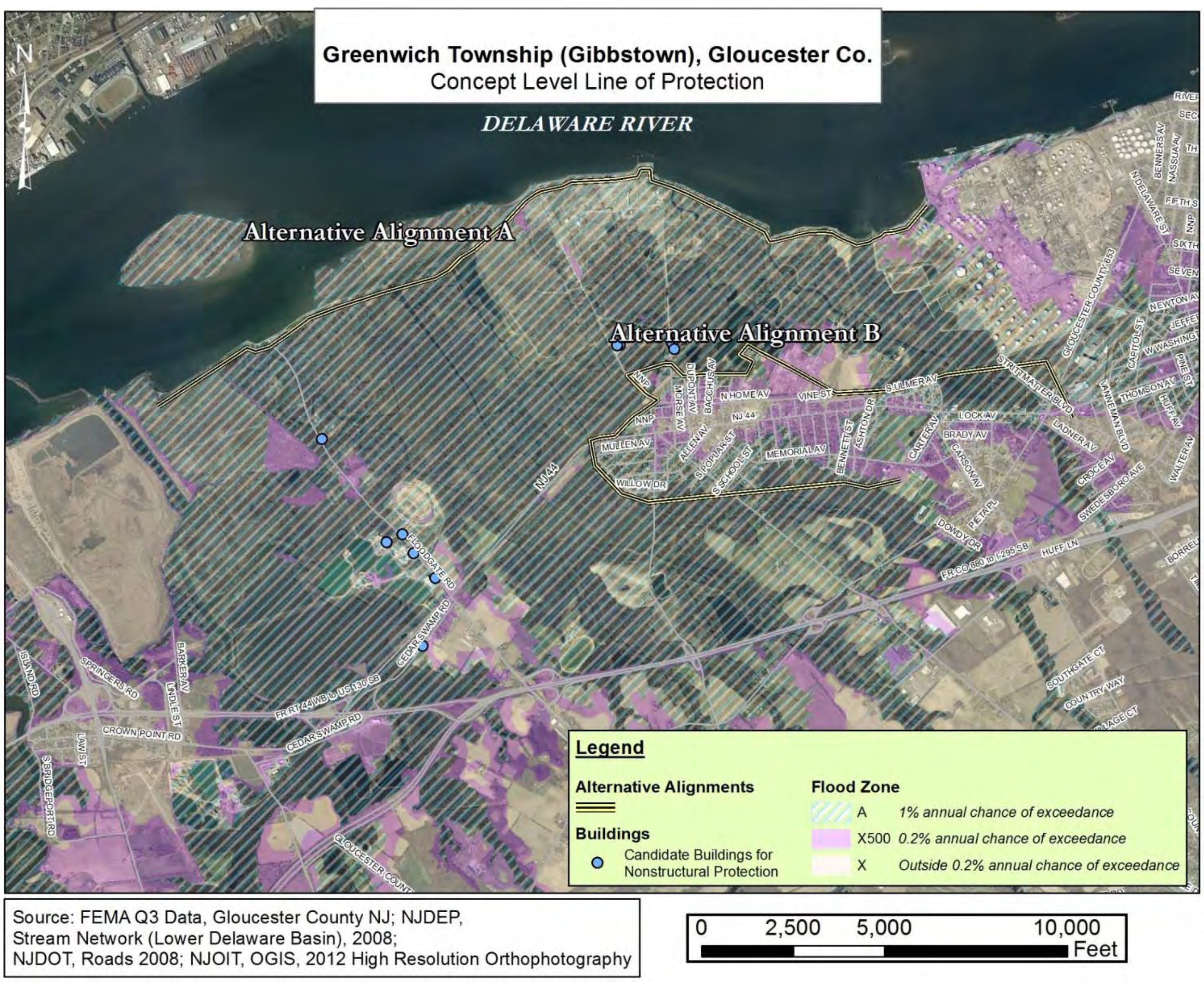

**Figure 5.3: Alternative Alignments Gibbstown**

Three different Alternative Plans were created with the selected plan alignment of the levee/floodwall system. In addition to the line of protection including 13,788 LF of floodwall and 7,386 LF of levee (total LF of 21,339 including two closure gates), two additional structural alternative plans to reduce wetland impacts were developed by replacing levee sections with floodwalls. Alternative 2 consists of a total of 21,174 linear feet of floodwall, not including the ringwalls or gates. Alternative 3 consists of a total of 16,765 linear feet of floodwall and 4,409 linear feet of levee, not including the ringwalls or gates. The ringwalls and gates are the same for all alternatives. Figures 5.4-5.6 show the three different Alternative Plans. Table 5.16, compares these options and includes the reduction in mitigation requirements afforded in the Alternative Plans 2 and 3.

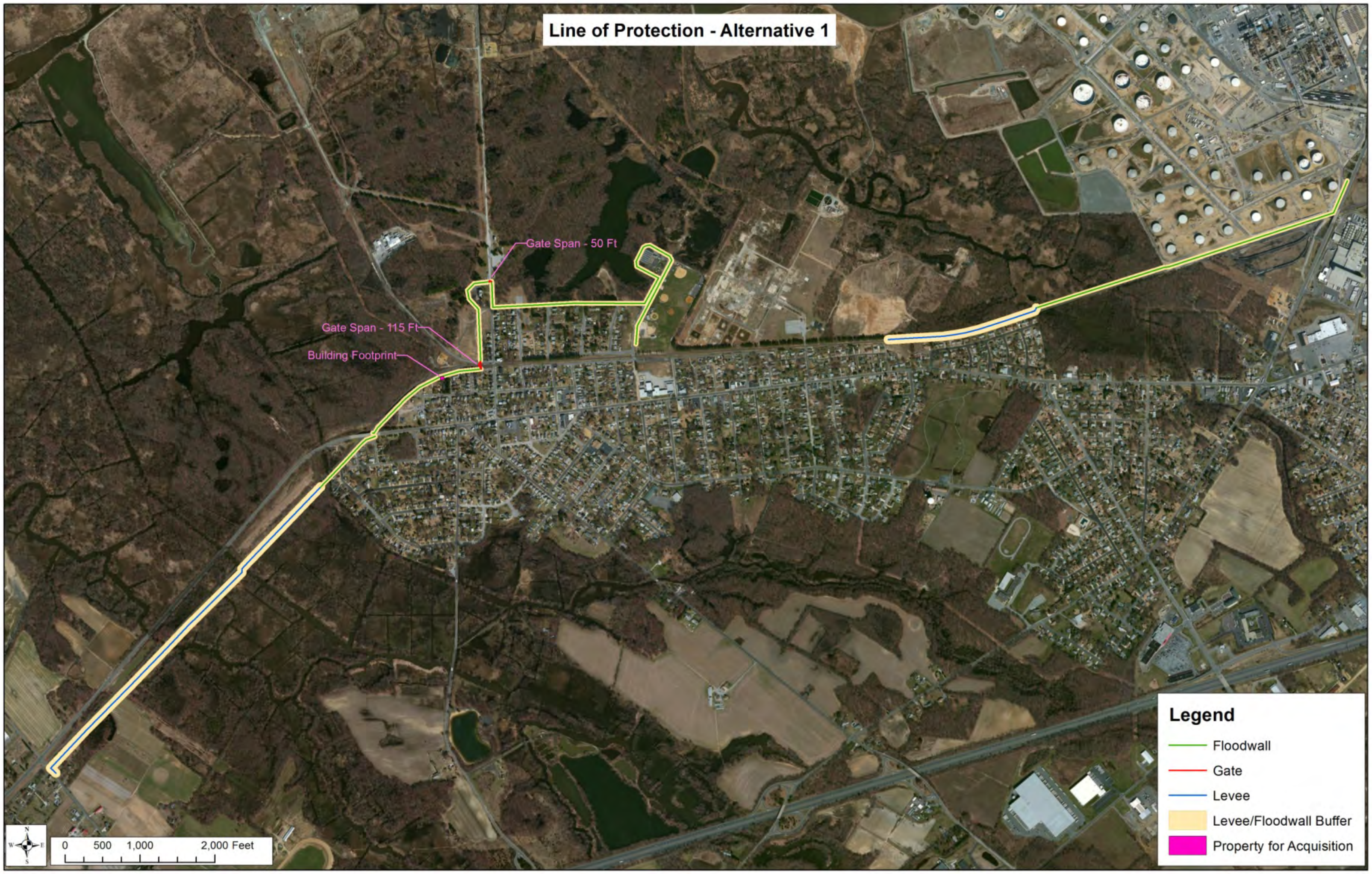


**Figure 5.4: Alternative Plan 1**

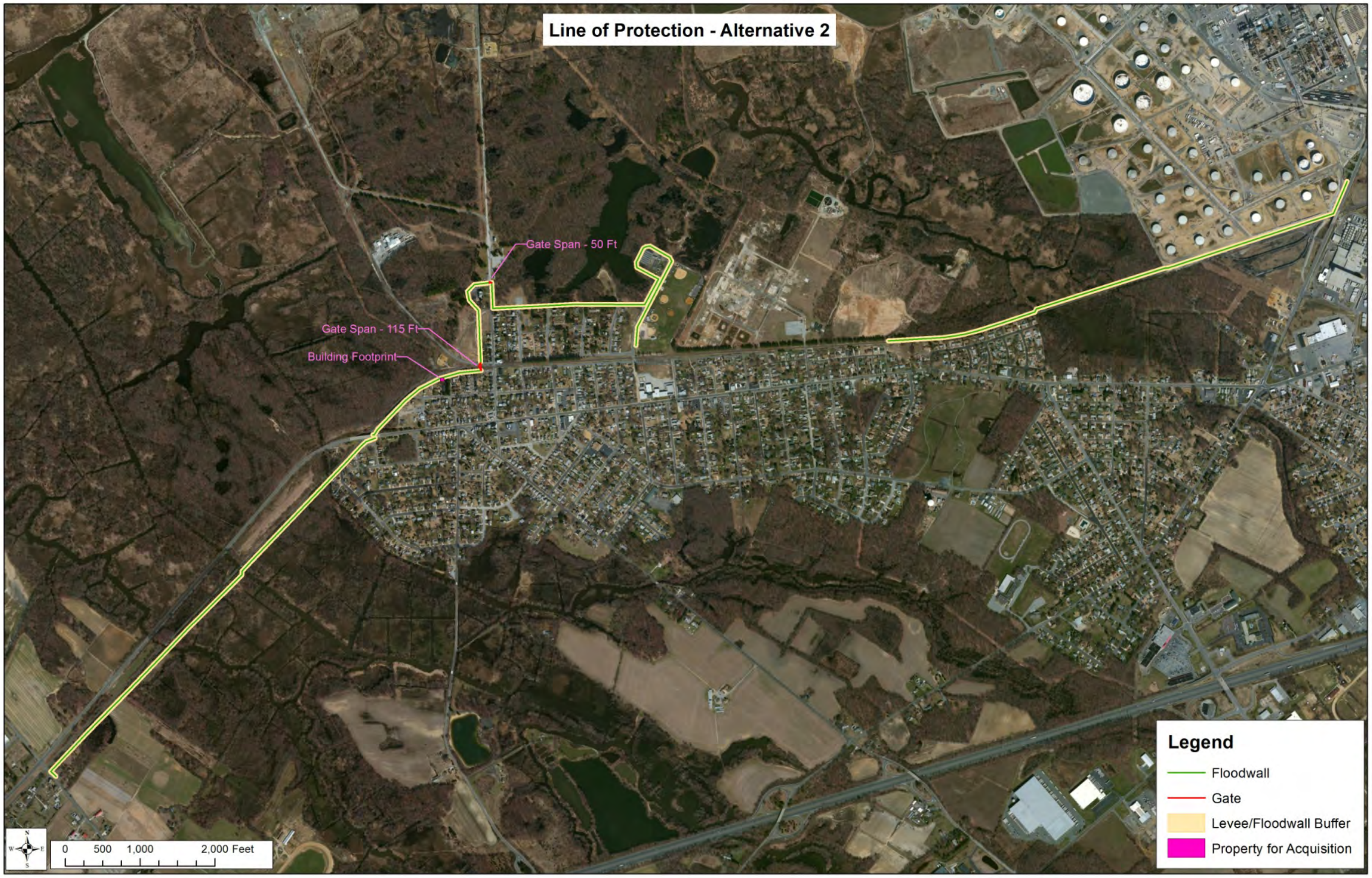


**Figure 5.5: Alternative Plan 2**

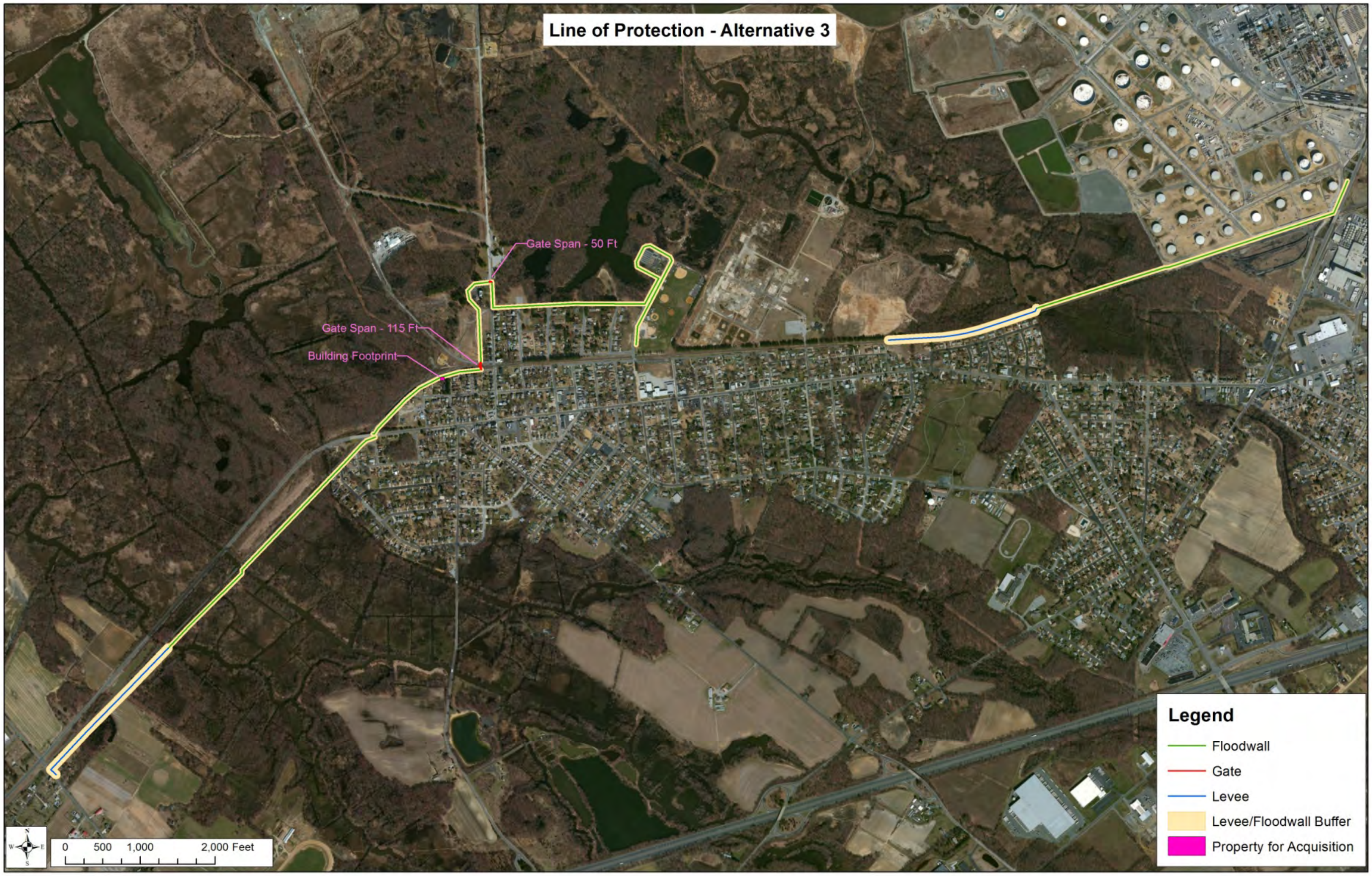


**Figure 5.6: Alternative Plan 3**

Alternative 1 - Floodwall and Levee System (emphasis on levee)
This alternative emphasizes the levee component of the protection system (Figure 5.4). This combination of 7,386 feet of levee and 13,788 feet of floodwall is the least expensive, but has the largest environmental impact (see Table 5.16). The ecological footprint of the proposed levee sections is 120 ft and the ecological footprint of the floodwall sections is 60 ft. Both of these estimated footprints include a maintenance access road adjacent to the levee or floodwall. In addition, there will be three associated ringwalls for community areas outside the area of protection and 17 buyouts.

Alternative 2 - Complete Floodwall System (floodwall emphasis)
This alternative considers just a floodwall as a component of the protection system (Figure 5.5). This system with only 21,174 feet of floodwall is the most expensive, but has the least environmental impact (see Table 5.16). The ecological footprint of the proposed floodwall sections is 60 ft and this footprint includes a maintenance access road adjacent to the floodwall. In addition, there will be three associated ringwalls for community areas outside the area of protection and 17 buyouts.

Alternative 3 - Floodwall and Levee System (mix of levee and floodwall)
This alternative (Figure 5.6) is a different combination of levee and floodwall components than Alternative 1. This combination of 4,409 feet of levee and 16,765 feet of floodwall is in the middle range for cost and environmental impact (see Table 5.16). As previous stated, the ecological footprint of the proposed levee sections is 120 ft and the ecological footprint of the floodwall sections is 60 ft. Both of these estimated footprints include a maintenance access road adjacent to the levee or floodwall. In addition, there will be three associated ringwalls for community areas outside the area of protection and 17 buyouts.

**Table 5.16: With- and Without-Project Alternatives Analysis for Gibbstown**

| | No Action | Alternative 1 | Alternative 2 | Alternative 3 |
|---|---|---|---|---|
| | No Action | Levee / Floodwall System(mix of both treatments, but with emphasis on the levee) | Complete Floodwall System | Levee / Floodwall (mix of both treatments) |
| **Economic & Social Effects** | | | | |
| Monetary Benefits | N/A | $14,920,000 | $14,920,000 | $14,920,000 |
| Costs | N/A | $8,286,000 | $9,439,000 | $8,684,000 |
| BCR | N/A | 1.8 | 1.6 | 1.7 |
| Net Benefits | N/A | $6,634,000 | $5,481,000 | $6,236,000 |
| Flood Damage Reduction | N/A | Expected damage reduction of $14,920,000 for 608 structures at 0.4 ACE future conditions. Number will be refined after plan optimization. | Expected damage reduction of $14,920,000 for 608 structures at 0.4 ACE future conditions. Number will be refined after plan optimization. | Expected damage reduction of $14,920,000 for 608 structures at 0.4 ACE future conditions. Number will be refined after plan optimization. |

**Table 5.16 Con't: With- and Without-Project Alternatives Analysis for Gibbstown**

| | No Action | Alternative 1 | Alternative 2 | Alternative 3 |
|---|---|---|---|---|
| Social Fairness | Area remains at risk of flooding. | Structures on the river side of the structural line of protection receive nonstructural measures, including acquisition. | Structures on the river side of the structural line of protection receive nonstructural measures, including acquisition. | Structures on the river side of the structural line of protection receive nonstructural measures, including acquisition. |
| **Residual Risks** | | | | |
| Residual Damage | $15,237,000 | $317,000 | $317,000 | $317,000 |
| Transformed Risks/ Structure Hazards | Unchanged risk | Significantly reduced probability of flooding. Consequence may increase if evacuation is delayed due to perceived high level of structural protection. | Significantly reduced probability of flooding. Consequence may increase if evacuation is delayed due to perceived high level of structural protection. | Significantly reduced probability of flooding. Consequence may increase if evacuation is delayed due to perceived high level of structural protection. |
| Transferred Risks/ Induced Flooding | N/A | None | None | None |

**Table 5.16 Con't: With- and Without-Project Alternatives Analysis for Gibbstown**

| | No Action | Alternative 1 | Alternative 2 | Alternative 3 |
|---|---|---|---|---|
| Life-Safety | Significant life-safety risk due to perceived protection from existing landform. | Improved life-safety protection due to decreased risk of impacts from breach of existing dike. | Improved life-safety protection due to decreased risk of impacts from breach of existing dike. | Improved life-safety protection due to decreased risk of impacts from breach of existing dike. |
| **Environmental Considerations** | | | | |
| Environmental Benefits | No change | None | None | None |
| Avoid Negative Environmental Impacts | No change | A temporary impact during construction. Potential post-construction loss of connectivity of 4 streams for fish. Mitigation using "fish-friendly" gates proposed for the 2 largest streams. 11.5 acres of wetlands will be impacted by this alternative. Mitigation of 12.5 acres proposed. | A temporary impact during construction. Potential post-construction loss of connectivity of 4 streams for fish. Mitigation using "fish-friendly" gates proposed for the 2 largest streams. 7.9 acres of wetlands will be impacted by this alternative. Mitigation of 9.0 acres proposed. | A temporary impact during construction. Potential post-construction loss of connectivity of 4 streams for fish. Mitigation using "fish-friendly" gates proposed for the 2 largest streams. 8.8 acres of wetlands will be impacted by this alternative. Mitigation of 10.0 acres proposed. |

**Table 5.16 Con't: With- and Without-Project Alternatives Analysis for Gibbstown**

| | No Action | Alternative 1 | Alternative 2 | Alternative 3 |
|---|---|---|---|---|
| Impacts to Historic and Cultural Resources | No change | In a letter dated March 12, 2015 the SHPO was unable to concur with the recommendations regarding site 28GL349 and requested further Phase II eligibility testing in conjunction with further analysis of the existing archaeological assemblage if the Gibbstown Alternative is selected for construction. | In a letter dated March 12, 2015 the SHPO was unable to concur with the recommendations regarding site 28GL349 and requested further Phase II eligibility testing in conjunction with further analysis of the existing archaeological assemblage if the Gibbstown Alternative is selected for construction. | In a letter dated March 12, 2015 the SHPO was unable to concur with the recommendations regarding site 28GL349 and requested further Phase II eligibility testing in conjunction with further analysis of the existing archaeological assemblage if the Gibbstown Alternative is selected for construction. |
| HTRW | Soil and groundwater remediation on site and on adjacent properties proceeds as scheduled. | Extra effort will be expended to ensure that construction of the TSP will produce a net neutral or positive impact to existing environmental conditions. | Extra effort will be expended to ensure that construction of the TSP will produce a net neutral or positive impact to existing environmental conditions. | Extra effort will be expended to ensure that construction of the TSP will produce a net neutral or positive impact to existing environmental conditions. |

**Table 5.17: Alternative Plan Economics – Gibbstown**

| | Alt 1<br>Lowest Construction Cost Plan | Alt 2<br>Maximum Wetland Avoidance Plan | Alt 3<br>Intermediate Wetland Avoidance Plan |
|---|---|---|---|
| **Equivalent Annual Without Project Damage** | | | |
| CSRM Damage | $15,237,000 | $15,237,000 | $15,237,000 |
| Total Damage | $15,237,000 | $15,237,000 | $15,237,000 |
| **Equivalent Annual With Project Damage** | | | |
| CSRM Damage | $317,000 | $317,000 | $317,000 |
| Interior Flood Damage | $0 | $0 | $0 |
| Total Damage | $317,000 | $317,000 | $317,000 |
| **Equivalent Annual Benefits** | | | |
| CSRM Damage | $14,920,000 | $14,920,000 | $14,920,000 |
| Additional Benefit Categories | $0 | $0 | $0 |
| **Total Benefit** | **$14,920,000** | **$14,920,000** | **$14,920,000** |
| **First Costs** | | | |
| Line of Protection | $177,173,000 | $204,215,000 | $186,859,000 |
| Mitigation Costs | $4,753,000 | $3,645,000 | $4,011,000 |
| Total | $181,926,000 | $207,860,000 | $190,870,000 |
| **Interest & Investment Cost** | | | |
| Interest During Construction (IDC)* | $7,780,000 | $8,889,000 | $8,163,000 |
| Total Investment | $189,706,000 | $216,749,000 | $199,033,000 |
| **Annual Costs** | | | |
| Annualized Investment* | $8,088,000 | $9,241,000 | $8,486,000 |
| O&M Cost | $198,000 | $198,000 | $198,000 |
| **Total Cost** | **$8,286,000** | **$9,439,000** | **$8,684,000** |
| **Benefit to Cost Comparison** | | | |
| **Net Benefits** | **$6,634,000** | **$5,481,000** | **$6,236,000** |
| **BCR** | **1.8** | **1.6** | **1.7** |

Price Level: May 2014, Interest Rate: 3.50%, Period of Analysis: 50 years

The non-structural features to provide risk management for buildings located to the riverside of the levee and floodwall were refined. Given the increasing risk of coastal flooding and isolation during these storm events, it was considered to be more prudent to acquire and demolish 17 properties in that area. As sea level changes there are concerns that even elevated homes would become isolated during flood events and pose a safety risk for residents. There are also three industrial properties in the area. It is anticipated that flood risks would be managed with individual ring structures (levee/floodwall/closure gates) for each of these properties. Costs are based on the conceptual layouts presented in Figure 5.7 and 5.8.


**Figure 5.7: Location of Residential Structures Proposed for Acquisition and Demolition**

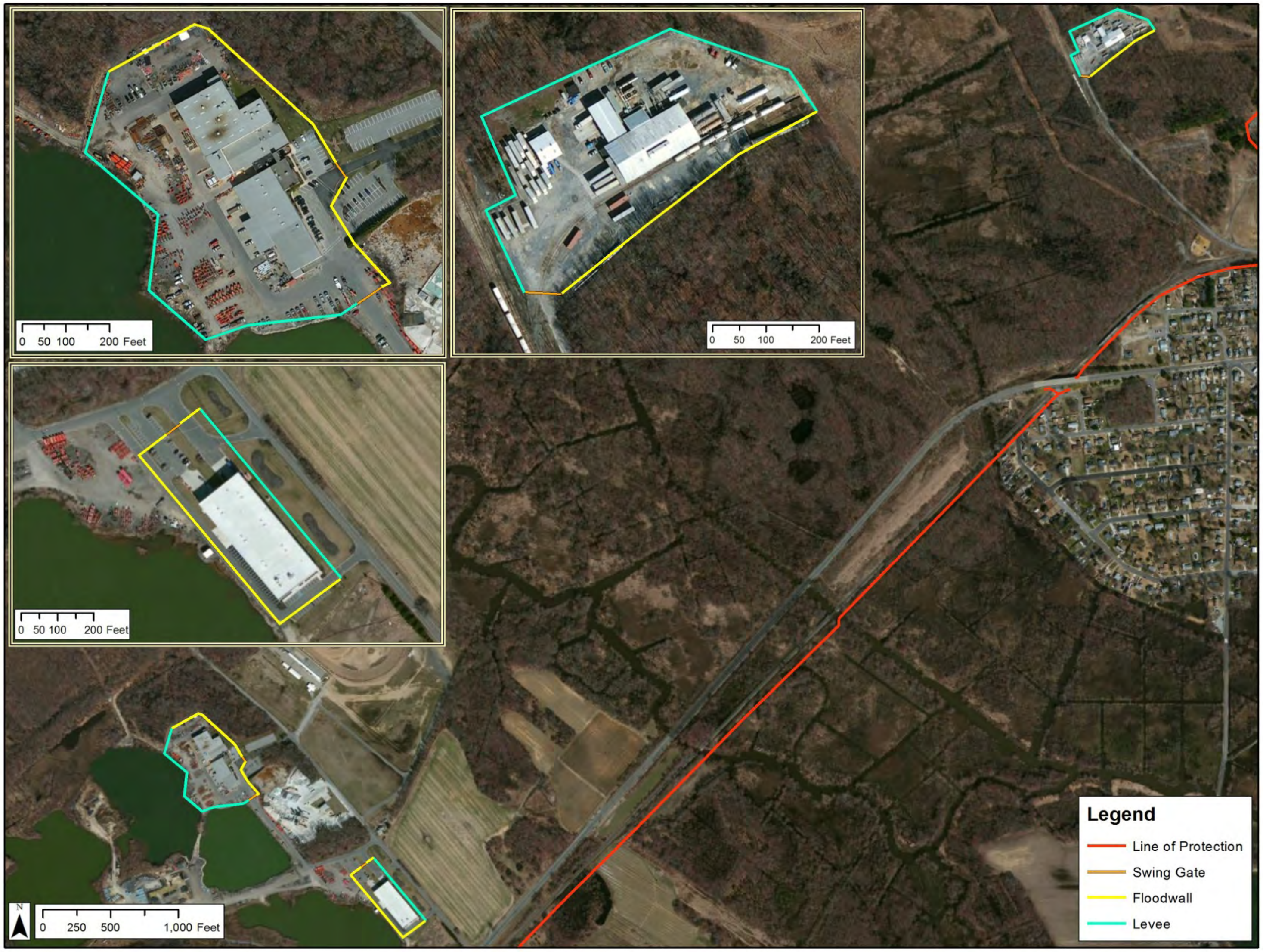


**Figure 5.8 Location of Properties Proposed for Individual Ring Structures**

5.9.1.2 Interior Drainage

Local stormwater systems are usually the responsibility of local entities. However, levees and floodwalls interrupt interior drainage (stormwater drainage on the landward side of the levee or floodwall). Therefore, levee and floodwall design must address how the impact will be mitigated and continued stormwater drainage will occur through, around or over the flood risk management structure. For further information about the interior drainage analysis, see Appendix B: Interior Drainage Analysis.

In Gibbstown, areas landward of the levee/floodwall will have minimal risk of flooding from storm surge but are still subject to interior flooding from stormwater runoff. Thus, interior drainage facilities are required to safely store and discharge the runoff to limit interior residual flooding in excess of existing conditions. The interior areas were studied to determine the specific nature of flooding and to formulate interior drainage alternative plans to maximize National Economic Development (NED) benefits.

In accordance with the Army Corps of Engineers Engineering Manual (EM) 1110-2-1413, Hydrologic Analysis of Interior Areas, the interior drainage facilities are evaluated separately from the line-of-protection. First, a minimum facility plan is identified. The minimum facility plan is considered the smallest plan that can be implemented as part of the line-of-protection that does not result in increased stormwater flooding. It is the starting point from which additional interior facilities planning commences.

Next, the benefits accrued from alternative interior drainage plans are attributable to the reduction in the residual flood damages which may have remained under the minimum facility condition. Finally, an optimum drainage plan is selected based on meeting NED objectives.

The interior drainage facilities must be formulated to maximize NED benefits while meeting NED objectives to provide a complete, effective, efficient, and acceptable plan of protection.

The four separate interior drainage areas that form local interior ponding areas behind the proposed line of protection at Gibbstown are shown in Figure 5.9. The largest of these areas, the Repaupo/White Sluice (Repaupo) area to the western side of the project contains four streams that are interconnected with ditches in the low lying areas prior to reaching the line of protection. These interconnections form a common ponding area with three crossings of the levee/floodwall system (Repaupo Creek, White Sluice Race and Sand Ditch).

The next largest area is the Clonmell Creek watershed (Clonmell), located at the eastern side of the project, where a single stream passes through the line of protection.

An approximately fifty-acre portion of the town center (Town Center) area of Gibbstown, adjacent to and sloping towards the line of protection will drain independently through the line of protection. The smallest interior drainage area also lies within the town center (Town Center 2) and is a 22-acre area confined between the proposed line of protection adjacent to the railroad, and West Broad Street which rises up to overpass the railroad.

Conditions for each of the interior areas were evaluated using a HEC-HMS model with the drainage sub-areas shown on Figure 5.9.


**Figure 5.9 Gibbstown Interior Drainage Areas**

For the Repaupo/White Sluice Interior Ponding area, six 6-foot high by 10-foot wide box culverts convey the flow of 3 creeks through the levee and were sufficient to meet minimum facility requirements. The size of these minimum facility outlets was chosen based on the size of the existing creeks and the peak flows at the sites.

For the Clonmell Creek Interior Ponding area three 4-foot high by 10-foot wide box culverts conveying the flow of the creek through the levee were sufficient to meet minimum facility requirements.

For the main town center interior ponding area three 3-foot high by 4-foot wide box culverts conveying the flows of the local runoff through the levee were sufficient to meet minimum facility requirements. For the smaller town center interior ponding area a 3-foot diameter culvert draining the local runoff through the levee was sufficient to meet minimum facility requirements.

Various alternatives that could potentially improve interior drainage to enhance the established minimum facilities were evaluated for each interior ponding area to determine their viability and cost effectiveness. The alternatives considered were:

- Increased capacity of gravity outlets.
- Pump stations to draw down interior ponding levels.
- Excavated detention areas adjacent to the line-of-protection.
- Construction of interior levees.

Economic and hydraulic analyses indicated that the interior flood levels will result in relatively low levels of annual flood damages and that none of the alternatives considered were cost effective. (See Appendix B: Interior Drainage Analysis.)

### 5.9.2 Lambertville Plan

5.9.2.1 Line of Protection

The original plan identified for Lambertville was to construct a 590 LF levee segment to protect against Delaware River backwater at Alexauken Creek, in combination with an 810 LF floodwall segment along the Delaware & Raritan Canal.

There are very limited alternatives available for the Alexauken Creek area of Lambertville. There are no alternative locations for the floodwall due to physical constraints associated with developed property on one side and the historic Delaware and Raritan Canal on the other side. These impediments also leave no room for a levee. A house on the river side of the proposed floodwall is designated for purchase because there is high life safety risk associated with having a house on the river side of the floodwall with occupants potentially unable to exit through a gate in time. Along Alexauken Creek there is room for the less expensive option of a levee. In addition, a floodwall along the Creek would have impeded visual and pedestrian access. The levee is set back several hundred feet from the Creek because if it was located closer to the Creek, it would have increased environmental and hydraulic impacts.

Refinements were also made to the structural features for Lambertville. These refinements utilized more detailed topography and slightly altered the structure layout. This update identified an area where existing grade elevations along an embankment were at or above the proposed structure crest elevation. New geotechnical borings (see Appendix A: Engineering Technical Appendix, Section 4: Geotechnical Investigations), however, indicate that the embankment may not provide a sufficient level of stability to meet safety standards. The borings also revealed that bedrock is approximately 13 ft below the surface and that there are some areas of soft or pervious soils. The floodwall design and costs were therefore modified to incorporate a sheetpile cutoff wall extending to bedrock, even where the current embankment grades exceed the top of floodwall elevation. The revisions address several concerns identified as potential risks to accurate selection of the TSP.

The revised plan was to construct 516 LF of 10 to 12 feet high levee to protect against backwater at Alexauken Creek, in combination with a 1,409 LF floodwall segment with a maximum height of about 5 feet along the Delaware & Raritan Canal.

The flood risk management benefits for this plan were refined to reflect an update of the structure inventory and a more detailed delineation of economic reaches and the identification of the structures affected by the levee/floodwall plan. The refinements modified the HEC-FDA file to accurately reflect the extent of protection. These revisions resulted in an increase to the estimated BCR and net benefits.

While updating the structure inventory in 2014, it was noted that access to one home would be cut off by the proposed line of protection. Acquisition and demolition of that home was added to the plan and included in the total cost of the Tentatively Selected Plan.

5.9.2.2 Interior Drainage

As described for Gibbstown, local stormwater systems are usually the responsibility of local entities. However, levees and floodwalls interrupt interior drainage (stormwater drainage on the landward side of the levee or floodwall). Therefore, levee and floodwall design must address how the impact will be mitigated and continued stormwater drainage will occur through, around or over the flood risk management structure.

**Figure 5.10: Delaware Avenue Diversion Structure**

There are two drainage areas landward of the levee/floodwall being considered for Lambertville. Draining to the north through the proposed levee to Alexauken Creek is a small area of about 50 acres. To the south is a much larger area that forms the existing Ely Creek. This area has a complex drainage system including several existing diversion structures that direct the majority of flow to the south, around the existing Ely Creek outlet that runs under the D&R Canal. A recent photograph of the diversion structure at Delaware Ave is provided in Figure 5.10. Using funds from a FEMA mitigation grant, the Ely Creek outlet was recently modified to include a sluice gate to prevent direct backflow from the Delaware River (see Figure 5.11).

**Figure 5.11: Ely Creek Sluice Gate**

The USACE's HEC-HMS (Hydrologic Modeling System) was used to analyze the runoff and interior drainage features' performance. The model incorporates the existing drainage features. Based on the hydrologic analysis it was determined that the existing outlet at Ely Creek was sufficient to meet Minimum Facility requirements and that a new 48-inch diameter pipe would meet the minimum facility requirements for the northern drainage area. Figure 5.12 provides an overview of the outlet locations.

The impacts and annual damages associated with interior flooding were evaluated and it was determined that the interior damages in the northern area are negligible. Given the lack of damages to support additional improvements, the Minimum Facility was identified as the most cost effective interior plan.

A total of five Interior Drainage Alternatives were identified for Ely Creek in an attempt to reduce the interior damages, which were calculated to average over $196,000 per year. Table 5.18 provides a summary of the costs, NED benefits and net benefits for each of the alternatives. The three alternatives that provide additional outlet capacity are each cost effective with BCRs ranging from 2.0 to 2.3. Both of the pump station alternatives considered had annual costs that exceed the reduction in annual damages. Table 5.20 presents a combined summary of damages, benefits and costs for the Lambertville line of protection and interior drainage analyses. Alternative 1 has been identified as the Interior Drainage component of the TSP for Lambertville.

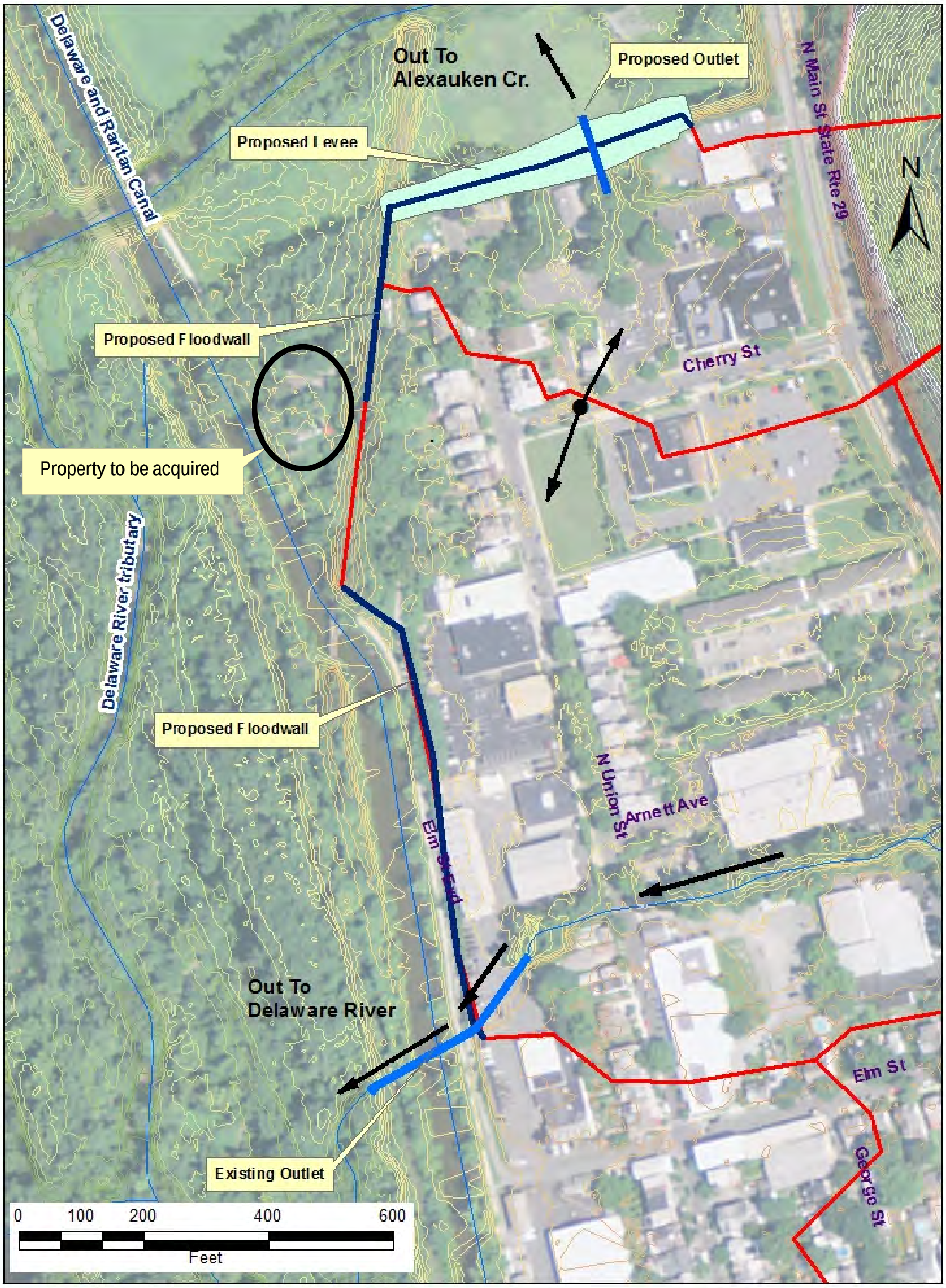


**Figure 5.12: North Lambertville Outlet Locations**

**Table 5.18: Lambertville Interior Drainage Alternatives 1 to 5, Summary of BCRs**

| Alternative | Interior Drainage Area | Flood Damages[1] Minimum Facility | Flood Damages[1] With Alternative | Annual Benefits | Total First Cost[2] | Total Investment Cost[3] | Total Annual Cost[4] | Net Benefits | BCR |
|---|---|---|---|---|---|---|---|---|---|
| Alt 1 | Alexauken | $38 | $0 | $38 | | | | | |
| 54” pipe | Ely | $196,127 | $51,899 | $144,228 | | | | | |
| | **Total** | **$196,165** | **$51,899** | **$144,266** | **$1,315,400** | **$1,372,000** | **$64,000** | **$80,300** | **2.25** |
| Alt 2 | Alexauken | $38 | $0 | $38 | | | | | |
| 2x42” pipe | Ely | $196,127 | $41,573 | $154,554 | | | | | |
| | **Total** | **$196,165** | **$41,573** | **$154,592** | **$1,564,300** | **$1,631,000** | **$76,100** | **$78,500** | **2.03** |
| Alt 3 | Alexauken | $38 | $0 | $38 | | | | | |
| 3x36” pipe | Ely | $196,127 | $35,255 | $160,872 | | | | | |
| | **Total** | **$196,165** | **$35,255** | **$160,910** | **$1,655,300** | **$1,726,000** | **$80,600** | **$80,300** | **2.00** |
| Alt 4 | Alexauken | $38 | $1 | $38 | | | | | |
| 50 cfs pump | Ely | $196,127 | $143,395 | $52,733 | | | | | |
| | **Total** | **$196,165** | **$143,395** | **$52,770** | **$5,262,500** | **$5,488,000** | **$256,100** | **($203,300)** | **0.21** |
| Alt 5 | Alexauken | $38 | $0 | $38 | | | | | |
| 100 cfs pump | Ely | $196,127 | $97,939 | $98,188 | | | | | |
| | **Total** | **$196,165** | **$97,939** | **$98,227** | **$7,154,300** | **$7,460,000** | **$348,200** | **($250,000)** | **0.28** |

Price Level: May 2014, Interest Rate: 3.50%, Period of Analysis: 50 years

Notes: 1) Average Annual Damages
2) Includes contingencies (35%)
3) Includes IDC
4) Includes O&M

**Table 5:19: With- and Without-Project Analysis for Lambertville**

| | No Action | Levee / Floodwall System |
|---|---|---|
| **Economic & Social Effects** | | |
| Monetary Benefits | N/A | $805,000 |
| Costs | N/A | $432,000 |
| BCR | N/A | 1.9 |
| Net Benefits | N/A | $373,000 |
| Flood Damage Reduction | N/A | Expected damage reduction of $805,000 for 60 structures at 0.8% ACE future condition. Number will be refined after plan optimization. |
| Social Fairness | Project area remains at risk of flooding. | Flood risk management provided for a portion of the municipality. Other areas in the municipality remain at risk. |

**Table 5:19 Con't: With- and Without-Project Analysis for Lambertville**

| | No Action | Levee / Floodwall System |
|---|---|---|
| **Residual Risks** | | |
| Residual Damage | $1,147,000 | $342,000 |
| Transformed Risks/ Structure Hazards | Unchanged risk | Significantly reduced probability of flooding. Consequence may increase if evacuation is delayed due to perceived high level of structural protection. |
| Transferred Risks/ Induced Flooding | N/A | None |
| Life-Safety | N/A | Improved life-safety protection due to decreased risk of impacts from flooding. |
| **Environmental Considerations** | | |
| Environmental Benefits | None | None |

**Table 5:19 Con't: With- and Without-Project Analysis for Lambertville**

| | No Action | Levee / Floodwall System |
|---|---|---|
| Avoid Negative Environmental Impacts | No impacts | No impacts |
| Impacts to Historic and Cultural Resources | No impacts | Potential to impact cultural and historic resources as a result of this project. If the proposed Lambertville flood risk management structure is constructed on the current alignment, deep archaeological testing is recommended to test the Bw horizon at greater depth. In addition, no Historic Structures analysis was conducted at this time for the Lambertville; however, several resources eligible for or listed on the National Register of Historic Places are within the project's Area of Potential Effect (APE). |
| HTRW | No change in HTRW conditions of the site. | Construction of the TSP will have no affect on any potential or existing HTRW issues in Lambertville. |

**Table 5.20: Alternative Plan Economics – Lambertville**

| | |
|---|---|
| **Equivalent Annual Without Project Damage** | |
| Flood Damage | $1,147,000 |
| Total Without Project Damage | $1,147,000 |
| **Equivalent Annual With Project Damage** | |
| Flood Damage | $290,000 |
| Interior Flood Damage | $52,000 |
| Total With Project Damage | $342,000 |
| **Equivalent Annual Benefits** | |
| Flood Damage Reduction | $805,000 |
| Other Benefit Categories | $0 |
| **Total Benefit** | **$805,000** |
| **First Costs** | |
| Total | $8,911,000 |
| **Interest & Investment Cost** | |
| Interest During Construction (IDC)* | $381,000 |
| Total Investment Cost | $9,292,000 |
| **Annual Costs** | |
| Annualized Investment* | $396,000 |
| O&M Cost | $36,000 |
| **Total Cost** | **$432,000** |
| **Benefit to Cost Comparison** | |
| **Net Benefits** | **$373,000** |
| **BCR** | **1.9** |

*Price Level May 2014, Interest Rate 3.5%, 50 Year Period of Analysis, 30 Month Construction Period

### 5.9.3 Nonstructural Plan

As with the structural features for Greenwich and Logan (Gibbstown) and Lambertville, refinements were made to the nonstructural data for the remainder of the Basin. The most significant change to the non-structural plans was to refine the analysis of benefits. The initial analysis based the benefits of the non-structural plans on the estimated without project damage to the structures in each plan. The annual damages for individual structures were calculated using a non-risk based probability weighting technique and did not precisely reflect residual damages. The update modified the HEC-FDA file to reflect the characteristics of each structure with the plan in place.

An optimization process was used to determine the highest net benefits by municipality and in aggregate. When net benefits were calculated separately for each by municipality, 38 structures would be included in a nonstructural plan. Aggregation of the municipalities resulted in 28 structures qualifying for a nonstructural plan. Neither approach would provide comprehensive coverage. When evaluated aggregately, the included structures would be in the 50% ACE (2 year) floodplain because that coverage optimized the net benefits of the plan. When evaluated separately by municipality, the included structures would be in the 50% ACE (2 year) floodplain or, at most, in the 20% ACE (5 year) floodplain. Because some communities were optimized to include a large floodplain, there were more structures included than when the plans were aggregated, hence 38 structures versus 28 structures.

For formulation the municipalities were considered in aggregate so that the outcome wouldn't result in a checkerboard of coverage, with, for instance, 50% ACE coverage in a municipality and 20% ACE coverage in the next municipality. Under either scenario, very few structures would be addressed in any given municipality and some municipalities would receive no nonstructural measures. In addition, the effort would require creation of a program overlapping with an existing program under FEMA's purview.

Therefore, it is recommended that the local communities, working with the State and FEMA, prioritize non-structural retrofits for the identified structures and, if these programs cannot address the issue for any reason, USACE may reconsider these solutions under the Continuing Authorities Program.

### 5.9.4 System of Accounts Assessment

Another method of displaying the positive and negative effects of various plans is through use of the System of Accounts, as suggested by the US Water Resources Council. The accounts are categories of long-term impacts, defined in such a manner that each proposed plan can be easily compared to one another. The four accounts used to compare proposed water resource development plans are National Economic Development, Other Social Effects, Regional Economic Development and Environmental Quality.

The intent of comparing alternative flood risk management plans in terms of National Economic Development is to identify the beneficial and adverse effects that the plans may have on the national economy. The Other Social Effects account typically includes long-term community impacts in the areas of public facilities and services, recreational opportunities, transportation and traffic and human-made and natural resources. The Regional Economic Development Account is intended to illustrate the effects that the proposed plans would have on regional economic activity, specifically, regional income and regional employment. The Environmental Quality account is intended to display the long-term effects that the alternative plans may have on significant environmental resources. The Water Resources Council defines significant environmental resources as those components of the ecological, cultural and aesthetic environments that, if affected by the alternative plans, could have a material bearing on the decision-making process. The System of Accounts assessment for the Gibbstown and Lambertville alternatives is provided in Table 5.21.

**Table 5.21: System of Accounts – Evaluation of Alternatives**

**National Economic Development (NED)**

| Resource Categories | No Action Plan | Alternative 1 (Tentatively Selected Plan) | Alternative 2 (Gibbstown Only) | Alternative 3 (Gibbstown Only) |
|---|---|---|---|---|
| Equivalent Annual Damage | Gibbstown: $15,237,000<br>Lambertville: $1,147,000 | Gibbstown: $317,000<br>Lambertville: $342,000 | Gibbstown: $317,000 | Gibbstown: $317,000 |
| Equivalent Annual Benefits | No Impact | Gibbstown: $14,920,000<br>Lambertville: $805,000 | Gibbstown: $14,920,000 | Gibbstown: $14,920,000 |
| Equivalent Annual Interest and Investment Cost | No Impact | Gibbstown: $8,286,000<br>Lambertville: $432,000 | Gibbstown: $9,439,000 | Gibbstown: $8,684,000 |
| Net Benefits | No Impact | Gibbstown: $6,634,000<br>Lambertville: 373,000 | Gibbstown: $5,481,000 | Gibbstown: $6,236,000 |
| Benefit-Cost Ratio | No Impact | Gibbstown: 1.8<br>Lambertville: 1.9 | Gibbstown: 1.6 | Gibbstown: 1.7 |

* NED benefits for the Alternatives are expressed in Section 5.9.

**Other Social Effects (OSE)**

| Resource Categories | No Action Plan | Alternative 1 (Tentatively Selected Plan) | Alternative 2 (Gibbstown Only) | Alternative 3 (Gibbstown Only) |
|---|---|---|---|---|
| Aesthetics | No Impact | Temporary adverse impacts on sight and smell due to construction activities (equipment, earth moving) would disappear upon end of construction period. | Temporary adverse impacts on sight and smell due to construction activities (equipment, earth moving) would disappear upon end of construction period. | Temporary adverse impacts on sight and smell due to construction activities (equipment, earth moving) would disappear upon end of construction period. |
| Displacement effects | No Impact | In Lambertville, 1 structure acquisition and demolition and in Gibbstown, 17 structure acquisitions and non-structural protection (ringwall) for 3 commercial structures. No additional permanent displacement of people, businesses, or farms. | 17 structure acquisitions and non-structural protection (ringwall) for 3 commercial structures. No additional permanent displacement of people, businesses, or farms. | 17 structure acquisitions and non-structural protection (ringwall) for 3 commercial structures. No additional permanent displacement of people, businesses, or farms. |
| Educational, cultural, and recreational opportunities | No impact | Permanent increase in availability of transportation routes during and after severe storm events. Increased level of protection prevents disruption of community services such as schools, hospitals, and utilities. | Permanent increase in availability of transportation routes during and after severe storm events. Increased level of protection prevents disruption of community services such as schools, hospitals, and utilities. | Permanent increase in availability of transportation routes during and after severe storm events. Increased level of protection prevents disruption of community services such as schools, hospitals, and utilities. |
| Emergency Preparedness | No Impact | Permanent increase in access to flexible reserves of water supplies, critical power supplies, scarce fuels, evacuation routes and emergency transport to health facilities during and after storm events. | Permanent increase in access to flexible reserves of water supplies, critical power supplies, scarce fuels, evacuation routes and emergency transport to health facilities during and after storm events. | Permanent increase in access to flexible reserves of water supplies, critical power supplies, scarce fuels, evacuation routes and emergency transport to health facilities during and after storm events. |
| Long-term productivity | No Impact | Negligible impact on long-term productivity of resources. | Negligible impact on long-term productivity of resources. | Negligible impact on long-term productivity of resources. |

**Table 5.21: System of Accounts – Evaluation of Alternatives Con't**

| | | | | |
|---|---|---|---|---|
| Security of life, health, and safety | Significant safety risk due to perceived protection from existing Federally Uncertified Landform | Significant mitigation of related health risks, such as loss-of-life, trauma, hypothermia, water & air pollution, water-borne diseases, vector-borne diseases (through ephemeral water-bodies), and food & water supply disruption. | Significant mitigation of related health risks, such as loss-of-life, trauma, hypothermia, water & air pollution, water-borne diseases, vector-borne diseases (through ephemeral water-bodies), and food & water supply disruption. | Significant mitigation of related health risks, such as loss-of-life, trauma, hypothermia, water & air pollution, water-borne diseases, vector-borne diseases (through ephemeral water-bodies), and food & water supply disruption. |
| Social Vulnerability | Significant social vulnerability to environmental hazards due to high percentage of senior citizens | Permanent reduction in flood hazard exposure for highly vulnerable populations identified in the Social Vulnerability Index, including senior citizens, minorities, and persons living in poverty. | Permanent reduction in flood hazard exposure for highly vulnerable populations identified in the Social Vulnerability Index, including senior citizens, minorities, and persons living in poverty. | Permanent reduction in flood hazard exposure for highly vulnerable populations identified in the Social Vulnerability Index, including senior citizens, minorities, and persons living in poverty. |

** Social Vulnerability Index (SVI) is developed by the Agency for Toxic Substances and Disease Registry (ATSDR), a federal public health agency of the U.S. Department of Health and Human Services

**Regional Economic Development (RED)**

| Resource Categories | No Action Plan | Alternative 1 (Tentatively Selected Plan) | Alternative 2 (Gibbstown Only) | Alternative 3 (Gibbstown Only) |
|---|---|---|---|---|
| Employment distribution | No Impact | Temporary increase in construction-related jobs during construction. Permanent indirect positive impacts on employment opportunities for protected businesses, including opportunities for minority workers. | Temporary increase in construction-related jobs during construction. Permanent indirect positive impacts on employment opportunities for protected businesses, including opportunities for minority workers. | Temporary increase in construction-related jobs during construction. Permanent indirect positive impacts on employment opportunities for protected businesses, including opportunities for minority workers. |
| Fiscal condition of State and Local sponsor | No Impact | Permanent reduction in clean-up, emergency response, resource allocation, and other flood-related costs. Permanent increase in tax base of workers and businesses. | Permanent reduction in clean-up, emergency response, resource allocation, and other flood-related costs. Permanent increase in tax base of workers and businesses. | Permanent reduction in clean-up, emergency response, resource allocation, and other flood-related costs. Permanent increase in tax base of workers and businesses. |
| Population distribution and composition | No Impact | Minimal temporary impact on population distribution or composition. | Minimal temporary impact on population distribution or composition. | Minimal temporary impact on population distribution or composition. |
| Real income | Loss of business income and wages as businesses close during and/or after storm events | Permanent increase in real income for below-poverty and near-poverty workers from temporary construction work and permanent wage opportunities from open businesses. | Permanent increase in real income for below-poverty and near-poverty workers from temporary construction work and permanent wage opportunities from open businesses. | Permanent increase in real income for below-poverty and near-poverty workers from temporary construction work and permanent wage opportunities from open businesses. |

**Environmental Quality (EQ)**

| Resource Categories | No Action Plan | Alternative 1 (Tentatively Selected Plan) | Alternative 2 (Gibbstown Only) | Alternative 3 (Gibbstown Only) |
|---|---|---|---|---|
| Water Resources | No Impact | Gibbstown: The loss of approximately 11.5 acres of wetlands. This impact will be mitigated with 12.5 acres of restored wetlands. Lambertville: No impact to water or wetland resources. | The loss of approximately 7.9 acres of wetlands. This impact would be mitigated with 9.0 acres of restored wetlands. This alternative will have the least impact on wetlands. | The loss of approximately 8.8 acres of wetlands. This impact would be mitigated with 10.0 acres of restored wetlands. |

**Table 5.21: System of Accounts – Evaluation of Alternatives Con't**

| | | | | |
|---|---|---|---|---|
| Air Quality | No Impact | Minimal temporary impact due to construction activity consisting of fugitive dust and exhaust emissions from construction equipment | Minimal temporary impact due to construction activity consisting of fugitive dust and exhaust emissions from construction equipment | Minimal temporary impact due to construction activity consisting of fugitive dust and exhaust emissions from construction equipment |
| Biological Resources | No Impact | Gibbstown: Temporary impact during construction. Loss of connectivity in the watershed. | Temporary impact during construction. Loss of connectivity in the watershed. | Temporary impact during construction. Loss of connectivity in the watershed. |
| Land Use | No Impact | Permanent impact on local land use in the Gibbstown area and parts of Lambertville due to the construction of a 21,174LF levee and floodwall system (24,200 LF with ring structures) in Gibbstown and a 1,925 LF levee and floodwall system in Lambertville. | Permanent impact on local land use in the Gibbstown area due to the construction of a 21,174 LF floodwall system (24,200 LF with ring structures). The land impact will be less since this alternative consists of all floodwall and the estimated footprint of a section of floodwall is 60 ft in width versus a levee, which is estimated at 120 ft in width. | Permanent impact on local land use in the Gibbstown area due to the construction of a 21,174 LF levee and floodwall system (24,200 LF with ring structures). The land impact will be less since this alternative consists of more floodwall and less levee than Alternative 1. |
| Cultural Resources | No Impact | Lambertville: The Phase IB shovel testing for the Lambertville alignment identified no archaeological sites; however, the geomorphological testing found the southern-most portion of the alignment was located on an intact alluvial terrace of the Delaware River, with the potential to contain deeply buried archaeological deposits. Gibbstown: In a letter dated March 12, 2015 the SHPO was unable to concur with the recommendations regarding site 28GL349 and requested further Phase II eligibility testing in conjunction with further analysis of the existing archaeological assemblage if the Gibbstown Alternative is selected for construction. | In a letter dated March 12, 2015 the SHPO was unable to concur with the recommendations regarding site 28GL349 and requested further Phase II eligibility testing in conjunction with further analysis of the existing archaeological assemblage if the Gibbstown Alternative is selected for construction. | In a letter dated March 12, 2015 the SHPO was unable to concur with the recommendations regarding site 28GL349 and requested further Phase II eligibility testing in conjunction with further analysis of the existing archaeological assemblage if the Gibbstown Alternative is selected for construction. |

**Table 5.21: System of Accounts – Evaluation of Alternatives Con't**

| | | | | |
|---|---|---|---|---|
| HTRW | Soil and groundwater remediation on site and on adjacent properties proceeds as scheduled. | Gibbstown: Design and construction of the proposed levee/floodwall system will proceed in close coordination with regulatory agencies and adjacent property owners, in order to control potential contaminant migration and exposures. The full set of precautions necessary to adequately protect the surrounding environment has not yet been determined for the project. Lambertville: Construction of the TSP will have no affect on any potential or existing HTRW issues. | Design and construction of the proposed levee/floodwall system will proceed in close coordination with regulatory agencies and adjacent property owners, in order to control potential contaminant migration and exposures. The full set of precautions necessary to adequately protect the surrounding environment has not yet been determined for the project. Lambertville: Construction of the TSP will have no affect on any potential or existing HTRW issues. | Design and construction of the proposed levee/floodwall system will proceed in close coordination with regulatory agencies and adjacent property owners, in order to control potential contaminant migration and exposures. The full set of precautions necessary to adequately protect the surrounding environment has not yet been determined for the project. |
| Noise | No Impact | Major temporary impact to local communities (Gibbstown and Lambertville) during construction of the project over the estimated 3-year time period (Gibbstown) and 1-year time period (Lambertville). | Major temporary impact to local community during construction of the project over the estimated 3-year time period. | Major temporary impact to local community during construction of the project over the estimated 3-year time period. |

#### 5.9.5 Summary of the Outcome of Phase 3 – Incremental Alternative Plan Development and Assessment

Phase 3 concluded with levee and floodwall systems remaining viable in the Alexauken Creek area of Lambertville and in the Gibbstown area of Greenwich and Logan Townships. Both areas also include nonstructural features and interior drainage measures. Together, these flood risk management measures constitute the Tentatively Selected Plan, which is described in more detail in Section 5.10.

## 5.10 Tentatively Selected Plan (TSP)*

The TSP includes two hydrologically separate areas. The northern area is located in Lambertville while the southern area is located in Greenwich and Logan Townships (Gibbstown area). The primary features of the plans are a system of levees and floodwalls with gravity drainage outlets. In both locations the levees and floodwall provide greater than a 90% reliability against overtopping during a 1% ACE flood. Further design information can be found in Appendix A: Engineering Technical Appendix, Sections 4 and 5, as well as Appendix B: Interior Drainage Analysis.

<u>Gibbstown</u>

The line of protection plan in Gibbstown includes approximately 7,386 feet of levee with a maximum height of 12 feet, 13,788 feet of floodwall with a maximum height of 10 feet, and the construction of two swing closure gates (one 115 foot railroad crossing gate and one 50 foot road crossing gate) and the acquisition and demolition of one garage/ carriage house adjacent to one of the closure gates. The plan also includes construction of ring levees/floodwalls, including closure structures for three industrial facilities (see Appendix A: Engineering Technical Appendix: Section 4.1: Description of the Selected Plan for further detail), and buyouts of 16 residential structures and one currently vacant commercial structure located outside of the proposed levee system. When combined with the Minimum Facility drainage feature, industrial ring structures and residential buyouts, the plan maximizes net benefits and is consistent with other project objectives. Therefore, Alternative 1 has been identified as the TSP for Gibbstown. Figure 5.13 provides an overview of the alignment for the Gibbstown plan. See page vii of the Executive Summary for a larger version of the map.

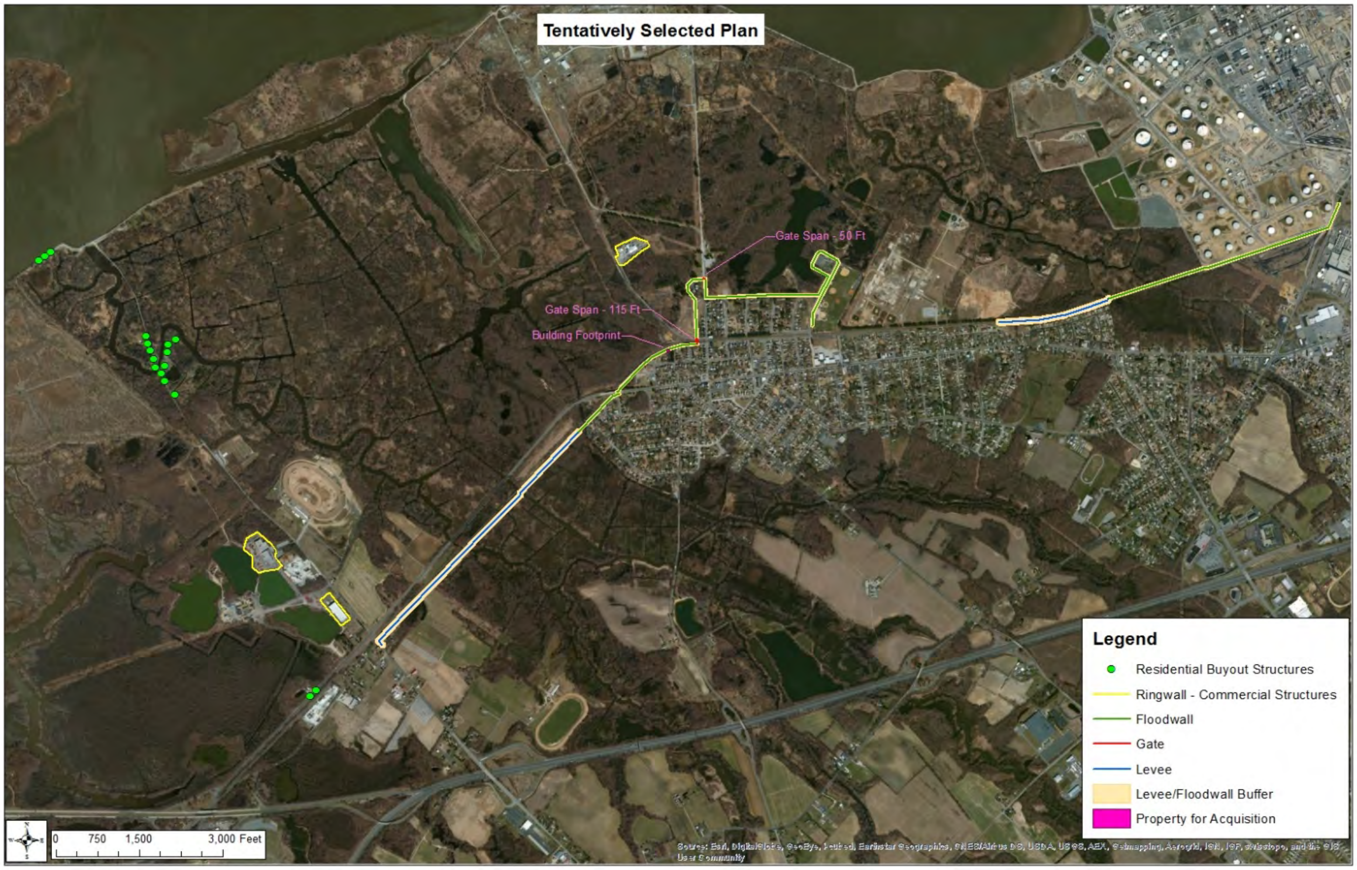


**Figure 5.13: Tentatively Selected Plan Overview – Gibbstown**

The design for the TSP reflects the results of a limited geotechnical study. In the Gibbstown area the borings indicate a layer of compressible soils near elevation 0 NAVD. In general the levee sections will utilize a design section with a 10 foot top width, a 10 foot wide impervious core extending to 6 feet below the levee and a 2.5 horizontal to 1 vertical side slope. Any levees exceeding 8 feet high in this area will likely require ground stabilization before and during construction. These treatments include surcharging the levee load and installing wick drains to accelerate soil compression, excavating unsuitable material and installing geo-grids under the levees. A typical levee section reflecting poor soil conditions is presented in Figure 5.14. With the exception of the relatively low walls at the northern project tie-off and the industrial ring structures, the floodwalls at Gibbstown are T-wall structures with a wide base to provide stability. These structures would be supported by 50 foot long steel piles with spacing of approximately 10 feet. A typical T-wall section reflecting poor soil conditions is presented in Figure 5.15.

As described in this report and Appendix D: Environmental Appendix, there are known and suspected contaminated sites within the Gibbstown study area that cannot be completely avoided by the project. These include the DuPont Repauno RCRA site, the Ashland/Hercules CERCLA site and the currently active Paulsboro Refinery site. Per ER

1105-2-100 and ER 1165-2-132, if sites cannot be avoided, the Corps will cost share related HTRW required activities involving studies or investigations, but the non-Federal sponsor has responsibility at 100% non-project cost for undertaking or ensuring remediation of any known or unknown HTRW to provide sites compatible with the land use necessary for the flood risk management project. NJDEP will undertake all appropriate inquiries prior to land acquisition and will adequately investigate State-owned lands. NJDEP will be responsible for ensuring that all lands provided for the project are remediated to the standards required for the uses of the flood risk management project as determined by the local regulator and with input from the Corps. NJDEP may undertake the remediation, or ensure the remediation is undertaken, prior to providing such lands for construction of project features. Prior to providing a parcel for project construction, NJDEP must ensure that it is either shown to be free of contamination through adequate site investigation, or that it has been remediated to regulator and Corps satisfaction to the standards necessary to support the flood risk management project. Additionally, the non-Federal sponsor will undertake necessary dewatering activities, including treatment and disposal, at 100% non-project cost in areas with contaminated groundwater. NJDEP is aware of these requirements and has accepted responsibility for delivering lands suitable for flood risk management and addressing groundwater contamination during dewatering.

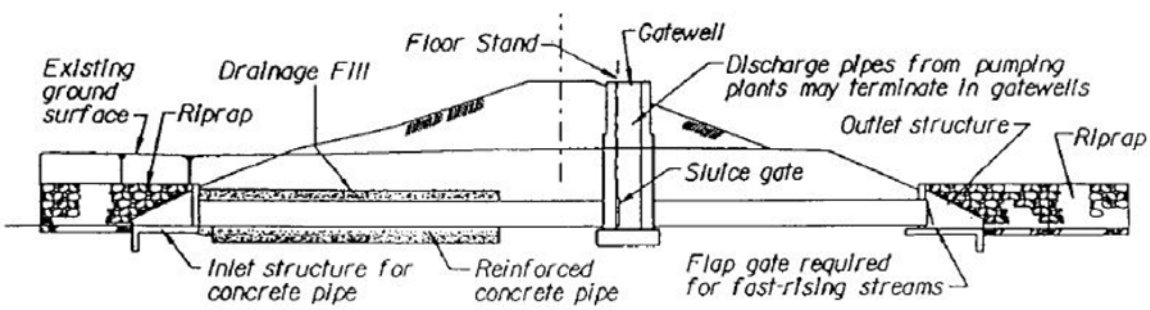


**Figure 5.14: Typical Levee Section – Gibbstown**

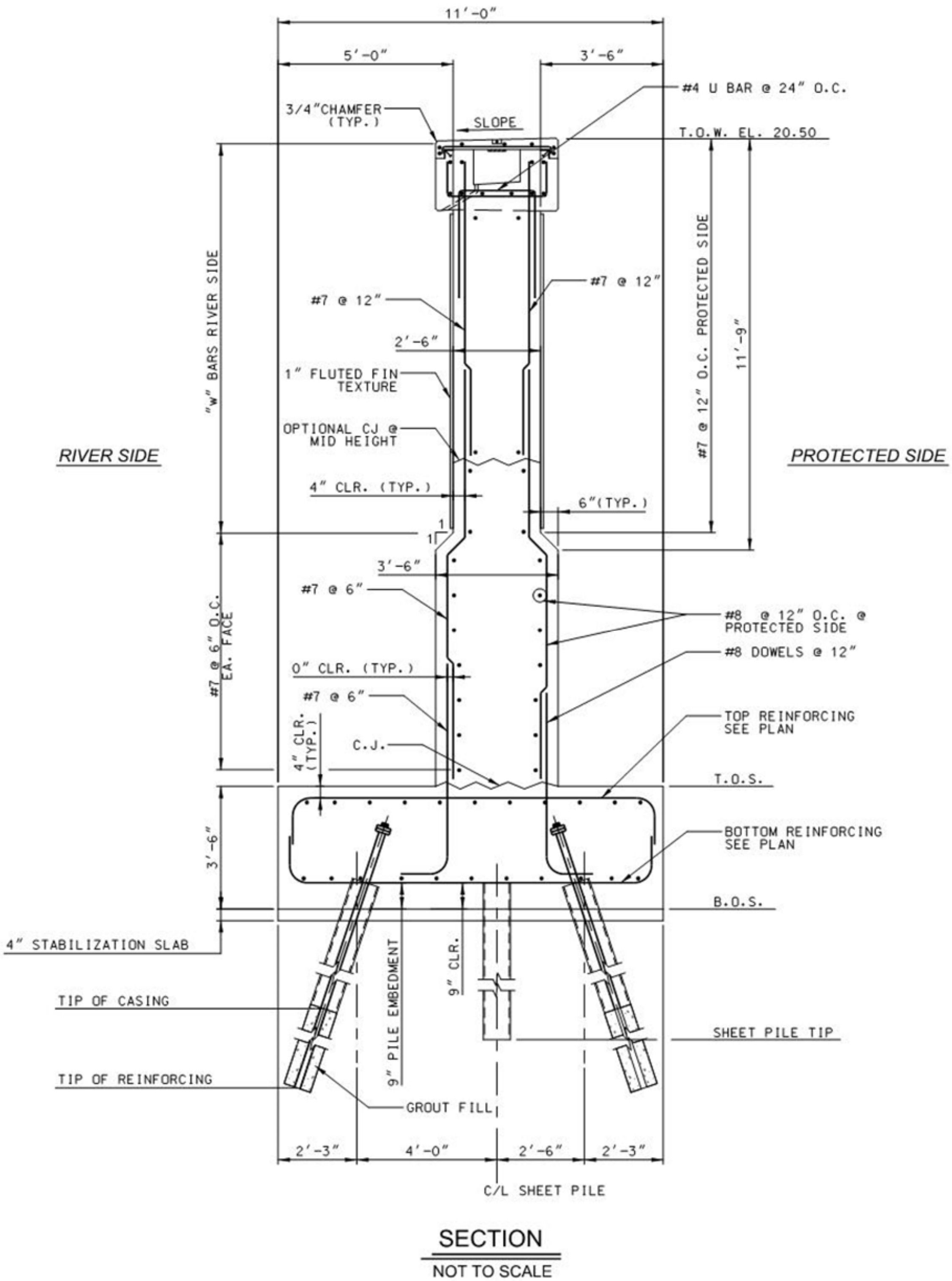


**Figure 5.15: Typical T-wall Section – Gibbstown**

Lambertville

The analysis of Alternatives for Lambertville has shown that the only cost effective structural plan is a system providing a 516-foot-long zoned earth levee along Alexauken Creek and a 1,409-foot-long concrete capped sheetpile floodwall near the Delaware and Raritan Canal. The TSP in Lambertville includes Interior Alternative 1 (construction of one additional 54 inch diameter gravity outlet in the area of Ely Creek) as the interior drainage component. One home is identified for acquisition because the plan may limit access and safe evacuation. Figure 5.16 provides an overview of the alignment for the Lambertville plan.

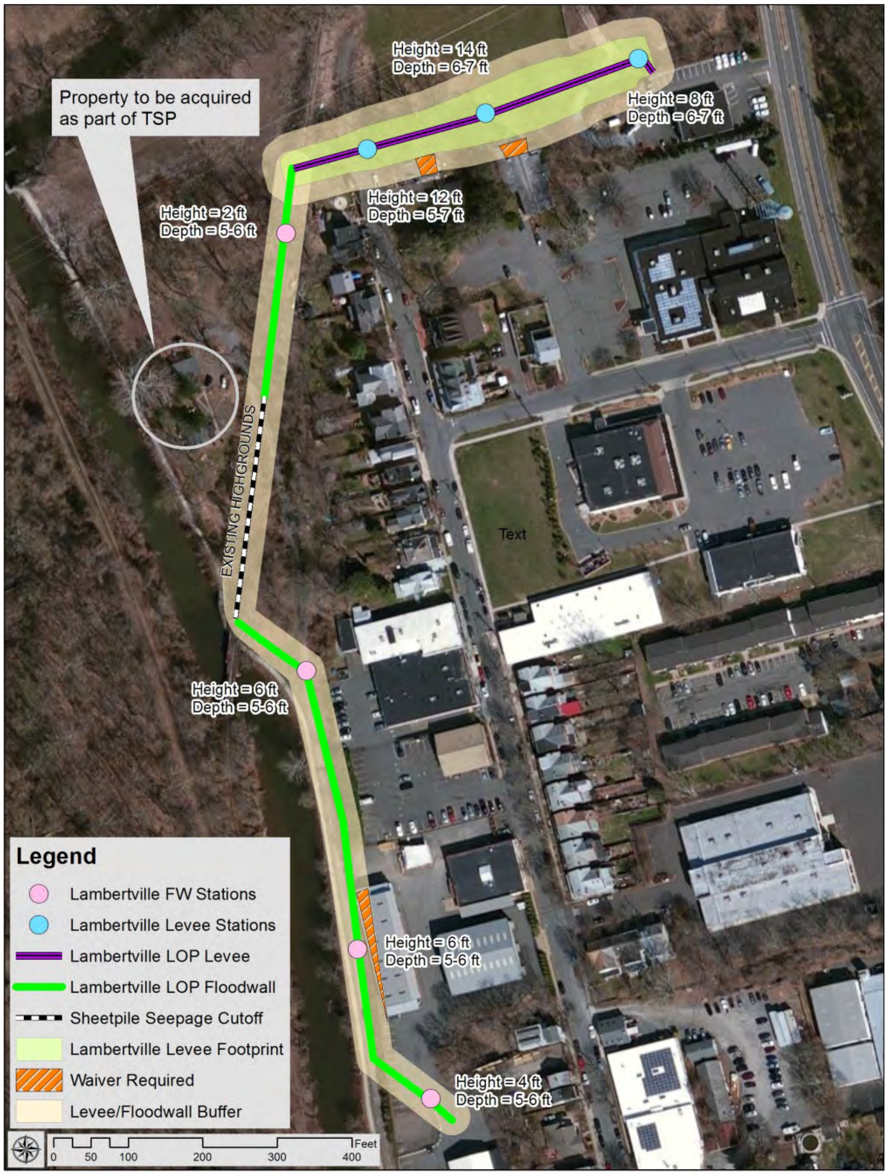


**Figure 5.16: Tentatively Selected Plan Overview – Lambertville**

In Lambertville the levee segments are generally 10 to 12 feet high and will utilize a design section with a 10-foot top width, a 10-foot-wide impervious core extending to 6 feet below the levee and a 2.5 horizontal to 1 vertical side slope. The floodwalls included in the NED Plan in Lambertville are generally about 5 feet high with a maximum height of about 7 feet. Given the relatively low heights and the limited area for construction, a cantilevered I-wall type structure was chosen. This structure consists of a sheetpile wall driven to bedrock at a depth of approximately 13 feet. The wall will include a concrete cap to ensure an impervious structure. Typical levee and floodwall sections for Lambertville are presented in Figures 5.17 and 5.18.

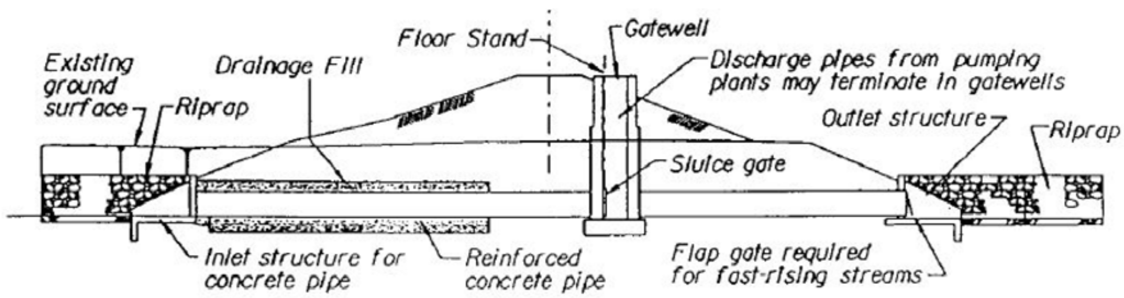


**Figure 5.17: Typical Levee Section – Lambertville**

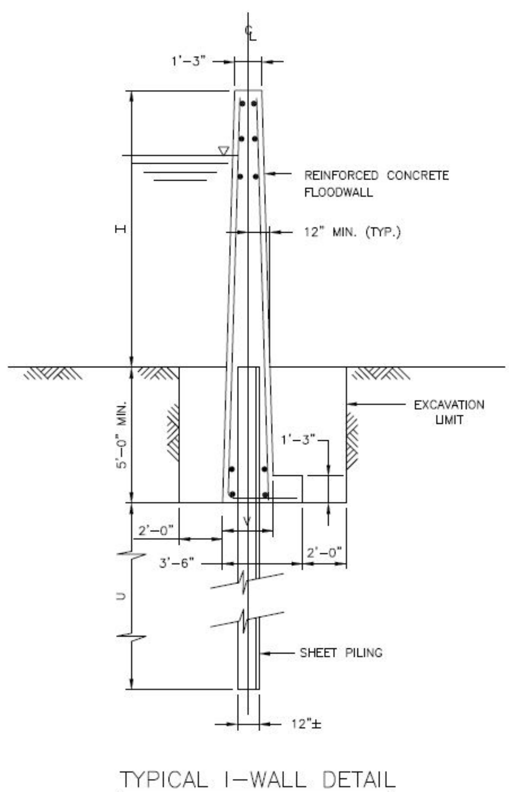


**Figure 5.18: Typical I-wall Section – Lambertville**

Due to the limited scope, geographic area and complexity of the proposed project and a preliminary cost within the limits of the Corps' Continuing Authorities Program (CAP), it is anticipated that the Lambertville segment of the TSP will be converted to the CAP. CAP projects differ from General Investigation (GI) projects in that legal agreements between the Corps and the non-Federal Sponsor do not typically require approval of Corps Headquarters and the projects do not require additional Congressional authorization for construction.

### 5.10.1 Benefits

Benefits estimated for the implementation of the TSP are summarized in Table 5.22.

**Table 5.22: Benefits Summary**

| Scenario | Gibbstown<br>Alternative 1 | Lambertville<br>Levee/Floodwall |
|---|---|---|
| **Annual Without Project Damage** | | |
| Flood Damage (Coastal) | $15,237,000 | $0 |
| Flood Damage (Riverine) | N/A | $1,147,000 |
| Interior Flood Damage | $0 | $0 |
| Total Damage | $15,237,000 | $1,147,000 |
| **Annual With Project Damage** | | |
| Flood Damage (Coastal) | $317,000 | $0 |
| Flood Damage (Riverine) | $0 | $290,000 |
| Interior Flood Damage | $0 | $52,000 |
| Total Damage | $317,000 | $342,000 |
| **Annual Damage Reduction** | | |
| **Total Flood Damage Reduction** | **$14,920,000** | **$805,000** |

Price Level: May 2014, Interest Rate: 3.50%, Period of Analysis: 50 years

### 5.10.2 Costs

Updated cost estimates were prepared for each feature of the plans based on anticipated construction quantities and parametric unit prices. All costs include contingencies, engineering and design and construction management. Annual costs include adjustments for Interest During Construction (IDC) and the cost of operations and maintenance. Tables 5.23 and 5.24, and 5.25 provide summary TSP cost estimates for Gibbstown and Lambertville. Details on how the updated cost estimates were developed are included in Appendix A: Engineering Technical Appendix, Section 15 – Cost Estimate.

**Table 5.23: Cost Estimate for Gibbstown Tentatively Selected Plan**

| ACCOUNT CODE | DESCRIPTION OF ITEM | ESTIMATED AMOUNT | CONTINGENCY % | CONTINGENCY | TOTAL |
|---|---|---|---|---|---|
| | | | | | |
| 01 | Lands and Damages | $5,182,600 | 35% | $1,814,000 | $6,996,000 |
| 02 | Utility relocation | $3,000,000 | 35% | $1,050,000 | $4,050,000 |
| 06 | Fish and Wildlife Facilities | $3,521,000 | 35% | $1,232,000 | $4,753,000 |
| 11 | Levees and Floodwalls | $84,875,000 | 35% | $29,708,000 | $114,583,000 |
| 15 | Floodway Control-Diversion Structure | $9,312,000 | 35% | $3,260,000 | $12,572,000 |
| 19 | Buildings & Grounds | $3,308,560 | 35% | $1,159,000 | $4,468,000 |
| 30 | Planning, Engineering, and Design | $16,365,000 | 15% | $2,455,000 | $18,820,000 |
| 31 | Construction Management | $13,638,000 | 15% | $2,046,000 | $15,684,000 |
| | Total First Cost | | | | $181,926,000 |
| | Interest During Construction | | | | $7,780,000 |
| | **Total Investment Cost** | | | | $189,706,000 |
| | Annualized Investment Cost | | | | $8,088,000 |
| | O&M Cost | | | | $198,000 |
| | **Total Annual Cost** | | | | $8,286,000 |

*Price Level: May 2014, Interest Rate 3.5%, 50 Year Period of Analysis, 30 Month Construction Period
Note: Includes Minimum Facility Interior Drainage Plan

**Table 5.24: Cost Estimate for Lambertville Tentatively Selected Plan**

| ACCOUNT CODE | DESCRIPTION OF ITEM | ESTIMATED AMOUNT | CONTINGENCY % | CONTINGENCY | TOTAL |
|---|---|---|---|---|---|
| | | | | | |
| 01 | Lands and Damages | $288,052 | 35% | $101,000 | $389,000 |
| 06 | Fish and Wildlife Facilities | $482,000 | 35% | $169,000 | $651,000 |
| 11 | Levees and Floodwalls | $3,216,000 | 35% | $1,127,000 | $4,343,000 |
| 15 | Floodway Control-Diversion Structure | $902,000 | 35% | $316,000 | $1,218,000 |
| 19 | Buildings and Grounds | $437,100 | 35% | $153,000 | $590,000 |
| 30 | Planning, Engineering, and Design | $816,000 | 15% | $122,000 | $938,000 |
| 31 | Construction Management | $680,000 | 15% | $102,000 | $782,000 |
| | Total First Cost | | | | $8,911,000 |
| | Interest During Construction | | | | $381,000 |
| | **Total Investment Cost** | | | | $9,292,000 |
| | Annualized Investment Cost | | | | $396,000 |
| | O&M Cost | | | | $36,000 |
| | **Total Annual Cost** | | | | $432,000 |

* Price Level: May 2014, Interest Rate 3.5%, 50 Year Period of Analysis, 30 Month Construction Period

**Table 5.25 : Summary of Tentatively Selected Plan Benefit-Cost Ratios**

| | Gibbstown | Lambertville |
|---|---|---|
| Annual Benefits | $14,920,000 | $805,000 |
| Annual Costs | $8,286,000 | $432,000 |
| Net Benefits | $6,634,000 | $373,000 |
| BCR | **1.8** | **1.9** |
| **Selected as Plan** | ✓ | ✓ |

Price Level: May 2014, Interest Rate 3.5%, 50 Year Period of Analysis, 30 Month Construction Period

## 5.11 Optimization

Pending

## 5.12 Public Law 113-2 (PL 113-2)

The Interim Feasibility Study for New Jersey has been prepared to account for Public Law 113-2 (the Disaster Relief Appropriations Act of 2013). Specifically, this section of the study addresses:

- The specific requirements necessary to demonstrate that the project is economically justified, technically feasible, and environmentally acceptable
- The specific requirements necessary to demonstrate resiliency, sustainability, and consistency with the North Atlantic Coast Comprehensive Study (NACCS)

### 5.12.1 Risks, Economics and Environmental Compliance*

Sections 5.7, 5.9, and 5.10 demonstrate how the TSP reduces flood and coastal storm risks, and contributes to improved capacity to manage such risks. It also identifies the TSP to be economically justified for the authorized period of federal participation.

This Interim Feasibility Study for New Jersey has been prepared to meet the requirements of NEPA and demonstrate that the TSP is compliant with environmental laws, regulations, and policies and has effectively addressed any environmental concerns of resource and regulatory agencies.

### 5.12.2 Resiliency, Sustainability, and Consistency with the NACCS

This section has been prepared to address how the TSP contributes to the resiliency of the Delaware River study area, how it affects the sustainability of environmental conditions in the affected area, and how it will be consistent with the findings and recommendations of the North Atlantic Coast Comprehensive Study (NACCS).

Resiliency is defined in the February 2013 USACE-NOAA Infrastructures Systems Rebuilding Principles white paper as the ability to adapt to changing conditions and withstand, and rapidly recover from disruption due to emergencies. Sustainability is defined as the ability to continue (in existence or a certain state, or in force or intensity), without interruption or diminution.

The Gibbstown Tentatively Selected Plan is a resilient, sustainable solution that also incorporates the increased risk of sea level change, where applicable. For the current stage of plan formulation, design of the system has considered a minimum of a 1% ACE event, which is a high surge or flood that would only be seen during rare storms and should therefore provide resilient and robust flood risk management for the study area. This will also allow for the flood risk management system to defend against back to back high intensity storms. Fifteen to twenty foot Flood Protection Levee Easements on either side of the Line of Protection will allow for future maintenance and potential future design modification to raise the height of the Line of Protection in response to potential accelerated increases in sea level. Additional design details will be dependent upon optimization.

An overriding NACCS principle is to reduce risk to vulnerable properties and the infrastructure they support. The TSP is consistent with this principle of the NACCS. The overall risk management is to be provided with a levee and floodwall system, as well as ringwalls and structure buyouts. A local Operations and Maintenance plan will be put in place with periodic Corps inspections to sustain a continuous level of risk management for the 50 year project life. Recognizing the Federal government’s commitment to ensure no inducement of development in the floodplain, pursuant to Executive Order 11988, this project will identify in the Project Partnership Agreement the need for the local partner to develop a Floodplain Management Plan, and a requirement for the local partner to certify that measures are in place to ensure the project does not induce development within the floodplain. See also Section 6.2.5 for further information on Executive Order 11988 compliance.

# 6 The Selected Plan*

Pending

## 6.1 Description of the Selected Plan

Pending

## 6.2 Environmental Impacts*

Impacts identified below are related to the TSP in Lambertville and Gibbstown. The impacts will be updated for the final Selected Plan.

### 6.2.1 Air Quality

Construction of the projects in Lambertville and Gibbstown will cause temporary reduction of local ambient air quality due to fugitive dust and emissions generated by construction equipment; however, these temporary reductions in air quality would not have a significant impact on the long term air quality of the surrounding area. A general conformity review and emission inventory will be conducted later in the planning process; a list of potential construction equipment has been identified. Since the level of detail needed to acquire an appropriate list of construction equipment has not been completed, this study will use another similar Corps project's air quality analysis as a placeholder for now.

The 2005 placeholder study, The Town of Bloomsburg, Columbia County, Pennsylvania Flood Damage Reduction Project, The Bloomsburg study involved approximately 14,000 feet of levee construction, whereas the Interim Feasibility Study for New Jersey involves approximately 20,000 feet of levee and floodwall. In addition, the Lambertville section includes approximately 2,000 feet of levee and floodwall.

Since the placeholder project was smaller in scale than the proposed construction for the Interim Feasibility Study for New Jersey, a multiplier has been applied to the Bloomsburg air quality numbers in order to more accurately reflect the potential impact to air quality. For Bloomsburg's 14,000 feet of levee construction, the study estimated emissions of 84.02 tons of NOx and 4.90 tons of VOCs. The scale of the proposed construction for the Interim Feasibility Study for New Jersey is approximately 1.6 times larger. The estimated emissions for the Interim Feasibility Study for New Jersey are 134.43 tons of NOx (Lambertville 16.82 / Gibbstown 117.62) and 7.84 tons of VOC (Lambertville 0.98 / Gibbstown 6.86). Since the period of construction is estimated at 3 years, the annual emissions for the project will be 44.81 tons of NOx (Lambertville 5.6 / Gibbstown 39.21) and 2.61 tons of VOC (Lambertville 0.32 / Gibbstown 2.29). These emissions are well below the Clean Air Act, Section 176, General Conformity trigger levels of 100 tons of NOx and 50 tons of VOC per year, as identified in 40 CFR 93, Subpart B.

Additional information on the air quality review can be found in Appendix D: Environmental Appendix.

### 6.2.2 Water Quality

Implementation of this project will have temporary impacts to water quality; however, all necessary best management practices will be used during construction. The proposed project will not have any long-term adverse impacts on water quality of creeks near the proposed construction locations including: Repaupo Creek, White Sluice Race, Nehonsey Brook, Clonmell Creek, and Alexauken Creek. Prior to construction of the project, all appropriate State approvals, including a Section 404 Water Quality Certificate, will be obtained from the NJDEP.

### 6.2.3 Biological Resources

6.2.3.1 <u>Wetlands</u>

#### *6.2.3.1.1 Lambertville*

Based on NJDEP's 2007 Wetland GIS data, as well as an on-the-ground verification of this data, no wetlands will be impacted by the proposed floodwall/levee for this area (see Figure 6.1).


**Figure 6.1: The proposed Lambertville alignment overlaid with wetland maps illustrating no anticipated impacts to wetlands.**

#### 6.2.3.1.2 Gibbstown

Based on NJDEP's 2007 Wetland GIS data, as well as an on-the-ground verification of this data, approximately 11.5 acres of wetlands will be impacted by the levee/floodwall system and ringwalls identified as the TSP. This impact can be broken down to approximately, 2.8 acres of forested, 3.5 acres of scrub/shrub, 1.7 acres of emergent, and 3.5 acres of Phragmites-dominated wetlands (see Figures 6.2).

The Corps considered levee/floodwall alternatives that avoided and minimized impacts to wetlands. The alignment for the proposed levee/floodwall system was evaluated for environmental, real estate, engineering, hydraulic, and public interest concerns. The proposed alignment was identified to avoid and minimize as many of these concerns as possible. In addition, an evaluation of conversion of the entire levee/floodwall system to a floodwall system with a narrower footprint (60 ft vs. 125 ft) was completed, and at this point in the plan formulation process, rejected for economic reasons.

Mitigation for the wetland impacts was evaluated using a Habitat Evaluation Procedure (HEP) for replacement of habitat value for each of three representative species (red-spotted newt, great blue heron, and barred owl) for the TSP. A HEP is an ecological assessment method which provides a numerical index incorporating food, water, cover, and breeding relationships indicative of a habitat's carrying capacity for a given species. Once the habitat value is assessed (in habitat units), one can calculate the number of acres needed to mitigate for that assessed habitat value. Three options meeting the mitigation objectives were considered and mitigation Option #1 was determined to be the recommended mitigation option. This option will replace 8.8 habitat units with approximately 12.5 acres. The HEP analysis concluded that 7.0 acres of habitat would be sufficient to replace the habitat impacted by the TSP; however, since forested wetlands will be impacted by the proposed project and science has demonstrated that forested wetlands take approximately 25-50 years to replace loss function and structure, this supports the need to add mitigation acreage above the HEP computed value of 7.0 acres. After taking this into account, the proposed mitigation acreage for the TSP is 12.5 acres.

A map of the three mitigation options for the TSP and further information about the mitigation analysis including coordination with other agencies, can also be found in Appendix D: Environmental Appendix.

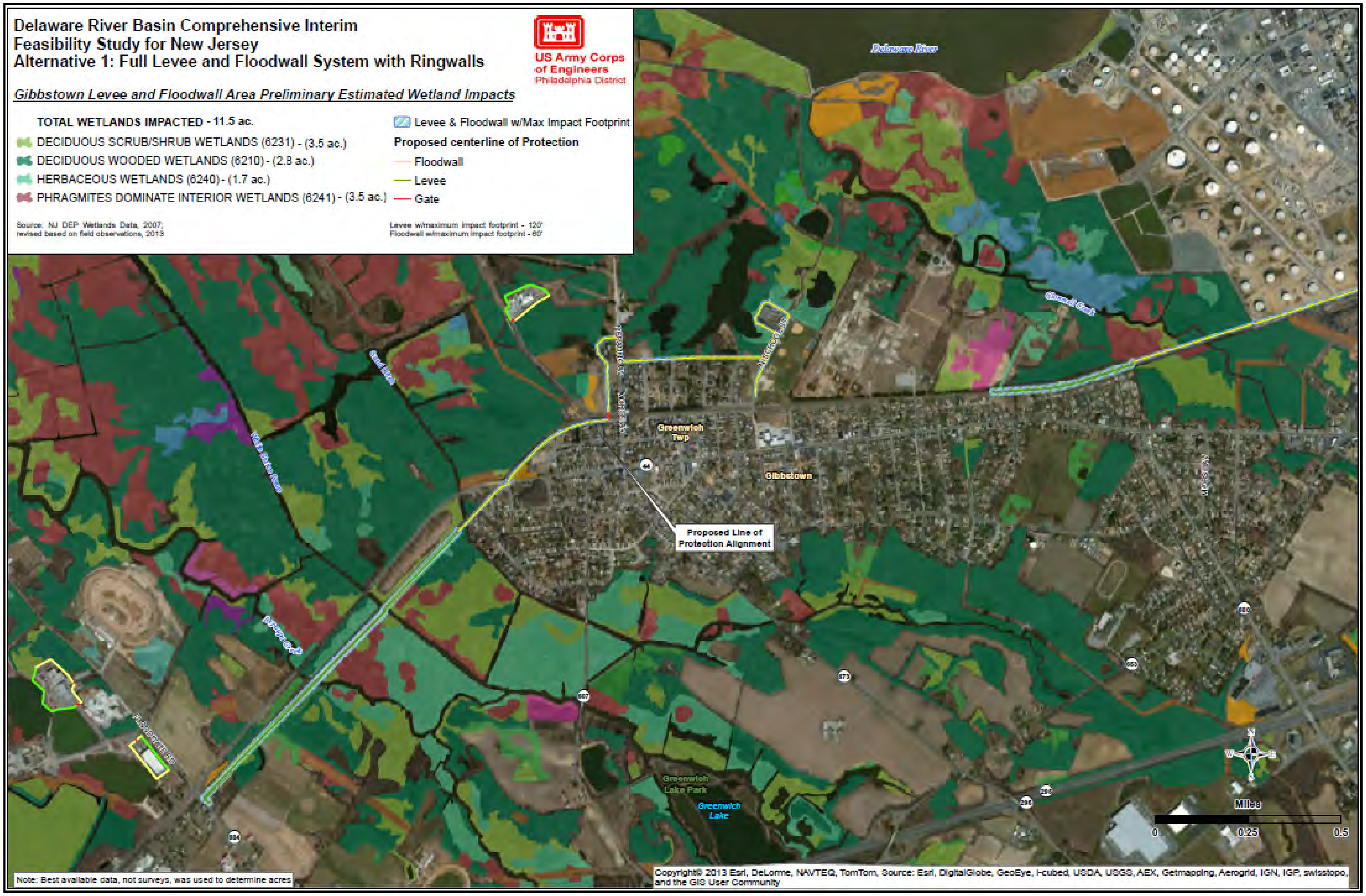


**Figure 6.2: The proposed Gibbstown alignment and the impact on wetlands in the area.**

### 6.2.3.2 Fish and Wildlife

#### *6.2.3.2.1 Fisheries*

Lambertville

The Alexauken Creek in Lambertville has confirmed spawning runs of alewife and blueback herring, collectively called river herring, a "species of concern" to the NMFS. The proposed levee/floodwall in Lambertville will come within approximately 200 ft of this creek, but should not directly impact the creek. The levee will encroach on the riparian area adjacent to the creek, but this area is already currently disturbed by previous development in the area. During construction of the levee/floodwall, best management practices will be used to insure that Alexauken Creek is not impacted by this project.

The resident fish species using the human-made Delaware and Raritan Canal may be impacted during construction of the floodwall adjacent to the banks of the canal. However, all best management practices will be used to prevent sediment from washing into the canal due to construction activities.

Gibbstown

The proposed levee/floodwall for the Gibbstown area will have impacts on fisheries in the Repaupo Creek watershed. The most direct impact will be during construction of the levee system. The levee will have to cross four streams (Clonmell Creek, Nehonsey Brook, White Sluice Creek, and Repaupo Creek), resulting in impacts to those four streams, as well as to the fisheries and aquatic organisms residing in the creeks. Most of the impacts will be during the construction phase of the project, which will be temporary in nature. All sediment and erosion control best management practices will be used to minimize these impacts as much as possible.

The levee footprint of approximately 120 ft in width will cause permanent direct and indirect impacts to the creek systems. Access roads on either side of the levee will likely result in sediment and vehicle pollutants entering the creek more frequently than currently is the case. In addition, floodgate structures will have to be installed in and adjacent to the four creeks. This will have a direct impact on the creeks.

Based on discussions with the NJDEP Southern Regional Fisheries Biologist (Smith 2013), there is a rather substantial warm water fish population in all of the current impounded areas upstream of the existing floodgates at Repaupo Creek and White Sluice Race that would be affected by the proposed project. The native fish likely impacted would be warm water species including: the American eel (*Anguilla rostrata*), white sucker (*Catostomus commersonii*), and channel catfish (*Ictalurus punctatus*).

After further discussions with the Southern Regional Fisheries Biologist at NJDEP (Smith 2013) and consideration of the loss of connectivity to these streams due to the floodgates associated with the proposed levee/floodwall system, mitigation is proposed in the form of "fish friendly" floodgates at the two largest creeks (Repaupo and White Sluice). These "fish friendly" gates will allow fish passage at the new floodgates.

Costs for the recommended mitigation plan can be found in Table 6.1. Additional costs for other mitigation options and more details can be found in Appendix D: Environmental Appendix.

**Table 6.1: Total Mitigation Costs Based on Wetland Option 1 & Fish Passage Option 1**

| | | | | |
|---|---|---|---|---|
| | Mitigation Acres | Required Mitigation HUs | Cost/Acre or Unit | Total Cost |
| Forested Wetland | 5.5 | 3.9 | $241,300 | $1,327,150 |
| Scrub/Shrub Wetland | 2.0 | 1.4 | $196,500 | $393.000 |
| Emergent Wetland | 5.0 | 3.5 | $191,400 | $957,000 |
| Real Estate (marsh) | 12.5 | | $27,500 | $343,750 |
| Fish Passage (fish friendly floodgate on Repaupo Creek) | | | $250,000 | $250,000 |
| Fish Passage (fish friendly floodgate on White Sluice Race) | | | $250,000 | $250,000 |
| | | | | |
| Total | | 8.8 | | **$3,520,900** |

### *6.2.3.2.2 Essential Fish Habitat*

No essential fish habitat (EFH) has been designated within the study area (letter from NMFS dated March 25, 2009); therefore, there will be no impact to this resource.

### 6.2.3.2.3 *Wildlife*

#### 6.2.3.2.3.1 Lambertville

There will be very limited impact on wildlife due to the urban nature of the project location. There will be some loss of connectivity for land species moving through the watershed.

#### 6.2.3.2.3.2 Gibbstown

The construction of the levee/floodwall system at Gibbstown will have an impact on wildlife in the region. The temporary loss of approximately 11.5 acres of wetlands (3.5 acres of *Phragmites*, 1.7 acres emergent, 2.8 acres forested, and 3.5 acres scrub/shrub) will reduce cover, foraging, and nesting habitat for mammals, reptiles, and amphibians in the project area. In addition, the levee/floodwall system will result in the loss of connectivity and impact movement of wildlife that use the riparian corridor around all four of the streams

(Clonmell Creek, Nehonsey Brook, White Sluice Creek, and Repaupo Creek) which the project crosses.

##### *6.2.3.2.4 Threatened and Endangered Species*

Through continued informal consultation with the USFWS, New Jersey Field Office, surveys to determine the presence or absence of roosting trees will be performed in the next phase of the study. In addition, if trees for roosting bats are found in the project area, seasonal restrictions on tree removal activities will be instituted during construction to minimize any impacts on federally listed bats. Pursuant to Section 7 of the Endangered Species Act of 1973 as amended by P.L. 96-159 and SMART Planning Guidance, consultation with the USFWS and NMFS will be completed on this study prior to the Civil Works Review Board (CWRB) Milestone. Further details on the Threatened and Endangered Species Act, Section 7 consultation can be found in Appendix D: Environmental Appendix.

### 6.2.4 Cultural Resources

#### 6.2.4.1 Archaeological Investigations

In 2014 the Corps conducted a Phase IB archaeological survey and geomorphological assessment for selected segments of proposed flood risk management measures in Lambertville and Gibbstown.

##### *6.2.4.1.1 Lambertville*

The Phase IB shovel testing for the Lambertville alignment identified no archaeological sites; however, the geomorphological testing found the southern-most portion of the alignment was located on an intact alluvial terrace of the Delaware River, with the potential to contain deeply buried archaeological deposits. Although no artifacts were recovered, auger testing documented a thick Holocene-age Bw horizon with the potential to contain archaeological deposits below the effective shovel testing limit of 80 centimeters (31.5 inches). The bucket auger test was terminated at the auger limit of 200 centimeters (80 inches) below surface in the Bw horizon. If the Lambertville flood risk management structure is constructed on the current alignment, deep archaeological testing is recommended to test the Bw horizon at greater depth.

##### *6.2.4.1.2 Gibbstown*

Phase I testing for the Gibbstown alignment consisted of the excavation of 62 combination shovel test and bucket auger tests and two 1x1-meter Test Units. Shovel testing resulted in the identification of one prehistoric archaeological site (28-GL-349), and one isolated find. Site 28-GL-349 was manifest as a lithic scatter vertically located in stacked plow zones Ap1 and Ap2, which also contained modern historic artifacts. In all, 25 artifacts were recovered, 13 historic and 12 prehistoric.

Excavation of two TUs revealed a discontinuous sandy C horizon with water rounded pebbles and occasional cobbles located between the Ap1 and Ap2 horizons. The presence of high concentrations of water rounded pebbles in the Ap1 and Ap2 horizons may be attributed to deposition of the C horizon, a high energy flood event that differentially scoured the Ap2 surface and deposited unconsolidated sands and gravel which became incorporated in the Ap1 and Ap2 horizons by subsequent plowing. Under normal flood conditions the pebbles and occasional cobbles found in the Ap1, C, and Ap2 horizons would be too dense and massive to be transported in the suspended load during overbank flooding of the closest stream, Repaupo Creek. The presence of historic artifacts mixed with prehistoric artifacts and the stratigraphic position of the C horizon indicates that the C horizon was deposited historically under high energy flood conditions. A likely event would be the catastrophic flooding caused by Hurricane Agnes in the summer of 1972.

The low artifact density, lack of diagnostic artifacts and lack of stratigraphic integrity makes it unlikely that further work at the site would yield significant information pertaining to the regions prehistory. No further work is recommended. In a letter dated March 12, 2015 the SHPO was unable to concur with the recommendations regarding site 28GL349 and requested further Phase II eligibility testing in conjunction with further analysis of the existing archaeological assemblage if the Gibbstown flood risk management structure is constructed. The Corps will include the Phase II work as a stipulation to the Programmatic Agreement that is currently being developed.

6.2.4.2 Historic Above Ground Resource Investigations

No Historic Structures analysis was conducted at this time for the Lambertville or Gibbstown alignments; however, several resources eligible for or listed on the National Register of Historic Places are within the project's Area of Potential Effect (APE). The Corps will negotiate a Programmatic Agreement (PA) with the New Jersey State Historic Preservation Office, the Tribes and other interested parties pursuant to 36 CFR 800.14(b)(1). The PA will stipulate the necessary actions to be completed in order for the Corps to comply with the Section 106 of the National Historic Preservation Act (NHPA) during the Project Engineering and Design phase (PED).

### 6.2.5 Executive Order 11988

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

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

*1. Determine if a proposed action is in the base floodplain (that area which has a one percent or greater chance of flooding in any given year).*

The proposed action is within the base floodplain. However, the project is designed to reduce damages to existing infrastructure located landward of the proposed project.

*2. If the action is in the base flood plain, identify and evaluate practicable alternatives to the action or to location of the action in the base flood plain.*

Chapter 5 of this document presents an analysis of potential alternatives. Practicable measures and alternatives were formulated and evaluated against the Corps of Engineers guidance, including non-structural measures such as elevation and land acquisition.

*3. If the action must be in the flood plain, advise the general public in the affected area and obtain their views and comments.*

Meetings and field trips were conducted in each municipality in 2007 to discuss flood risk management options with local representatives and other agencies. Meetings were then held with municipal officials in 2011 to present work to date, including conceptual options for flood risk management. Attendees' views and comments were documented and addressed. Workshops were subsequently held in 2012 to present the same information to the general public.

A Public Notice will be sent to all Federal, State and local agencies prior to agency review of the Draft Feasibility Report and Integrated Environmental Assessment. The public will also be notified of the public review period and a public meeting will be held. The electronic versions of the report will be made available on compact disc and online.

*4. Identify beneficial and adverse impacts due to the action and any expected losses of natural and beneficial flood plain values. Where actions proposed to be located outside the base flood plain will affect the base flood plain, impacts resulting from these actions should also be identified.*

The anticipated impacts and related mitigation associated with the TSP are summarized in this chapter of the report. The project will impact wetlands and fish passage. Actions have been taken to avoid and minimize impacts. Mitigation will occur as required.

*5. If the action is likely to induce development in the base flood plain, determine if a practicable non-flood plain alternative for the development exists.*

The project will not induce development in the base flood plain due to legal restrictions on development in that area. The restrictions apply with or without the presence of the project. New Jersey Administrative Code 7:13 Flood Hazard Area Control Act Rules states the following in Section 7:13-11.5 Requirements for a building, Subsections a-c and g:

*(a) This section sets forth specific design and construction standards that apply to any building proposed in the areas listed in (b) below. Subsection (c) below establishes standards that apply to all buildings, and subsections (d) through (t) below provide additional standards for various types of buildings.*
*(b) The requirements in this section apply to a building that is constructed or reconstructed in the following areas:*

*1. A flood hazard area; and*

*2. An area that was previously situated in a flood hazard area, but which was filled, raised or otherwise removed from the flood hazard area after January 31, 1980, whether in accordance with or in violation of this chapter, except in the following cases:*

*i. A Department delineation is available for the site, and the Department approves a revision of its delineation that removes the area in question from the flood hazard area; or*

*ii. No Department delineation is available for the site, but FEMA issues a Letter of Map Amendment that removes the area in question from the 100-year flood plain.*

*(c) The Department shall issue an individual permit to construct or reconstruct a building of any kind only if the following requirements are satisfied:*

*1. Any new building is located at least 25 feet from any top of bank or edge of water;*

*2. If an existing building located near any top of bank or edge of water is to be expanded, the expanded portion is located at least 25 feet from the top of bank or edge of water, where possible;*

*3. If an existing building located near any top of bank or edge of water is to be reconstructed, the new building shall be relocated at least 25 feet from the top of bank or edge of water, where possible;*

*4. Any exterior wall being constructed or reconstructed is designed to resist hydrostatic and hydrodynamic pressure caused by flooding up to the flood hazard area design flood elevation; and*

*5. All applicable requirements contained in (d) through (t) below are satisfied.*

*(g) The Department shall issue an individual permit to construct a new habitable building only if the following requirements are satisfied:*

*1. The lowest floor of a private residence is set at least one foot above the flood hazard area design flood elevation;*

*2. The lowest floor of a public building is set at least one foot above the flood hazard area design flood elevation;*

*3. The lowest floor of a multi-residence building is set at least one foot above the flood hazard area design flood elevation, unless all of the following are satisfied:*

*i. The building is used for both residential and non-residential purposes;*

*ii. The lowest floor of any residential portion of the building, including any common area, such as a lobby or other portion of the building that is used for both residential and non-residential purposes, is set at least one foot above the flood hazard area design flood elevation;*

*iii. The applicant demonstrates that it is not feasible to set the lowest floor of any or all of the non-residential portions of the building at least one foot above the flood hazard area design flood elevation;*

*iv. The lowest floor of the non-residential portions of the building identified in (g)3iii above is set as close as feasible to one foot above the flood hazard area design flood elevation; and*

*v. An architect or engineer certifies that the non-residential portions of the building identified in (g)3iii above will be constructed in accordance with the flood-proofing requirements at (q) below; and*

*4. The lowest floor of any habitable building not identified in (g)1, 2 or 3 above, such as a commercial business, house of worship, office complex or shopping center, is set at least one foot above the flood hazard area design flood elevation, unless all of the following are satisfied:*

*i. The applicant demonstrates that it is not feasible to construct the lowest floor of any or all portions of the building at least one foot above the flood hazard area design flood elevation;*

*ii. The lowest floor of the portions of the building identified in (g)4i above is constructed as close as feasible to one foot above the flood hazard area design flood elevation; and*

*iii. An architect or engineer certifies that the portions of the building identified in (g)4i above will be constructed in accordance with the flood-proofing requirements at (q) below.*

Terms used in the Administrative Code are defined as follows:

*"Flood hazard area" means land, and the space above that land, which lies below the flood*

*hazard area design flood elevation. Structures, fill and vegetation that are situated on land that lies below the flood hazard area design flood elevation are described as being "in" or "within" the flood hazard area. The inner portion of the flood hazard area is called the floodway and the outer portion of the flood hazard area is called the flood fringe. Figures A and B at N.J.A.C. 7:13-2.3 illustrate these areas as well as the riparian zone along a typical water. The flood hazard area on a particular site is determined using the methods set forth at N.J.A.C. 7:13-3. There are two types of flood hazard areas:*

> *1. Tidal flood hazard area, in which the flood hazard area design flood elevation is governed by tidal flooding from the Atlantic Ocean. Flooding in a tidal flood hazard area may be contributed to or influenced by stormwater runoff from inland areas, but the depth of flooding generated by the tidal rise and fall of the Atlantic Ocean is greater than flooding from any fluvial sources; and*
>
> *2. Fluvial flood hazard area, in which the flood hazard area design flood elevation is governed by stormwater runoff. Flooding in a fluvial flood hazard area may be contributed to or influenced by elevated water levels generated by the tidal rise and fall of the Atlantic Ocean, but the depth of flooding generated by stormwater runoff is greater than flooding from the Atlantic Ocean.*

*"Flood hazard area design flood" means a flood equal to the 100-year flood plus an additional amount of water in fluvial areas to account for possible future increases in flows due to development or other factors. This additional amount of water also provides a factor of safety in cases when the 100-year flood is exceeded. N.J.A.C. 7:13-3 describes the various methods of determining the flood hazard area design flood for a particular water as well as the additional amount of water to be added in various situations.*

*"Flood hazard area design flood elevation" means the peak water surface elevation that will occur in a water during the flood hazard area design flood.*

*6. As part of the planning process under the Principles and Guidelines, determine viable methods to minimize any adverse impacts of the action including any likely induced development for which there is no practicable alternative and methods to restore and preserve the natural and beneficial flood plain values. This should include reevaluation of the "no action" alternative.*

It is expected that wetlands mitigation will be required for the Gibbstown Selected Plan. This chapter and Appendix D: Environmental Appendix detail the efforts at avoidance and minimization of impact, as well as plans for mitigation. It is also expected that mitigation will be needed due to interruption of fish passage by floodgates in the Gibbstown levee/floodwall structure. "Fish friendly" gates will be installed in two streams to mitigate the impact. As described in this chapter, if mitigation of cultural resources is found to be needed, a programmatic agreement will be negotiated with the appropriate parties. The project will not induce development in the flood plain. Chapter 5 of this report summarizes the alternative identification, screening and selection process. The "no action" alternative was included in the plan formulation phase.

*7. If the final determination is made that no practicable alternative exists to locating the action in the flood plain, advise the general public in the affected area of the findings.*

The Draft Feasibility Report and Integrated Environmental Assessment will be provided for public review and a public meeting will be held during the public review period.

*8. Recommend the plan most responsive to the planning objectives established by the study and consistent with the requirements of the Executive Order.*

The TSP is the most responsive to all of the study objectives and the most consistent with the EO.

### 6.2.6 Induced Flooding

#### 6.2.6.1 Lambertville

The proposed alignment of the Lambertville levee/ floodwall system, structures in the structures inventory database, and Hunterdon County LiDAR topography from 2006 are shown in the Figure 6.3.

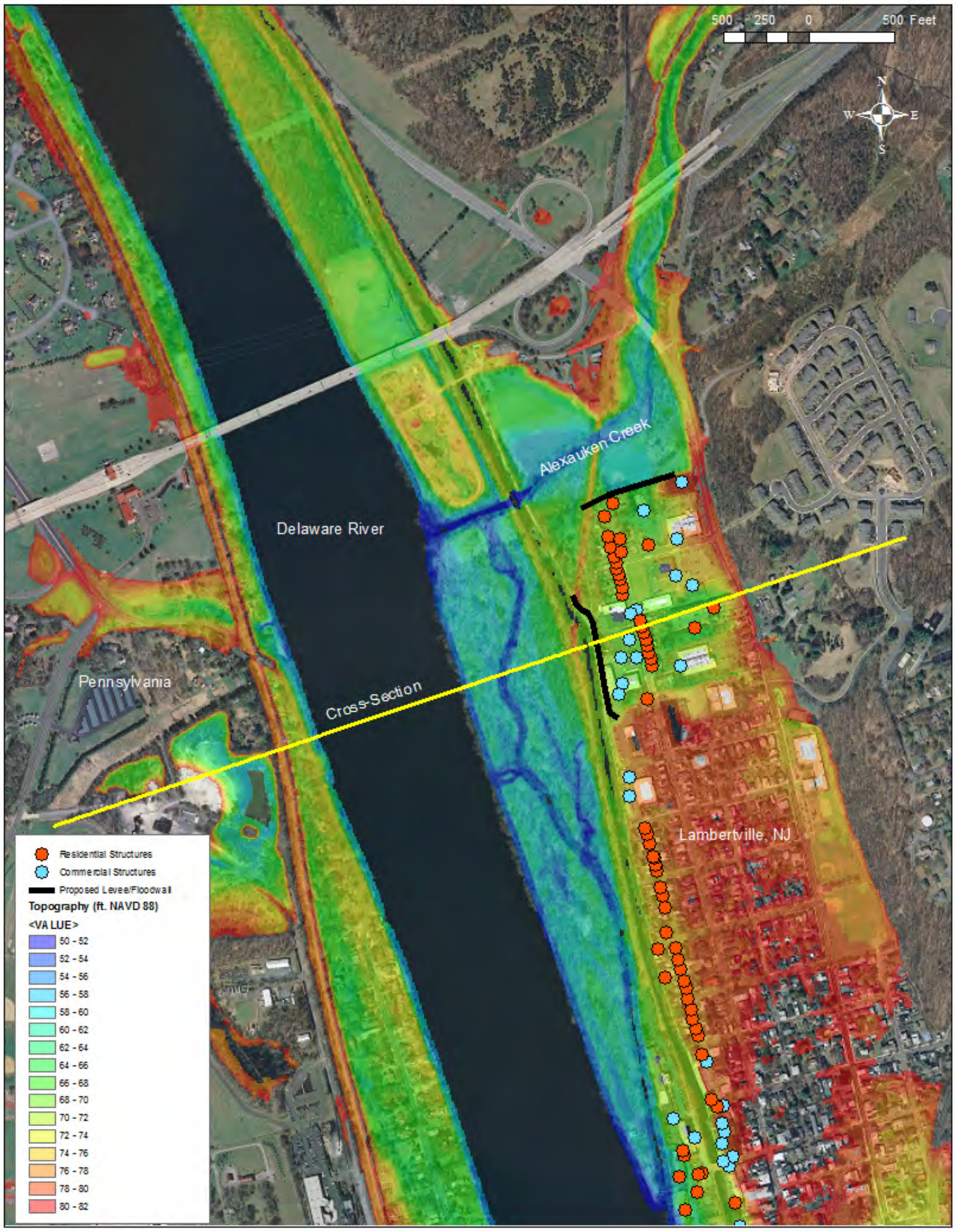


**Figure 6.3: LiDAR topography of the Lambertville area.**

A hydraulic analysis was conducted to verify that the proposed levee/floodwall system would not induce flooding on both the interior and exterior sides of the system. Interior of the proposed levee/floodwall, a detailed interior drainage analysis was conducted which identified the minimum facilities needed to safely convey storm water runoff that collects on the protected side. The drainage facilities were sized accordingly so that there is no increase in stormwater flooding above existing conditions within Lambertville. Specific details of the interior drainage analysis are presented in Appendix B: Interior Drainage Analysis.

An exterior hydraulic analysis was also conducted that compared Delaware River stages without the proposed levee/floodwall system in-place and with it in-place. The existing HEC-RAS model utilized for the study was modified accordingly by adding a cross-section at the proposed floodwall location along the D&R Canal running parallel with the Delaware River. Two HEC-RAS model simulations were conducted; one without the floodwall in-place at the cross-section shown in the previous figure, and one with it in-place. A suite of eight storms were simulated from the 0.5 to the 0.002 ACE events (2-yr to 500-yr). The topographic cross-section from the model showing the location of the proposed floodwall along with the computed 0.01 annual chance of exceedance stage with the project in-place (100-yr) is shown below (Figure 6.4).

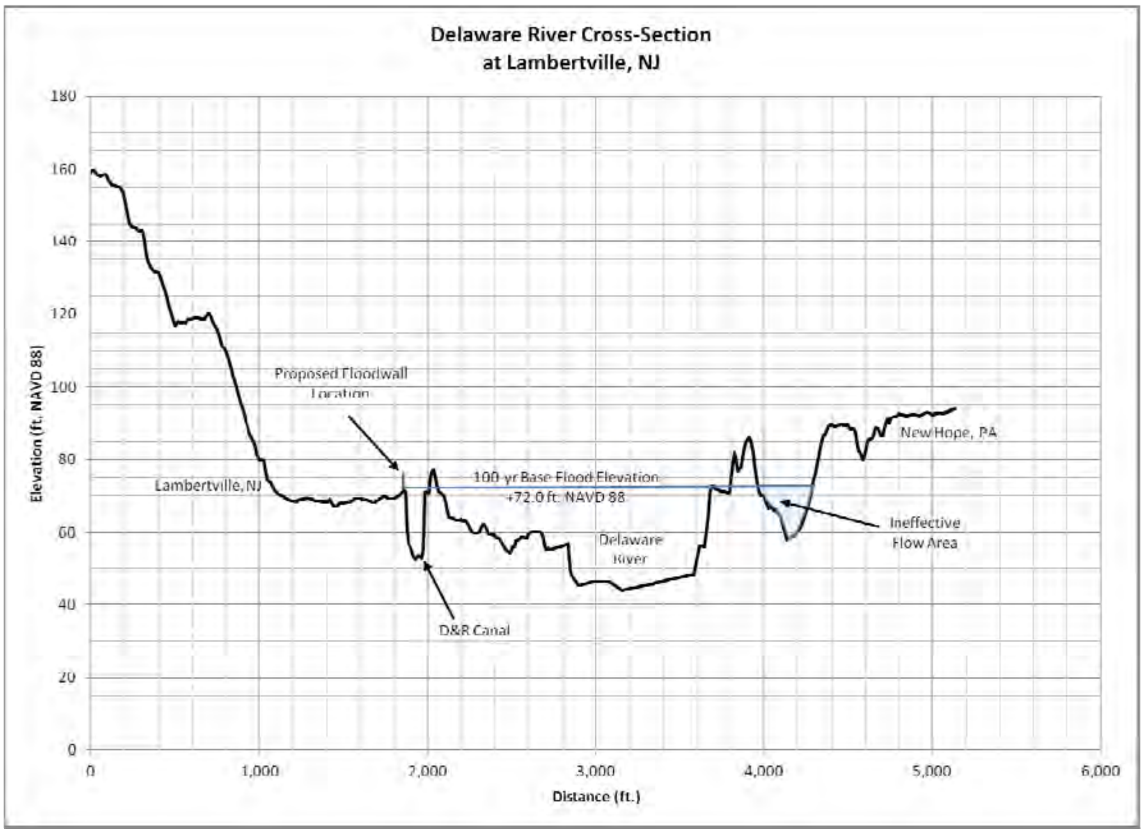


**Figure 6.4: A topographic cross section of the proposed floodwall in Lambertville.**

Examination of the LiDAR topography of the area and aerial imagery indicates that without the floodwall in-place the floodplain adjacent to the river within Lambertville is ineffective in nature. Ineffective areas are those that provide storage but do not actively convey flow. The proposed floodwall location will reduce the available floodplain storage area; however, results of the HEC-RAS simulations confirmed that the Delaware River stages do not increase due to the removal of the floodplain storage area landward of the proposed floodwall. Therefore, it is anticipated that there will not be any induced flooding between the Delaware River and the proposed floodwall since there is no increase in modeled river stages. No change in computed stages was observed for all events simulated in the HEC-RAS model, from the 50% to 2% ACE events (2-yr to 500-yr).

6.2.6.2 Gibbstown

The proposed alignment of the Gibbstown levee and floodwall system along with the most recent preliminary flood zones from FEMA are shown in Figure 6.5.

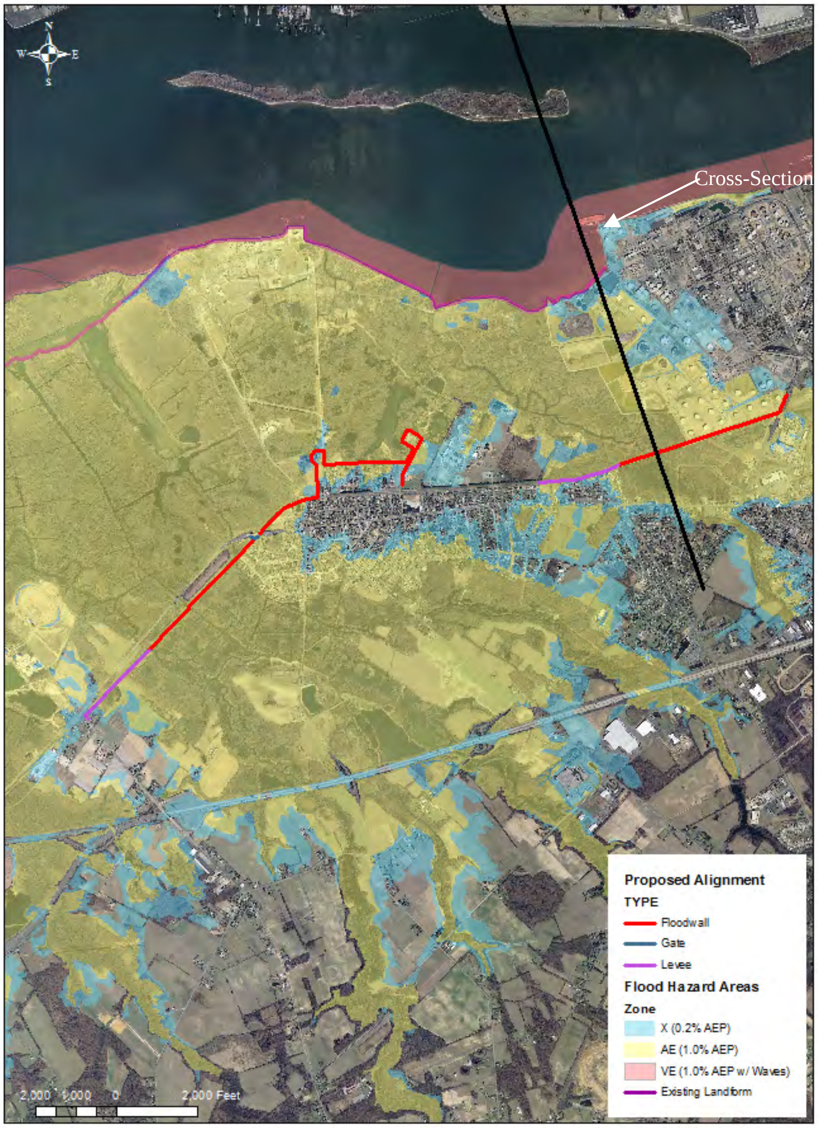


**Figure 6.5: The proposed levee/floodwall alignment with flood zones identified in Gibbstown**

The flood zones are preliminary and are based upon FEMA's coastal storm surge modeling of the Delaware Bay and Estuary. The figure shows that the proposed floodwall and levee system is at a minimum one mile away from the Delaware River, and the floodplain storage area made unavailable by the proposed levee and floodwall system is a small percentage of the total storage area. Examination of the topography of the area taken from the LiDAR DEM used in FEMA's coastal storm surge model also indicates that the floodplain adjacent to and south of Gibbstown is ineffective in nature. A cross-section showing the existing topography and the ineffective flow area is shown in Figure 6.6.

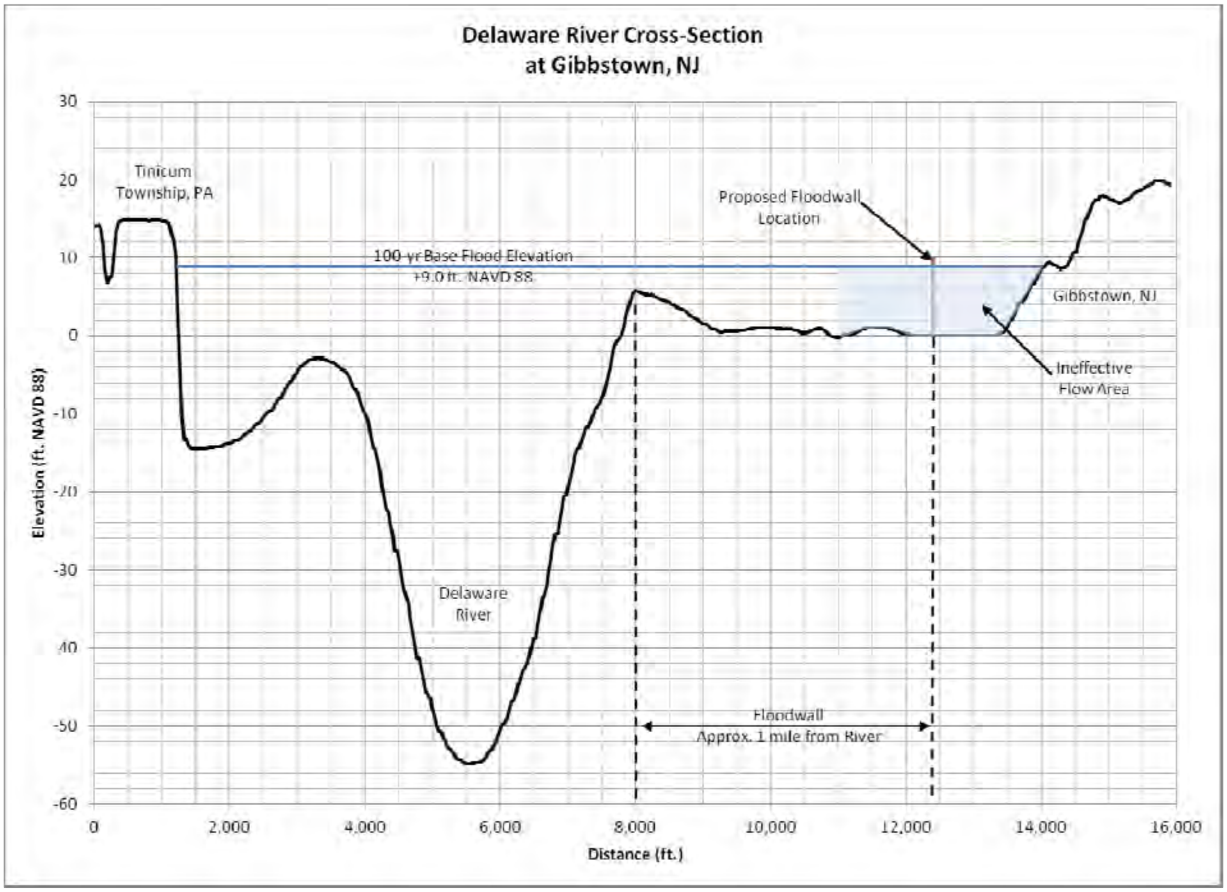


**Figure 6.6: Cross section of the topography of Gibbstown**

The Delaware River in this location from bank to bank is over 4,000 feet wide as the cross-section shows, and on the New Jersey side is characterized by a low and flat floodplain providing an additional 6,000 feet in width. Therefore, it is reasonable to conclude that the proposed levee/floodwall system will not increase stages in the Delaware River due to removal of floodplain storage because the volume excluded by the levee is small compared to the volume in the rest of the cross section. Also, examination of topography in the vicinity of the levee/floodwall system indicates that drainage areas exterior to the proposed system do not contribute to the interior drainage runoff; this includes the Paulsboro Refinery area which has been raised as a potential area of concern. Topography in this area generally slopes from the northeast to the southwest towards the exterior side of the proposed levee/floodwall system. As Figure 6.7 shows, exterior drainage would run east to west along the proposed levee/floodwall system until it reaches Clonmell Creek and would not pond above existing conditions within the Paulsboro Refinery property itself. However, future drainage analysis during design utilizing detailed topography may dictate the need for minor grading to create a channel to ensure positive drainage and convey flow to Clonmell Creek.

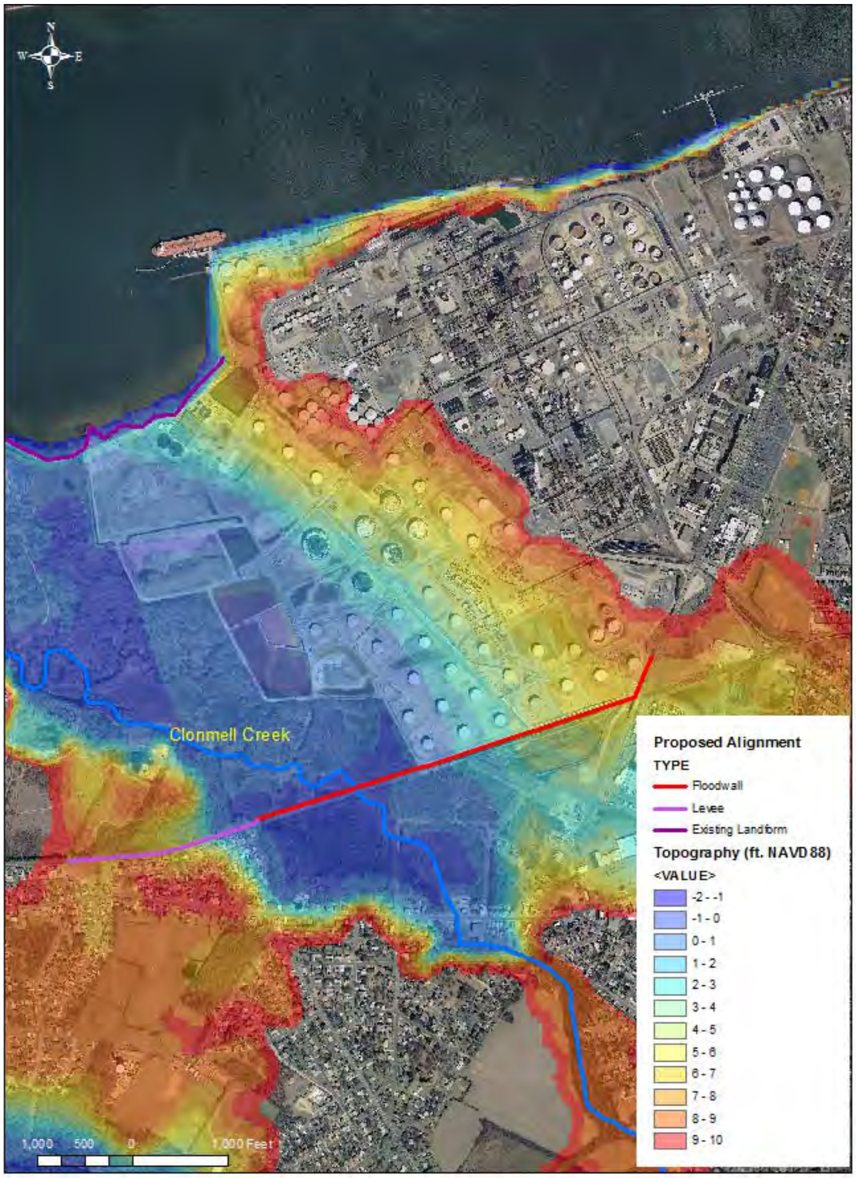


**Figure 6.7: Proposed alignment and drainage patterns in Gibbstown**

Interior of the proposed levee/floodwall an analysis was conducted and interior drainage facilities were identified that safely convey storm water runoff that collects on the protected side. The drainage facilities were sized accordingly so that there is no increase in stormwater flooding above existing conditions. Specific details of the interior drainage analysis are presented in Appendix B: Interior Drainage Analysis.

### 6.2.7 Wild and Scenic Rivers

There are no anticipated impacts to rivers designated as Wild and Scenic and under the purview of the National Park Service (NPS); however, additional coordination with the NPS will occur with the release of this draft report to confirm this finding. Both proposed projects under this study will be located away from the main stem Delaware River, which is designated under various statues of the Wild and Scenic Rivers Act.

### 6.2.8 Prime and Unique Farmland

It appears that the TSP for Gibbstown will have minor impacts on two potential important soil types: MamuAV and WokA. (See Figure 6.8.) As discussed previously, MamuAV has a rating of unique and WokA has a rating of prime. Initial coordination with the local NRCS field office indicated that MamuAV is considered unique due the historic use for salt hay farming; however, that is not considered a currently viable crop in today's agriculture, so would likely not be an issue. Additional coordination on this issue, including the completion of a Farmland Conversion Impact Rating form, will be completed with the Assistant State Soil Scientist for New Jersey during the public and agency review period for the study.

### 6.2.9 Hazardous, Toxic, and Radioactive Waste

HTRW occurrences in the Gibbstown study area are expected to impact implementation of the proposed project. Contaminants detected in shallow groundwater along the southern border of the Ashland/Hercules facility, are likely to be encountered during excavation for floodwall construction. The history of spills and other environmental impacts at the Paulsboro refinery also suggest potential for impacts to floodwall construction.

According to USACE policy, construction should be avoided in HTRW project areas where practicable. However, it would not be possible to implement any of the alternatives and still avoid the adjacent sites with known contamination (Ashland/Hercules the DuPont Repauno Plant and the Paulsboro Refinery). Investigation and remediation of the identified HTRW sites in the study area would be conducted before construction activities are undertaken near the affected sites. For contaminated groundwater that cannot be addressed prior to construction activities, the non-federal sponsor would be responsible at 100% non-project cost for addressing treatment and disposal of contaminated groundwater during dewatering activities.

The USACE would share the cost of investigations for HTRW contamination but would not contribute funds for preparing response plans and conducting remediation activities. The State of New Jersey would be responsible for conducting remediation or ensuring remediation by responsible parties at contaminated sites to support the project with the oversight of the appropriate regulatory agencies in accordance with all applicable laws, regulations, and ordinances. In addition, it is possible that undocumented soil or groundwater contamination is present in the study area and could be identified after completion of this feasibility study. The risk of encountering unknown contamination during design or construction would be minimized through completion of ASTM type Phase I and Phase II Environmental Site Assessments, and also by the sponsor undertaking industry-standard inquiries according to ASTM standards that are consistent with the CERCLA brownfields amendments and the All Appropriate Inquiries Rule prior to land acquisition and providing lands to the project.


**Figure 6.8: Proposed alignment and soils in Gibbstown**

It is recommended that soil and groundwater quality near the project alignment be tested at locations where contamination is suspected. Sampling locations and procedures would be coordinated with the New Jersey Department of Environmental Protection, USEPA Region 2, and local government agencies, as applicable. Any contamination found would be addressed in accordance with all applicable laws, regulations, and ordinances in a manner that would be protective of human and ecological health, so no adverse HTRW impacts are expected. Furthermore, BMPs will be in place, including standard procedures for addressing any contaminants uncovered or inadvertently released during construction, including containment, handling, disposal and reporting requirements.

An environmental records search was completed for the Lambertville area and none are expected to impact the proposed Lambertville area project. Additional information on HTRW issues can be found in the Appendix D: Environmental Appendix.

### 6.2.10 Cumulative Impacts

Cumulative impacts, as defined in CEQ regulations (40 CFR Sec. 1508.7), are the "impacts on the environment which result from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time."

Providing Gibbstown and Lambertville with flood risk management projects would contribute to the protection of life and to the reduction of physical and environmental damage. Significant flooding often results in contamination of drinking water supplies, dispersion of HTRW, and dispersion of large quantities of solid waste that require clean-up and disposal. Experience has shown that vast quantities of debris (e.g., homes, vehicles, mobile homes, etc.) and sediment must be collected and hauled away after a flooding event. Hauling the collected debris to a local municipal landfill requires significant transportation costs and adds huge quantities of solid waste to available landfill space. Providing flood risk management significantly reduces the probability that these environmental consequences of flooding will be incurred. Another positive cumulative effect of implementing the TSP will include the temporary expansion of the local economy during the 3-year construction period.

Negative cumulative effects associated with implementation of the TSP would be the permanent visual impact of the floodwall and levee system to the local communities. In addition, there will be a permanent loss of habitat connectivity for both aquatic and land species in the local watersheds. However, there are no anticipated cumulative air quality concerns, as the total direct and indirect emissions from construction of the project have been conservatively estimated and do not exceed the General Conformity limits under the Clean Air Act.

### 6.2.11 Environmental Justice

All of the alternatives, including the selected plan, identified in this Environmental Assessment are expected to comply with Executive Order 12989-Environmental Justice in Minority Populations and Low-Income Populations, dated February 11, 1994. No negative impacts are expected to occur to any minority or low-income communities in the area, as a result of this project.

### 6.2.12 Relationship of Selected Plan to Environmental Requirements, Protection Statutes, and Other Requirements

Compliance with environmental quality protection statutes and other environmental review requirements is ongoing. Table 6.2 provides a listing of compliance with environmental statutes.

**Table 6.2: Compliance with Appropriate Environmental Quality Protection Statutes and other Environmental Review Requirements**

| STATUTE | COMPLIANCE STATUS |
|---|---|
| Clean Water Act | Partial* |
| Coastal Zone Management Act | N/A |
| Endangered Species Act | Partial* |
| Fish and Wildlife Coordination Act | Partial* |
| National Historic Preservation Act | Partial* |
| National Environmental Policy Act | Partial* |
| Clean Air Act | Partial* |
| Executive Order (EO) 11988 | Full |

NOTE:
Full Compliance: Having met all requirements of the statute, E.O., or other environmental requirements for the current stage of planning.
Partial Compliance: Some requirements of the statute, E.O., or other policy and related regulations remain to be met.
*All applicable laws and regulations will be fully complied with upon completion of the environmental review, obtaining state water quality certification, coastal zone consistency determination, and concurrence with determination on cultural resources.
Noncompliance: None of the requirements of the statute, E.O., or other policy and related regulations remain to be met.

## 6.3 Project Benefits

Pending for the Selected Plan. See Appendix C: Economic Analysis for benefits associated with the TSP.

## 6.4 Project Cost Estimates

Pending for the Selected Plan. See Tables 5.22 and 5.23, as well as Appendix A: Engineering Technical Appendix, Section 15: Cost Estimate for costs associated with the TSP.

## 6.5 Risk and Uncertainty

The Line of Protection will be the first line of defense against river flooding in Lambertville and coastal storm surge in Gibbstown. However, extremely rare events would exceed the NED Plan Line of Protection design height and would cause overtopping, extensive damages to structures in the study area, and life-safety risks.

ER 1105-2-101, "Risk Analysis for Flood Damage Reduction Studies (USACE, January 3, 2006) stipulates that the risk analysis for a flood risk management project should quantify the performance of the plan and evaluate the residual risk, including the consequences of exceedance of the project's capacity. The guidance specifically stipulates, along with the basic economic performance of a project, the engineering performance of the project is to be reported in terms of:

- The annual exceedance probability
- The long-term risk of exceedance
- The conditional non-exceedance probability

The overall performance of the line of protection plans for Gibbstown and Lambertville have been computed in HEC-FDA and the results are presented in Table 6.3.

| Table 6.3: Project Performance Analysis - Line of Protection | | | | | |
|---|---|---|---|---|---|
| | **Condition** | **Gibbstown (Base Year)** | **Gibbstown (Future Year)** | **Lambertville (Base Year)** | **Lambertville (Future Year)** |
| Annual Exceedance Probability of Levee Design Stage | Median | 0.3% | 0.4% | 0.3% | 0.6% |
| | Expected | 0.3% | 0.4% | 0.4% | 0.8% |
| Long Term Exceedance Probability | 10 Years | 3% | 4% | 4% | 8% |
| | 30 Years | 8% | 11% | 12% | 21% |
| | 50 Years | 13% | 17% | 19% | 33% |
| Conditional Non-Exceedance Probability | 10% | 100% | 100% | 100% | 100% |
| | 4% | 100% | 100% | 100% | 100% |
| | 2% | 100% | 100% | 99% | 94% |
| | 1% | 100% | 100% | 92% | 72% |
| | 0.4% | 91% | 66% | 58% | 32% |
| | 0.2% | 18% | 1% | 32% | 13% |

Note: Future year analyses are based on projections of the current historical, or low, rate of sea level rise.

The annual exceedance probability of the project is the likelihood that the levee design elevation is exceeded by flood waters in any year and can be considered as an indication of the level of risk management provided by the Plan.

The line of protection design elevation was used to calculate the base year median and expected annual exceedance probability for the TSP Plan. The median base year values of 0.3% annual probability of exceedance (equivalent to events with a 333-year return period) for both Gibbstown and Lambertville reflect the basic as-designed performance of the plan without the application of uncertainty to the basic discharge-frequency and/or stage-discharge functions. The expected base year values of 0.3% and 0.4% annual probability of exceedance (equivalent to events with a 333-year and a 250-year return period respectively) are computed from the results of the Monte Carlo simulations which take into account uncertainty in hydrologic/hydraulic functions and project features. Hence the difference between the two is an indication of the uncertainty associated with the project performance.

The long-term risk of exceedance is the probability that the design stage will be exceeded at least once in the specified durations of 10, 30, and 50 years. In this instance, the table indicates that over a 30-year period (i.e. the life of a typical mortgage), the probability of the Gibbstown line of protection being exceeded at least once is 8%, using base year conditions, rising to 11% using future conditions based on projecting the historic, or low, trend of sea level rise.

The conditional non-exceedance probability measures the likelihood that the project will not be exceeded by a specified hydrologic event. This is a measure of how reliable the plan is in providing the intended levels of risk reduction. For this analysis the base year conditional non-exceedance probability has been computed for each scenario for the 10%, 4%, 2%, 1%, 0.4% and 0.2% annual chance exceedance events (10-, 25-, 50-, 100-, 250- and 500-year floods).

A summary of the overall uncertainty in the estimation of benefits is provided in Table 6.4. This table shows, for example, that while the expected damage reduction in Lambertville is $857,000, there is a 25% probability that the damage reduction achieved by the plan will actually exceed $1.1 million. Note that a full Cost and Schedule Risk Analysis has yet to be completed so evaluations of the uncertainty in cost estimates (and hence in net benefits and subsequent benefit-cost ratios) are not available.

**Table 6.4: Expected and Probabilistic Values of Structure/Contents Damage Reduced by Alternative**

| Alternative | Equivalent Annual Damage (Line of Protection Only) | | | Probability that Damage Reduced Exceeds the Damage Values in the Table | | |
|---|---|---|---|---|---|---|
| | Without Project | With Project | Damage Reduced | 75% | 50% | 25% |
| Gibbstown +10 Ft NAVD | $15,237,000 | $317,000 | $14,920,000 | $13,575,000 | $14,870,000 | $16,236,000 |
| Lambertville +76 Ft NAVD | $1,147,000 | $290,000 | $857,000 | $535,000 | $793,000 | $1,111,000 |

Price Level: 2014, Interest Rate: 3.50%, Period of Analysis: 50 years

## 6.6 Sensitivity Analysis

6.6.1.1 Ecological Sensitivity to Sea Level Trends

In 2011, a preliminary ecological assessment of the natural resources within and around the vicinity of the proposed levee alignment in the Gibbstown area was completed to assist in characterization of the past and existing conditions of the project area and project “future without- project” conditions. The assessment was completed using current aerial imagery and mapping, as well as follow up site visits for ground-truthing. In addition, sea level change (SLC) models were used to determine what habitat will exist in the future (2065) without implementation of a flood risk management project.

SLC is not the only factor likely to affect potential habitat/land cover shifts between the present and the year 2065. As the climate changes, increased intensity and frequency of storm events are likely to occur. The assessment included estimates of the average ranges for various 100% to 0.2% ACE (1 year to 500 year) storm events over several SLC scenarios. For a 2011 100% ACE (1 year) storm event at the confluence of Repaupo Creek and the Delaware River, the peak tidal elevation was estimated at 4.52 ft (NAVD 88). Under a moderate SLC scenario (projecting a change of 0.96 ft), the peak tidal elevation for a 100%

ACE (1 year) at the confluence of Repaupo Creek and the Delaware River was estimated to be 5.92 ft (NAVD 88), a difference of +1.4 ft from the existing (2011) conditions.

For the purpose of this study, an intermediate increase in mean sea level was estimated to be 5.41 mm/year. This moderate rate of SLC was used to project the previously mentioned change of 0.96 ft in sea level elevations for the year 2065. Based on that rate of change, the elevation data was adjusted by subtracting 0.96 ft and adjusting the habitat/land cover ranges to those listed in Table 6.5.

**Table 6.5: Study area estimated habitat/land cover acreages for 2010 and 2065 (based on moderate SLC rise scenario)**

| Habitat/Land Cover Type | 2010 Acres | 2010 Percentage of Total Area (ac) | 2065 Acres | 2065 Percentage of Total Area (ac) |
|---|---|---|---|---|
| Agricultural | 335 | 7.0% | 908 | 20.0% |
| Emergent Wetland | 587 | 12.2% | 436 | 9.6% |
| Forested Wetland | 2,340 | 48.8% | 1,244 | 27.4% |
| Open Water | 390 | 8.1% | 1,368 | 30.2% |
| Upland Herbaceous | 229 | 4.8% | 146 | 3.2% |
| Urban Developed | 914 | 19.1% | 430 | 9.5% |

In 2065, the vegetation and landscape will be drastically different. An increase in water elevation will favor some species (wetland types), while other species (upland types) will not be able to tolerate the increased water and will no longer be part of the plant community. Projected global climate change, flooding, and sea level change will result in several impacts to habitats within the project area. Also, there is clearly potential for the forested wetland habitat to be subsiding and likely shifting to emergent wetland or open water. In addition, emergent wetlands are projected to maintain some stability under the assumption that some emergent wetlands will shift to open water while other areas may become viable for emergent wetland and some areas of forested wetland may become emergent. It should be noted that these losses and shifts could be greater if the rate of water level change exceeds the rate of habitat shift. Furthermore, without restoration work on the wetlands, it is likely that the current invasive species in the project area (e.g., common reed) will continue to expand and further degrade the system. If this happens, the functionality and value of the wetlands in the project area will continue to decline.

6.6.1.2 Economic Sensitivity to Sea Level Trends

The tidal part of the Study Area (Gibbstown) was analyzed with three different projections for future sea level change conditions. The three projections included the historic trend (low projection), an intermediate future projection, and a high future projection. Based upon sea-level guidance document EC 1165-2-211, Equivalent Annual Damage was estimated to be $17.8 million under low future trends, $21.7 million under the intermediate trends, and $35.7 million under the high trends.

The expected annual damage shows an increase of almost 30% between the base year and the historically trended future conditions. Assuming intermediate trends, the increase over the base year is over 50%, and the increase assuming high trends is about 160%.

Figure 6.8 presents the Gibbstown Line of Protection design elevation superimposed on the three anticipated rates of sea level change for the 10-yr, 100-yr, and 500-yr storm events.

6.6.1.3 FY 15 Sensitivity Analysis

Sensitivity results for the Selected Plan applying the FY15 Federal discount rate of 3 3/8% will be performed.

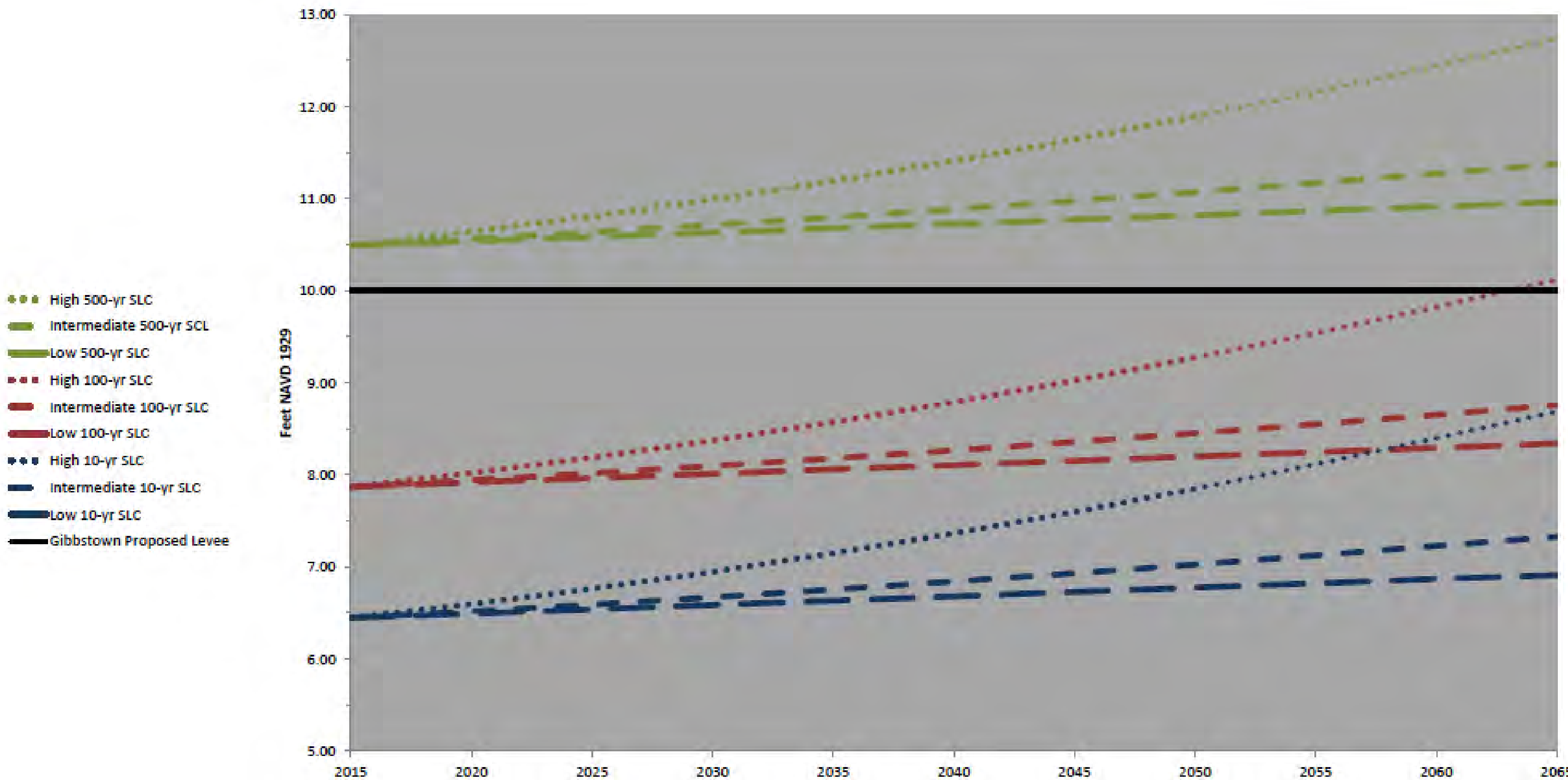


**Figure 6.9: Gibbstown Line of Protection Design versus Sea Level Change Curves**

# 7 Plan Implementation

Completion of this section is pending identification of the Selected Plan. The Selected Plan will be determined through a process of optimization, or identifying the plan with the greatest net benefits. In other words, the plan will return the greatest excess of benefits over costs. For the project under consideration, the process will include comparing potential structure heights, while also taking into consideration projected sea level change and physical constraints on the ground.

# 8 Public Involvement*

Over the course of the study, an extensive public outreach effort was conducted to provide information and elicit feedback from residents and local officials in the study area communities. Activities included development of a project-specific website, workshops conducted with local officials and staff, and open houses for the public. The project website (http://www.nap.usace.army.mil/Missions/CivilWorks/DelawareRiverBasinComprehensiveStudy.aspx) described the goals of the study, the history of flooding in the Delaware River basin and the overall Corps of Engineers process, while providing detailed maps of the community floodplains and the buildings included in the economic analysis. In addition, fact sheets for flood risk management measures and videos explaining the concepts of flood risk management were provided. A brochure for public distribution, providing a project overview, was also prepared and distributed.

Beginning in September 2011, workshops were held for the northern, central, and southern portions of the study area. Attendees include elected officials and technical staff such as municipal engineers, planners, and planning board members. Representatives from the Corps and NJDEP provided a project overview, discussion of data collection and analysis methods, potential implementation measures, a description of major milestones to follow, and elicited community feedback and discussion. Comment cards were distributed to capture input from attendees and to identify areas of particular flooding frequency or vulnerability, and to identify specific community representatives who should be invited to future events.

In February 2012, three public open houses were held in Washington, Lawrenceville, and Swedesboro, NJ for the northern, central, and southern areas. Using poster stations, staff from the Corps and NJDEP described the study process, analysis methods, and findings to date, while representatives from FEMA Region II, the National Weather Service, USDA-NRCS and the Nurture Nature Center described their programs and efforts at reducing the impacts of flooding. Attendees included members of the public, elected officials, and technical staff. Attendees were provided comment forms to provide their feedback on the overall project and the preliminary findings.

# 9 Conclusions and Recommendations*

Completion of this section is pending identification of the Selected Plan. The Selected Plan will be determined through a process of optimization, or identifying the plan with the greatest net benefits. In other words, the plan will return the greatest excess of benefits over costs. For the project under consideration, the process will include comparing potential structure heights, while also taking into consideration projected sea level change and physical constraints on the ground.

# 10 List of Preparers*

U.S. Army Corps of Engineers
Theresa Fowler – Project Management and Plan Formulation
Robert Selsor - Economics
Mark Eberle – Environmental Resources
Nicole Minnichbach – Cultural Resources
William Welk – Cost Engineering
Robert Lowinski – Hydrology and Hydraulics
Robert Phillips – Geotechnical Engineering
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William Harris – Geo-Environmental
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Robert Santos – Real Estate
Sharon Grayson – Geographic Information System Support
Steven Rochette – Public Outreach

URS
Michael Cannon – Plan Formulation
Brian Beckenbaugh – Plan Formulation and Public Outreach
Curtis Smith – Report Preparation
John Dromsky-Reed – Cost Estimating
Richard Franks – Economics

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James DeAngelo - Economics
Craig Wenger - Economics
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TetraTech
J.T. Marine – Archaeological Data
Michael Byle - Geotechnical Data

Versar
Christopher Bowen – Archaeological Data

Biohabitats
Edward Morgereth - Biological Data

Duffield
Brian Devine - Geotechnical Data

EDR
Hazardous, Toxic and Radioactive Waste Data

# 11 References*


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