# 3. PLAN FORMULATION – FLOOD DAMAGE REDUCTION

Plan formulation for the Passaic River at Long Hill Township feasibility study has been conducted in accordance with the six-step planning process described in *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (1983) and the *Planning Guidance Notebook* (1105-2-100, dated April 2000). The six steps in the iterative plan formulation process are:

1. Specify the water and related land resources problems and opportunities of the study area;
2. Inventory and forecast existing conditions;
3. Formulate alternative plans;
4. Evaluate alternative plans;
5. Compare alternative plans; and
6. Select the recommended plan.

The basis for selection of the recommended plan(s) is fully documented below, including the logic used in the plan formulation and selection process.

## 3.1 Problems And Opportunities

The primary water resources problem within the Long Hill Township portion of the Passaic River basin is persistent, recurring flooding. Flood damages are primarily attributable to backwater flooding from the Passaic River into a series of smaller tributaries which enter damage areas throughout Long Hill Township. Damages from past flood events have included structural damages to buildings and their contents; limitations on the uses of property because of the threat of flooding; impacts of flood-related interruptions in road transport on business and interstate commerce; and threats to public safety. In addition to residential and commercial flooding, many major thoroughfares are impacted by floodwaters, requiring roads to be closed to traffic during flood events. The Long Hill Township Police Station is located within the 100-year flood plain. Emergency flood protection measures in 1996 and 1999 prevented significant damage; however, the police station and related communications centers nearly were evacuated, which would greatly have hampered rescue and recovery efforts. The current flood plain for the Long Hill Township reach of the Passaic River is shown on Figure 3-1.

Five primary tributaries provide local drainage for the Township into three tributaries that empty into the Passaic River. The tributaries are depicted in Figure 3-2. Gradient along the tributaries ranges from 10 percent near the Long Hill Ridge north of the Township to nearly flat in the wetland area located between Gillette and Stirling. During low magnitude, high frequency rainfall events, the tributary system is sufficient to provide drainage for the township. During high magnitude, low frequency regional rainfall events, high stages on the Passaic River reduce the discharge capacity and effectiveness of the tributary drainage system. As stages on the Passaic River continue to rise, the tributary system becomes the pathway for floodwater from the Passaic River to enter the developed areas of the Township. Water surface elevations along the tributaries rise coincident with stages on the Passaic River.

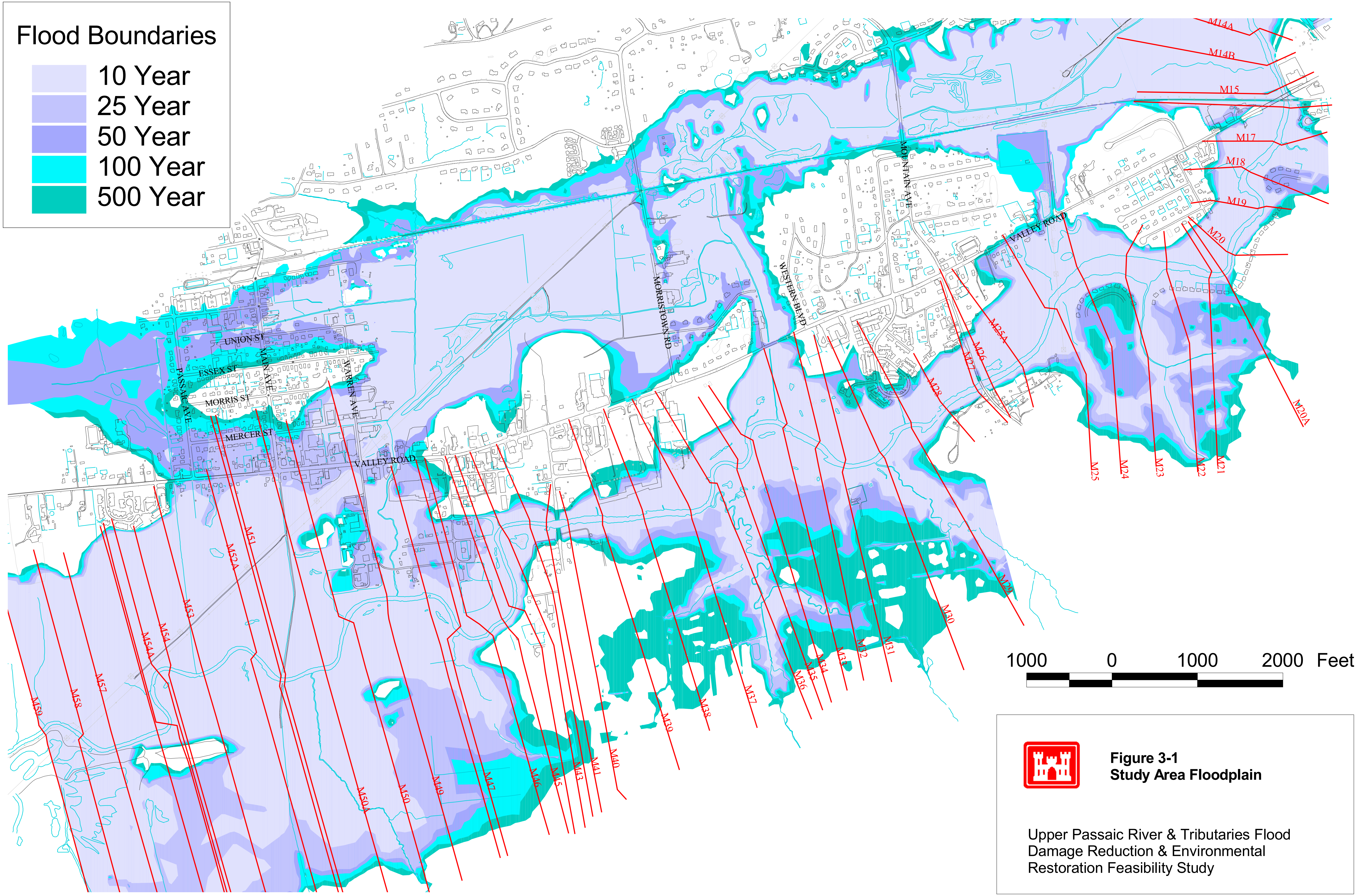


**Figure 3-1**
**Study Area Floodplain**


**FIGURE 3-2**
**Study Area with Tributaries Shown**

**Upper Passaic River & Tributaries Flood Damage Reduction & Environmental Restoration Feasibility Study** (not to scale)

### 3.1.1 History of Past Flooding

Recent major floods on the Passaic River (1968, 1971, 1977, 1984, 1996, and 1999) have impacted the Passaic River Basin and caused several billions of dollars in damages. The following is a brief listing of the most recent floods that directly affected Long Hill Township.

**September 16 1999**: Tropical Storm Floyd caused extensive flooding throughout the east coast of the U.S. Morris County was among nine New Jersey Counties declared Natural Disaster Areas. The peak discharge and stage during Tropical Storm Floyd was recorded at 2,210 cubic feet per second (cfs) and elevation 201.11 feet. At Millington, the peak discharge was recorded at 1,590 cfs with a water surface elevation of 224.51 feet. These peak discharges correspond to an event with a return period of approximately 33 years.

**October 19, 1996:** A rainfall of 9.63 inches in a two day period resulted in a 2 percent chance frequency (50-year recurrence interval) flood event. Reported damages from this flood were estimated at between $1 million and $3 million (reported to Emergency Operations Center vs. newspaper reports), with impacts spread over 20 percent of the township. A description of six representative damage areas is provided below.

1. <u>Crossing of a Passaic River tributary with Bungalow Terrace</u>. A small unnamed tributary of the Passaic River passes underneath Bungalow Terrace just west of the intersection with Old Forge Road. A culvert carries the flow underneath Bungalow Terrace. Flooding occurs in the area due to backwater flow through the culvert. As the waters of the Passaic River rise, the flow in the tributaries changes direction and volume of flow increases. The water then remains in the tributaries and retards natural drainage from the surrounding wetlands. Houses located on the north side of Bungalow Terrace and along Old Forge Road were flooded as a result of the October 19, 1996 storm. Flood depths were greatest to the north beyond Bungalow Terrace. Flooding decreased to the south along Old Forge Road. Flooding was reported to reach four (4) feet in some areas.

2. <u>Crossing of a Passaic River tributary with Morristown Road</u>. A small unnamed tributary of the Passaic River passes underneath Morristown Road just north of the road's intersection with Madison Street. The flow is conveyed under Morristown Road through a culvert. Between the tributary and the Madison Street intersection is a wastewater pump station. After the October 19, 1996 storm, residential areas along Morristown Road and Madison Street experienced severe flooding. Along Morristown Road, stalled cars remained inundated for up to seven (7) days. This tributary is a headwater connection to the tributary that runs under Valley Road near its intersection with Warren Avenue.

3. <u>Mountain Avenue bridge over the Passaic River</u>. The Passaic River is conveyed under a single lane bridge along Mountain Avenue. After the October 1996 storm, the water levels continued to rise, overtopping the bridge. Water depths required closure of the bridge and Mountain Avenue.

4. <u>Crossing of a Passaic River tributary with Valley Road</u>. Another small tributary of the Passaic River passes underneath Valley Road between Warren Avenue and Poplar Drive. This area is part of the business district. Many local businesses suffered extensive damage as a result of the October 19, 1996 storm. One business was inundated up to the bottom of its windows and incurred damages totaling $60,000.

5. Along the Passaic River at the South End of Main Avenue. South of Valley Road, Main Avenue turns into a dirt road which terminates prior to intersecting the Passaic River. The river at this point is shallow and wide, and debris is scattered along the river bottom. Local officials stated that the entire area from this point on the Passaic River extending north to Mercer Street was flooded as a result of the October 1996 storm. As the water level in the river rises, the water can be seen getting closer to Main Avenue. The area between the Passaic River and Valley Road is a non-residential wooded area. However, the area north of Valley Road is populated with residential and commercial buildings.
6. Long Hill Township Sewer Treatment Plant. The wastewater treatment plant that services the township is located on Cedar Avenue, just north of the Passaic River. As a result of the elevated stage of the river following the October 1996 storm, inundation occurred up to approximately 2 to 3 feet on the exterior wall of the treatment plant. Due to the impending hazard of the high waters, the plant had to shut down. Local officials stated that after a 2 to 3 inch rain, water begins to impact the plant property.

**April 1984:** A severe flood occurred when a two-day storm, which brought approximately five inches of rainfall, combined with snowmelt runoff from a 12-inch snowfall, which had occurred during the previous week. The flooding was the worst to occur in 45 years throughout the Passaic River Basin. This event was approximately a 10 percent chance exceedance event, causing roughly $740,000 in damages at current price levels.

**November 1977:** The storm of November 1977 caused extensive flooding throughout northeastern New Jersey, Particularly in Bergen County. In the Passaic River Basin, the main tributaries of the Basin, which included the Saddle, Ramapo and Pompton rivers, were hardest hit. Residences and businesses in Long Hill Township incurred minor damages from this 20 percent chance exceedance event. Only minimal damages were recorded

**August 1971:** The storm of August 1971 caused extensive flooding on the tributary system of the Passaic River. Except for the 1996 flood, this event was considered to be the most recent major flood in the Township. The 1971 flood was larger (50-year event); however, upstream development since 1971 has exacerbated flooding. At Long Hill Township, this storm was approximately a 25 year event, causing just over $3 million in damages.

**May 1968:** The flooding of May 1968 caused widespread damage over the Passaic River Basin. Flooding occurred on the main stem and all major and most minor tributaries from the headwaters to the City of Passaic, about 12 miles upstream of the mouth. Damage records were unavailable for this 12 year event, though current estimates would show between $800,000 and $1 million in damages.

Other major floods have been recorded on the Passaic River between 1902 and 1968. Based on the magnitudes of the floods and the flood prone areas within the township, it is believed that the study area would have been impacted. Since the study area was mostly undeveloped, flood damages would have been minimal. In response to past and potential flooding problems in Long Hill Township, this community has participated in the National Flood Insurance Program (NFIP) for at least 20 years. As required for NFIP participation, the community has enacted municipal ordinances regulating flood plain development.

### 3.1.2 Principal Flood Damage Reaches

The Upper Passaic River at Long Hill Township study area was divided into three reaches based on location and flooding pathways. Figure 3-3 shows an aerial photograph of the general study area with the locations of reaches 1, 2, and 3 identified. Closer views of Reaches 1, 2, and 3 are shown on Figures 3-4, 3-5, and 3-6. These reaches were used to evaluate the costs of structural and nonstructural flood damage reduction measures and to estimate the benefits of the alternative plans, based on the corresponding reduction in flood damages.

Reach 1: South of Valley Road. Reach 1 is bounded by Valley Road to the north and the Passaic River to the south (see Figure 3-4). Flooding in this reach causes inundation of roadways, public works, commercial and industrial structures, and residential structures. The flood pathway for all damageable property in this reach is via direct inundation by the Passaic River. The reach contains the Shop Rite Shopping Center, which is a multipurpose retail strip mall, a wastewater treatment plant, several restaurants, and about twenty residential structures. Flooding begins for structures in this reach at elevation +213 NGVD, which corresponds to roughly a 7 year event, though most damages begin to occur between the 10 and 15 year events. With the exception of the Shop Rite Shopping Center, all of the structures located within this reach are inundated between the 25 and 50 year events.

Reach 2: North of Valley Road. Reach 2 includes Valley Road and the area north of Valley road (see Figure 3-5). Similar to Reach 1, flooding in this reach damages residential property, roadways, public buildings, and commercial and industrial property. The Long Hill Township Police Department, the Township's Emergency Operations Center, is located within this reach. Floodwaters first inundate this reach due to backwater flow through the Passaic River tributaries that serve to drain stormwater flow from the reach. As the waters of the Passaic River rise, the flow in the tributaries changes direction and volume of flow increases as floodwaters are conveyed into the reach through culverts that cross beneath Valley Road.

Reach 3: Madison Avenue off of Mountain Road. Reach 3 is an isolated area of flood-prone properties, consisting solely of residential structures (see Figure 3-6). Floodwaters approach this reach through the drainage culvert that joins a Passaic River tributary. As the tributary fills with back flow from the Passaic, the flow in the culvert changes direction and floodwaters enter the reach. This isolated pocket contains less than ten structures at risk from flooding. After an examination of measures and alternatives (discussed later in this section), Reach 3 was combined with Reach 2. The principal reason for combining these reaches was that the measures that would protect Reach 2 also would protect Reach 3.

With- and without-project future conditions for the flood-prone reaches assume a stable level of development. Because flood plain regulations restrict new construction in areas that are subject to damage by a 100-year flood event, it was assumed that development of new residential, commercial, and industrial uses in the flood plain is not likely.

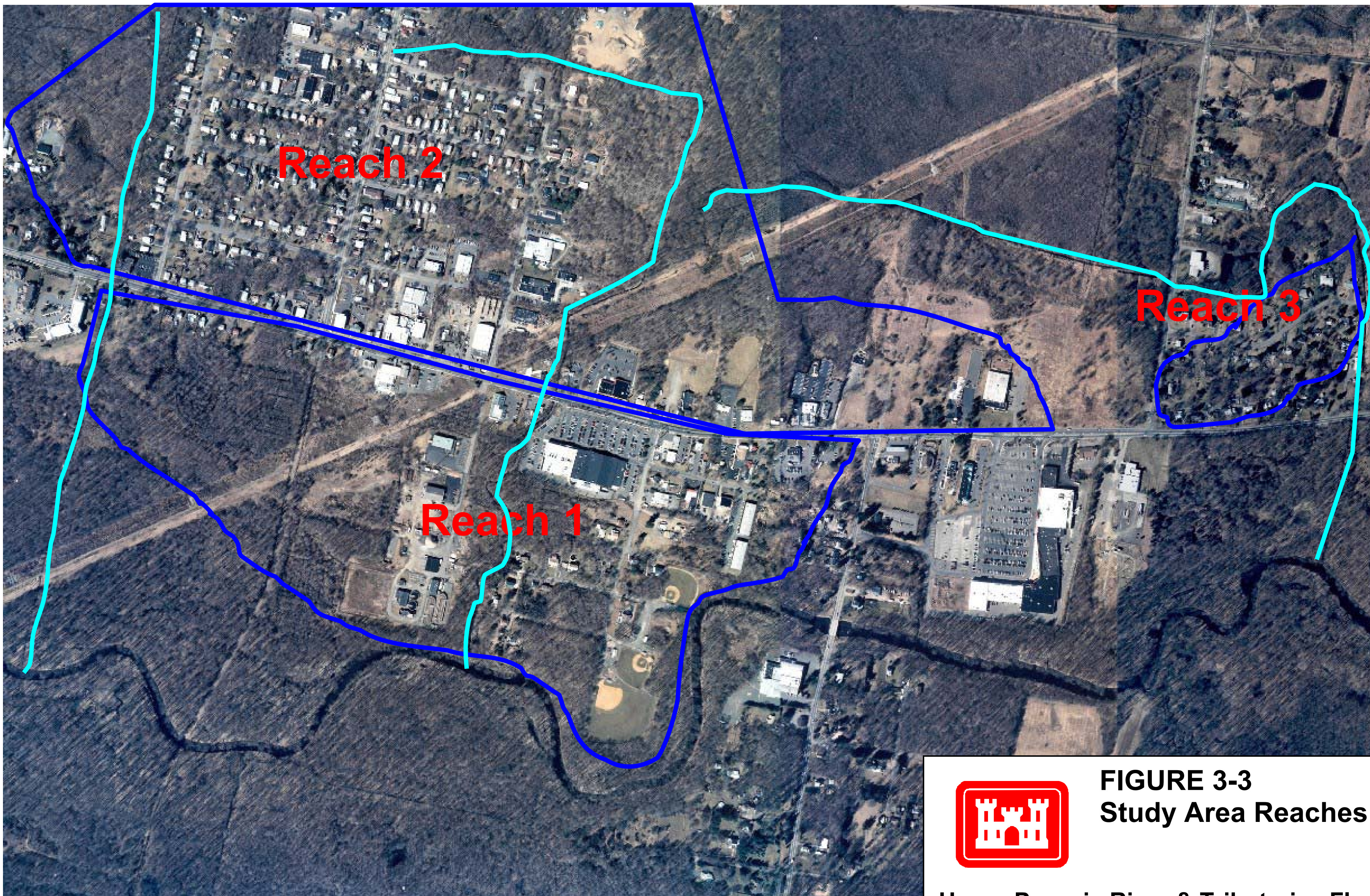


**FIGURE 3-3**
**Study Area Reaches**

**Upper Passaic River & Tributaries Flood Damage Reduction & Environmental Restoration Feasibility Study**

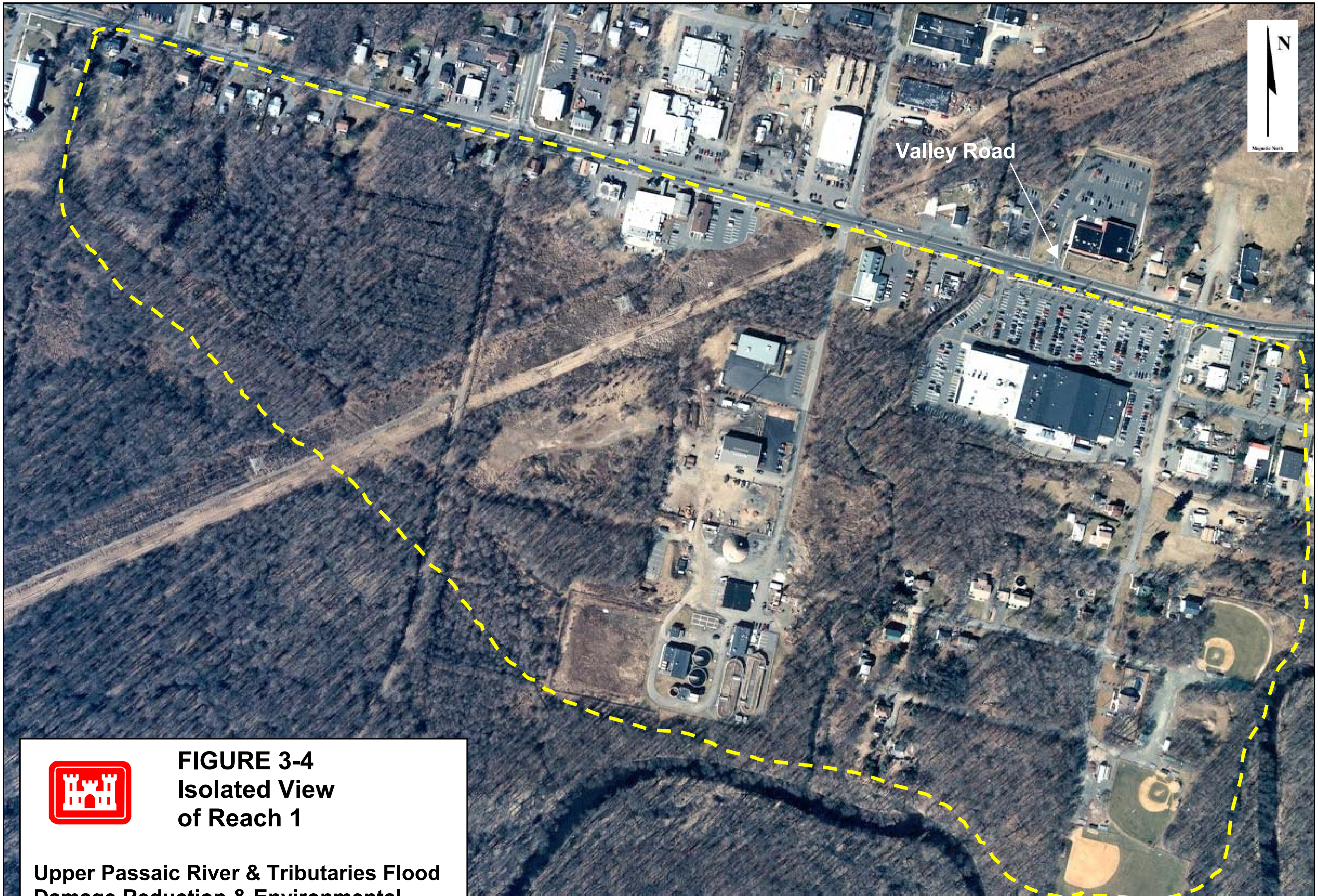


FIGURE 3-4
Isolated View
of Reach 1

Upper Passaic River & Tributaries Flood Damage Reduction & Environmental Restoration Feasibility Study (not to scale)

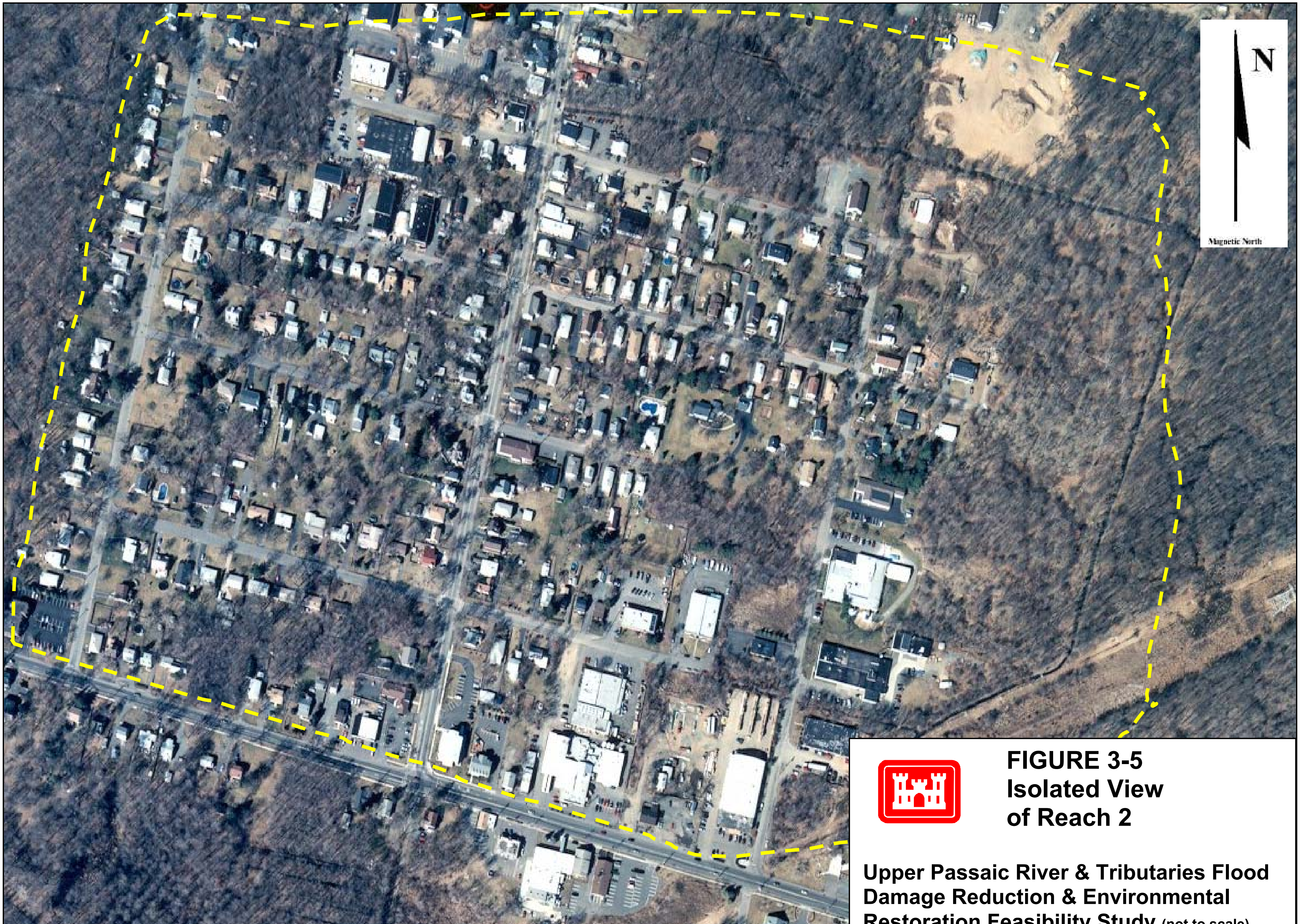


**FIGURE 3-5**
**Isolated View**
**of Reach 2**

**Upper Passaic River & Tributaries Flood Damage Reduction & Environmental Restoration Feasibility Study** (not to scale)


**FIGURE 3-6**
**Isolated View of Reach 3**

**Upper Passaic River & Tributaries Flood Damage Reduction & Environmental Restoration Feasibility Study** (not to scale)

## 3.2 Planning Objectives, Constraints, and Key Assumptions

The following discussions identify critical objectives, constraints, and assumptions used during formulation of alternative plans to address problems and opportunities of Federal interest in flood damage reduction along the Passaic River at Long Hill Township.

### 3.2.1 Planning Goals And Objectives

The Federal objectives in making investments in flood damage reduction projects are to contribute to National Economic Development (NED). The pursuit of planning objectives must be consistent with Federal, State and local laws and policies, and technical, economic, environmental, regional, social, and institutional considerations. Recommended plans should avoid, minimize, and then mitigate, if necessary, adverse project impacts to the environment. They should also maximize net economic benefit, avoid adverse social impacts, and meet local preferences to the fullest extent possible.

In pursuit of the goal to reduce flooding damages in the study area, the following objectives for flood damage reduction at Long Hill Township were established:

- Provide protection from frequent, low-level recurring floods in order to protect and maintain traffic corridors and ensure the operability of emergency and rescue facilities during storm events.
- Reduce the frequency and severity of backwater flooding from the Passaic River into the principal tributaries within the study area.
- Provide a plan that is compatible with future flood damage reduction and economic development opportunities.
- Avoid and minimize adverse environmental impacts.

### 3.2.2 Planning Constraints

The formulation and evaluation of alternative plans was constrained by a variety of considerations. The planning constraints used to guide the feasibility study are listed below:

- Technical constraints include the need for plans to be: (1) sound, safe, and acceptable solutions, (2) in compliance with sound engineering practice, (3) realistic and state-of-the-art, (4) consistent with existing local plans, and (5) complete and not dependent on future projects.
- Economic constraints include: 1) the need for flood damage reduction features to be efficient (*i.e.*, average annual benefits exceed average annual costs); and 2) the requirement to select the flood damage reduction plan that maximizes net excess benefits (*i.e.*, the NED plan) unless there are overwhelming reasons to select a different plan and an exception is granted by the Assistant Secretary of the Army (Civil Works).
- Environmental constraints affecting the formulation and selection of flood damage reduction features include the need for plans to: (1) avoid unreasonable impacts to

environmental resources, and (2) first consider avoidance followed by minimization, mitigation, and replacement.

- Regional and social constraints include the need for plans to: (1) weigh the interests of State and local public institutions and the public at large, and (2) consider the potential impacts of the project on other areas and groups.
- Institutional constraints include the need for plans to: (1) be consistent with existing Federal, State and local laws, (2) be locally supported, (3) provide public access to the project in accordance with Federal and State laws and regulations, and (4) find overall support in the region and state.

### 3.2.3 Critical Assumptions Guiding Plan Formulation

Critical assumptions guiding plan formulation for flood damage reduction features include the following:

- Economics of the project will be evaluated using a 50-year period of analysis.
- A Preconstruction Engineering and Design phase that will include development of a Design Documentation Report and Plans and Specifications will follow the feasibility phase.
- Prevailing Federal discount rate (5.625 percent) will be utilized in cost and benefit estimates.
- The line of protection and interior drainage features are separately formulated and optimized.
- Flood damages in the study area will worsen in the absence of Federal action.

## 3.3 Hydrologic and Hydraulic Analyses

Hydrologic, hydraulic, and statistical analysis were performed to develop existing conditions stage-frequency curves. Risk and uncertainty analyses were then conducted to quantify the uncertainty in discharge-frequency, stage-discharge, and stage-damage functions. This analysis progressed in the following steps:

- Statistical analysis of currently existing stream gage records, including confidence limits (Bulletin 17B)
- Development and calibration of existing conditions hydrologic model (HEC-HMS)
- Development and calibration of existing conditions hydraulic model (HEC-RAS)
- Uncertainty analysis of hydraulic data
- Development of existing conditions Hydraulic Engineering Center’s Interior Flood Hydrology (HEC-IFH) models
- Assessment of stability of existing channel

Below is brief discussion of each of the steps.

Statistical Analysis of Currently Existing Stream Gage Records. Flood frequency analyses were updated for three gaging stations on the Passaic River:

- the Millington gage (drainage area 55.4 square miles);
- the Chatham gage (drainage area 100 square miles); and
- the Little Falls gage (drainage area 762 square miles).

The Corps developed frequency curves during the Passaic River Flood Damage Reduction Project in 1995 for the Chatham and Little Falls gages. This analysis used data through 1994. The Millington gage was not evaluated in 1995. Frequency curves were updated to the 2000 water year for Chatham and Little Falls. By extending the record to year 2000, two significant flood events were included in the record that caused substantial damage – October 1996 and September 1999. Frequency curves were developed using data through the 2000 water year for the Millington gage. Annual peak data prior to 1965 was adjusted for urbanization using the same approach employed in the 1995 Passaic River Flood Damage Reduction analysis.

Development and Calibration of Existing Conditions Hydrologic Model. The 1995 Passaic River Flood Damage Reduction Project model above Chatham was used as the basis for the existing conditions hydrologic model. The HEC-HMS model was modified to reflect changes in the study area since 1995. The model uses the year 2000 as the base year. Boundaries for the 14 subbasins used in the model were referenced to sub areas obtained from the New Jersey Department of Environmental Protection (NJDEP). Current land use in the watershed was developed from NJDEP 1995 aerial photography, from community master plans, and from previous Corps studies. The existing conditions model was divided into two areas for calibration. An upper watershed model was developed for calibration against observed stream flow at the Millington gage, and a lower watershed model was developed for calibration against observed stream flow at the Chatham gage.

Development and Calibration of Existing Conditions Hydraulic Model. A HEC-RAS model was developed for the Upper Passaic River along the study reach to develop standard project water surface elevations for the 2-, 5-, 10-, 25-, 50-, 100-, 250-, and 500-year frequency storm events. Cross-section geometry for the flood plains and the main channel was surveyed in the summer of 2000 and incorporated into the model. Geometric data and hydraulic parameters for all bridge and culvert crossings was also surveyed in 2000 and incorporated into the model. The existing conditions HEC-RAS model was calibrated to high water marks in Stirling (Long Hill Township) from Tropical Storm Floyd.

Uncertainty analysis of hydraulic data. Risk-based analyses for flood control projects require the quantification of the uncertainty in discharge-frequency, stage-discharge, and stage-damage functions. Uncertainty was characterized for 3 reference points (Millington, Chatham, and Little Falls) regarding discharge (Bulletin #17B). The uncertainty in stage was assessed using the standard deviation of the estimate of roughness in terms of Manning's "n" in Manning Equation (EM1110-2-1619). Risk-based analyses followed the procedures outlined in EM1110-2-1619, Risk-based Analysis for Flood Damage Reduction Studies.

After calibration was complete, the hydraulic model was used to develop the water surface profiles for 50 HEC-RAS river stations for all design storm events, using discharge values determined by the HEC-HMS model. Water surface profiles for the eight modeled design storm events are provided in Table 3-1 below. Cross sections are shown for stations in the immediate vicinity of the damage centers, and can be seen in Figure 3-1 (shown previously).

***Table 3-1***
***Water Surface Profiles for Eight Modeled Storm Events***

| Cross Section | Water Surface Elevation (NGVD) 2-Yr | 5-Yr | 10-Yr | 25-Yr | 50-Yr | 100-Yr | 250-Yr | 500-Yr |
|---|---|---|---|---|---|---|---|---|
| 48 | 210.4 | 212.2 | 213.4 | 214.5 | 215.2 | 216.2 | 216.9 | 217.6 |
| 49 | 210.5 | 212.2 | 213.5 | 214.6 | 215.3 | 216.2 | 216.9 | 217.6 |
| 50 | 210.6 | 212.3 | 213.5 | 214.6 | 215.3 | 216.3 | 217.0 | 217.6 |
| 50a | 210.6 | 212.3 | 213.5 | 214.6 | 215.3 | 216.3 | 217.0 | 217.6 |
| 51 | 210.7 | 212.4 | 213.5 | 214.6 | 215.3 | 216.3 | 217.0 | 217.6 |
| 52 | 210.7 | 212.4 | 213.5 | 214.6 | 215.3 | 216.3 | 217.0 | 217.6 |
| 52a | 210.7 | 212.4 | 213.6 | 214.6 | 215.3 | 216.3 | 217.0 | 217.6 |
| 53 | 210.7 | 212.4 | 213.6 | 214.7 | 215.3 | 216.3 | 217.0 | 217.6 |

<u>Development of Existing Conditions HEC-IFH Models</u>. Several small tributaries drain through the study area and flow into the Passaic River. The upstream drainage boundaries of these tributaries are Long Hill Ridge. These tributaries do not have large drainage areas (1 to 2 square miles). Rainfall on Long Hill runs off quickly, discharging into low-lying areas at the base of Long Hill to the east and west of the central Stirling business district. The timing of interior drainage with flooding on the Passaic River is an important factor. Local officials report that coincident flooding is likely. However, given the large drainage area and long time of concentration of the Passaic River (84 square miles) compared to the relatively small drainage area and short time of concentration of the tributaries (1 to 2 square miles), coincident flooding appears unlikely, or at least would have a very low probability of occurrence. In addition, runoff from the upper Passaic River basin will be attenuated by the large storage volume in the Great Swamp. This will further delay and attenuate the peak discharge on the Passaic River. HEC-IFH models were developed for various initial storages in Sterling and various tailwater elevations on the Passaic River. Model results show that the Passaic River controls flooding within the interior area.

Detailed information on water surface elevations are presented in the Hydrology and Hydraulics Appendix (Appendix A). This appendix also includes detailed discussions of statistical procedures used to determine the uncertainty in water surface elevations associated with specific exceedance probabilities storm events.

For future watershed conditions (projected to year 2050), estimates of future land use for the planning period 2050 were obtained from the Corps 1995 Feasibility Report of the (lower) Passaic River Flood Control Project and were adjusted based on current information. The future conditions 100-year discharges will increase approximately 3% resulting in only 0.1 to 0.2 foot (average 0.15 foot) increase in flood elevations throughout the study reach.

## 3.4 Flood Damage Analyses

Flood damages under future with- and without-project conditions were estimated through: (1) an inventory of flood plain development, (2) estimation of depreciated structure replacement costs and content damages, (3) preparation of generalized stage-damage functions, and (4) combination stage/frequency relationships and stage/damage relationships into frequency/damage relationships. The process and results of damage estimation for the Passaic River at Long Hill Township are described in detail in the Economics Appendix (Appendix E), and are summarized below.

Flood Damage Surveys. A structure inventory was compiled by conducting field surveys of structures in the 500-year flood plain during February and March of 2002. There are approximately 175 total structures within the 500-year flood plain, including 2 municipal and 41 non-residential structures. Each structure was assigned a unique structure identification number. First floor and low opening elevations (measured off of known benchmarks using a transit) and street addresses were recorded for all structures. Structure information required to compute depreciated replacement values was collected for residential structures based on Means Real Estate Valuation Guide. Data collected included the following categories: structure type, style, construction material, quality, condition, effective age, finished floor area, and other exterior characteristics. Content values were estimated at 50 percent of the structure value. Interviews were held (spring 2002) with owners/operators of non-residential flood plain properties, including municipal and major industrial facilities. Actual damage information from the 1996 flood was obtained from the township and was used to calibrate depth-damage functions. Public emergency costs were calculated as a percentage of total damages based on local damage reports provided by the Long Hill Township Police Department (which also serves as the Township's Emergency Operations Center).

Depth-Damage Relationships. Depth-damage functions from Economic Guidance Memorandum 01-03 - Generic Depth-Damage Relationships (augmented with FEMA structure type specific basement depth-damage curves) were applied to the inventory of flood plain properties in order to develop depth-damage relationships. Current HEC-RAS output (discharge-frequency-water surface elevations) was combined with the depth-damage data in order to calculate average annual damages under existing conditions.

Structure and Content Damages. Given the relatively low number of structures in this analysis, a risk-based spreadsheet model (MS Excel running statistical modeling software) was used to estimate flood damages to non-residential and residential structures and contents. Structure specific information (identification number, structure type, value, first floor elevation, zero damage level, and reach designation) was included in a structure inventory database for input to the model. Residential structures were classified as one of five types: one-story with a basement, one-story without a basement, split-level, two-story with a basement, and two-story without a basement. The model used depth-percent damage curves corresponding to the structure type to relate flood depth to percent damage for residential and selected non-residential structures and their contents. Each structure was referenced to two cross sections which were used to determine the water surface elevations for the storm frequency events of 2-, 5-, 10-, 25-, 50-, 100-, 250- and 500-year return intervals.

Transportation Delay Costs. Traffic delays on Valley and Morristown Roads are common following floods in excess of the 10 percent chance exceedance event, which require partial or full roadway closures. Closure of Valley Road results in the diversion of east- and west-bound traffic along a route north to Long Hill Road. This additional distance is approximately 4.0 miles, and will add about 10 minutes to the motorists' travel time (25 miles per hour plus an allowance for congestion). Traffic delay damages for each impacted motorist are calculated as the sum of the opportunity cost of the additional time spent driving due to speed reductions or detours. Traffic count data published by Morris County in April of 2002 indicated that an average of 20,364 vehicles travel Valley Road on a daily basis.

Opportunity cost of time estimates are based upon the duration of the delay and the estimated annual wage of the motorist. The hourly wage ($41.57) was calculated from the Bureau of the Census 1999 estimate of median family income for Morris County[1] ($77,340) and adjusted to 2003 dollars using the Bureau of Labor Statistics Inflation Calculator. IWR Report 91-R-12 "Value of Time Saved for Use in Corps Planning Studies" indicates that the hourly opportunity cost for automobile trips delayed less than five minutes should be valued at 6.4% of the motorist's hourly wage. For delays greater than five minutes but less than 15 minutes the opportunity cost is valued at 32.2% of the motorist's hourly wage. Conducting the calculations indicates that the opportunity cost of time partial closure is $13.39 per person per hour delayed ($41.57 * 0.322 = $13.39) for all flood events that close Valley Road. The U.S. Bureau of Transportation Statistics estimates that there are 1.6 persons per vehicle on average. Using this occupancy estimate, the opportunity cost of time for a closure of valley road is $21.42 per vehicle per hour detoured around Valley Road during flood events.

<u>Risk and Uncertainty.</u> Planning guidance requires that risk and uncertainty be incorporated into flood damage reduction studies. Statistical modeling software and Microsoft Excel were used to incorporate uncertainty from damage input variables into the analysis. The evaluation process uses Monte Carlo Simulation to compute the expected value of damages while incorporating the variability associated with each input variable.

Variability in depth-damage curves were incorporated into the model by using standard deviations for specific damage percents taken directly from depth-damage functions provided in Economic Guidance Memorandum 01-03. Water surface elevations were allowed to vary based on the standard deviations for specific return events taken directly from the hydrologic and hydraulic analyses conducted as part of this feasibility study. Additional variability in first floor survey error (5 percent), and depreciated replacement values (estimated as a percent of the range shown in Means Cost Estimating Guides) were captured in the damage model.

### 3.4.1 Existing Conditions Damages

Damages begin for residential structures at the 20 percent chance exceedence (5-year reoccurrence interval) flood event, impacting twenty residential structures and five nonresidential structures with total estimated damages at cost of approximately $480 thousand. As shown in Tables 3-2 and 3-3, the 100-year event affects 132 structures and results in approximately $7.9 million in damages (of which, 3.4 million are damages to residential structures). Average annual damages to property through the 500-year event amount to over $700,000.

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[1] Median family income for Long Hill Township was not used because much of the traffic on Valley Road is assumed to be motorists transiting through the township with an alternate destination point.

***Table 3-2***
***Damages to Residential Structures and Contents***
***Without Project Conditions***

| | Reach 1 | | Reach 2 | |
|---|---|---|---|---|
| **Recurrence Interval** | **Structures Damaged** | **Damages ($1,000)** | **Structures Damaged** | **Damages ($1,000)** |
| 2-year | 0 | 0 | 0 | 0 |
| 5-year | 6 | 83 | 14 | 148 |
| 10-year | 12 | 234 | 29 | 550 |
| 25-year | 18 | 444 | 38 | 1,244 |
| 50-year | 18 | 591 | 50 | 1,734 |
| 100-year | 20 | 833 | 72 | 2,579 |
| 250-year | 20 | 1,011 | 78 | 3,326 |
| 500-year | 20 | 1,231 | 94 | 3,955 |

***Table 3-3***
***Damages to Non-Residential Property***
***Without Project Conditions***

| | Reach 1 | | Reach 2 | |
|---|---|---|---|---|
| **Recurrence Interval** | **Structures Damaged** | **Damages ($1,000)** | **Structures Damaged** | **Damages ($1,000)** |
| 2-year | 0 | 0 | 0 | 0 |
| 5-year | 0 | 0 | 5 | 249 |
| 10-year | 10 | 154 | 18 | 736 |
| 25-year | 10 | 366 | 21 | 1,656 |
| 50-year | 12 | 524 | 23 | 2,391 |
| 100-year | 14 | 802 | 26 | 3,670 |
| 250-year | 16 | 1,008 | 30 | 4,748 |
| 500-year | 18 | 1,229 | 34 | 5,575 |

Table 3-4 provides information on traffic delay costs that result from the closure of Valley Road during times of flooding. As shown in the table, road closures begin between the 5- and 10-year events. Closure times were obtained from data provided in the Hydrology and Hydraulics Appendix, and range from 25 hours for a 10-year event to 130 hours for a 500-year event. While the detour around the flooded areas of Valley Road is brief (expected to take less than ten minutes), the road's typical traffic volume yields total delay costs that range from $72,700 to $378,000. Average annual traffic delay costs for the intervals shown on the table amount to $51,650 through the 500-year event, and $48,200 through the 100-year event.

***Table 3-4***
***Traffic Delay Costs***

| Return Frequency | Closure Duration | Additional Travel Time | Vehicles Delayed | Delay Time Cost ($) |
|---|---|---|---|---|
| **2** | None | None | 0 | 0 |
| **5** | None | None | 0 | 0 |
| **10** | 25 hrs | 9.6 min | 21,213 | 72,700 |
| **25** | 70 hrs | 9.6 min | 59,395 | 203,500 |
| **50** | 90 hrs | 9.6 min | 76,365 | 261,700 |
| **100** | 110 hrs | 9.6 min | 93,335 | 319,900 |
| **250** | 120 hrs | 9.6 min | 101,820 | 348,900 |
| **500** | 130 hrs | 9.6 min | 110,305 | 378,000 |

## 3.5 Screening of Structural Flood Damage Reduction Measures

Based on the physical layout of the study area, the flood hydrology, and the profiles of structures at risk, the following structural flood damage reduction measures were considered for application to flooding problems in the study area: (1) closure structures on tributaries; (2) floodwalls and levees, (3) stream modifications, and (4) detention basins. These structural measures and the results of the initial screening are described below.

The screening of flood damage reduction measures includes an assessment of the potential engineering, economic, environmental, institutional, public, financial, and institutional feasibility of implementing each measure. Those measures that are not entirely screened out are carried forward for more detailed analysis as alternative plan components.

### 3.5.1 Closure Structures on Tributaries

Backwater flow from the Passaic River is the primary source of flooding in Long Hill Township. Closure structures for culverts on tributaries along Valley Road and Morristown Road would provide flood protection up to the existing roadway elevations. The lowest elevation, which would provide protection is the roadway elevation of +213.7 NGVD, located at the intersection of South Main and Valley Road.

Tributary closure structures would be required at the following locations:

- Valley Road east of Passaic Avenue,
- Valley Road between Poplar and Warren Roads, and
- Valley Road Between Morristown Road and Western Boulevard.

Locations of the tributary closure structures are shown on Figure 3-7. Each of the culverts would be enhanced with sluice gate-like closures. Under normal flow conditions and for small storm events, the gates would remain open. During flood events, the gates would be closed by emergency management personnel. The implementation of a flood warning system for the township would provide the required information for operation of the closure system. The closure structures would protect Long Hill Township residential and nonresidential property up gradient of Valley and Morristown Roads through a 10-year event, which is the approximate elevation of the road surfaces.

This measure would provide protection up to +213.7 NGVD (approximately the 10 percent chance exceedance event) to residential and non-residential structures and their contents located in damage reaches north of Valley Road. Properties located south of Valley Road would continue to be inundated, Valley Road will continue to be flooded, and blocked during lower frequency events.

Minor, yet temporary impacts to wetlands will occur as a result of constructing the tributary closures. The construction of the closure structures will require the temporary disturbance of approximately 0.68 acres (30,000 sq. ft.) of previously disturbed riparian wetlands (e.g., wetlands currently maintained as lawns). Construction of the closure structures would result in earth moving and excavation in the construction work area. However, no long-term impacts to wetlands are anticipated. All temporarily disturbed areas will be restored to their pre-construction condition upon the completion of construction. Furthermore, construction of the tributary closures would allow a controlled volume of water to migrate to upstream wetlands.

Additionally, best management practices for erosion and sediment control would be implemented to mitigate the potential for soil erosion during land clearing and foundation excavation. Impacts would be avoided or minimized to the greatest extent possible and all activities would be performed in accordance with the NJDEP Freshwater Wetlands Protection Act (N.J.A.C. 7:7A) rules and regulations.

While closure structures on tributaries provide a relatively low level of protection, this measure is, however, carried forward as a potential component of alternative plans.

### 3.5.2 Floodwater Barriers

Floodwater barriers, (e.g., floodwalls and levees) confine flood flows to the existing channel footprint, prevent breakout of floodwaters, and provide protection against flooding to homes, commercial buildings, municipal buildings, roadways and tributary bridges. While floodwalls and levees provide a cost-effective means to prevent flooding of low-lying areas, interior drainage facilities are often required to handle stormwater ponding behind them. Three vastly different floodwater barrier configurations were evaluated as potential flood damage reduction measures: a levee along the Passaic River; a setback levee/floodwall located south of Valley Road, and raising Valley Road itself.

**Levee Along the Passaic River.** Creation of an earthen levee and concrete floodwall along the Passaic River was evaluated as a measure to protect the entire study area from recurring flood damages. The levee would be located along the Passaic River (shown in Figure 3-8) with its eastern terminus tied into high ground at elevation +216 NGVD between Plainfield Road and Poplar Drive (between surveyor's cross sections 42 and 43). The western terminus would be located behind the Loudenberry Meadow Senior Condominium, also tied to high ground at elevation +216 NGVD.

Three closure structures would be incorporated into the levee to prevent backwater flooding. To provide flood damage reduction up to the 1 percent chance exceedance event, approximately 7,600 linear feet of levee at an average height of 7.5 feet would be required, resulting in an average width 57 feet, and a footprint of 9.94 acres, the majority of which is assumed to be located on State jurisdictional wetlands.

While a more efficient levee/floodwall alignment may be achieved through a close examination of benefits, real estate, footprint, and environmental mitigation requirements, the full-scale levee was carried forward as a component in alternative plans.

**Setback Floodwall/Levee South of Valley Road.** This measure consists of a 3,650 linear foot combination floodwall and levee located south of Valley Road. The floodwall and levee system would protect residential and commercial structures, local roadways (including Valley Road), and other public infrastructure from flood events up to the 1 percent chance exceedance event. The eastern terminus of the alignment was tied into existing high ground located west of Poplar Drive and at the western terminus of the alignment was tied into existing high ground west of Passaic Avenue (Shown in Figure 3-9).

The alignment was adjusted to minimize impacts to residential areas, community infrastructure, and roadways crossed by the floodwall/levee. The alignment bisects the Warren Road access road to the wastewater treatment plant and a gravel road extension of Main Avenue. At these locations, the alignment will be tied into road surfaces raised as part of the measure.

The top of the floodwall and levee would be constructed to elevation +216 NGVD, and protrude three to four feet from the existing terrain. Levee sections were designed using the standard Corps levee design with 3:1 horizontal: vertical slopes as the primary levee design. Vertical floodwalls were incorporated in areas where it was important to minimize the impact footprint and maintenance costs. Installation of the levee and floodwall was assumed to require a 20-foot wide construction right-of-way corridor to facilitate vehicle and equipment access.

Two closure structures would be required to restrict Passaic River backwater flow through small tributaries that are crossed by the alignment. At each tributary location, the floodwall would extend to within several feet of the top of bank of one side of the tributary and will continue at a location within several feet of the top of bank on the opposite side of the tributary. Alterations to

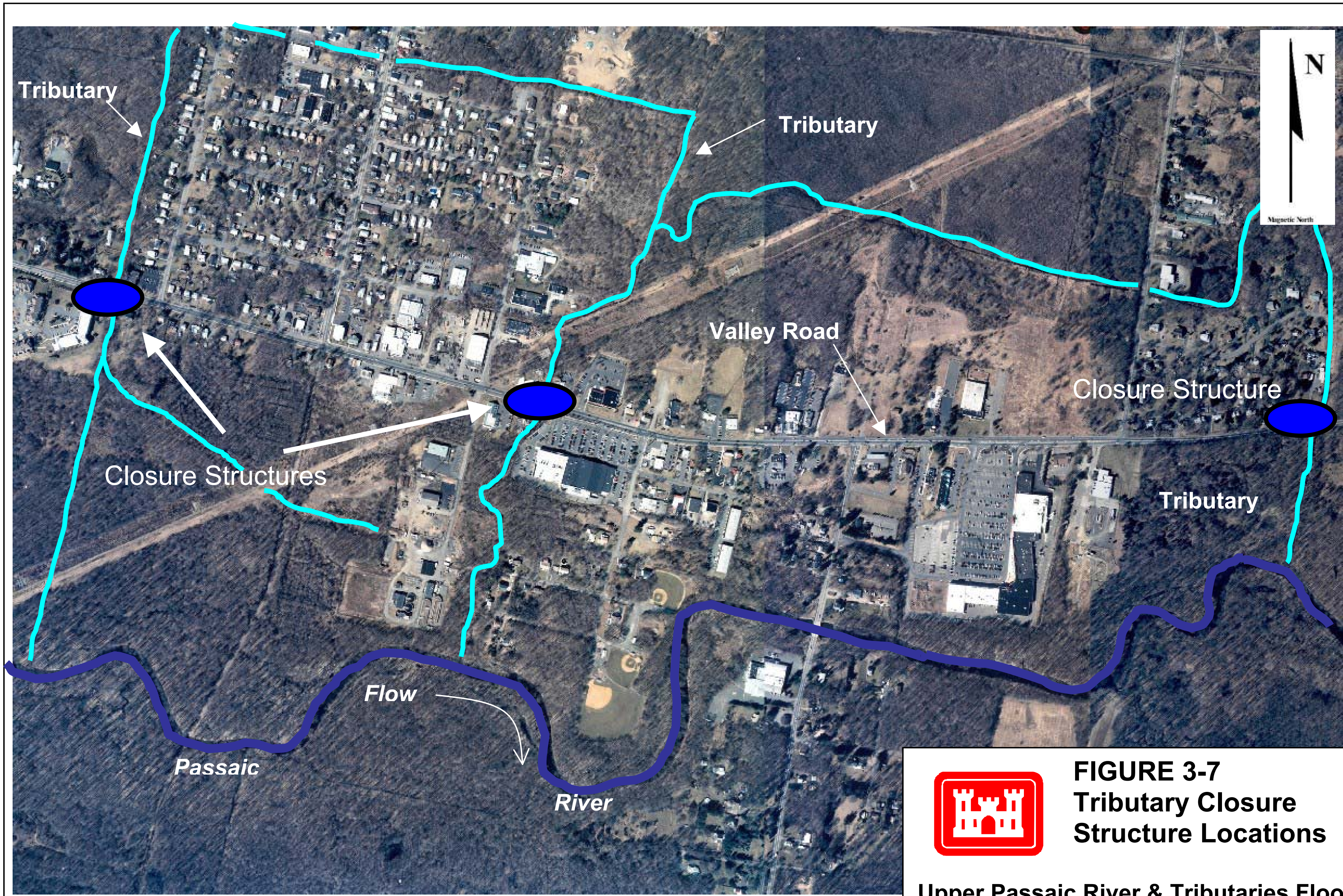



**FIGURE 3-7**
**Tributary Closure Structure Locations**

**Upper Passaic River & Tributaries Flood Damage Reduction & Environmental Restoration Feasibility Study** (not to scale)

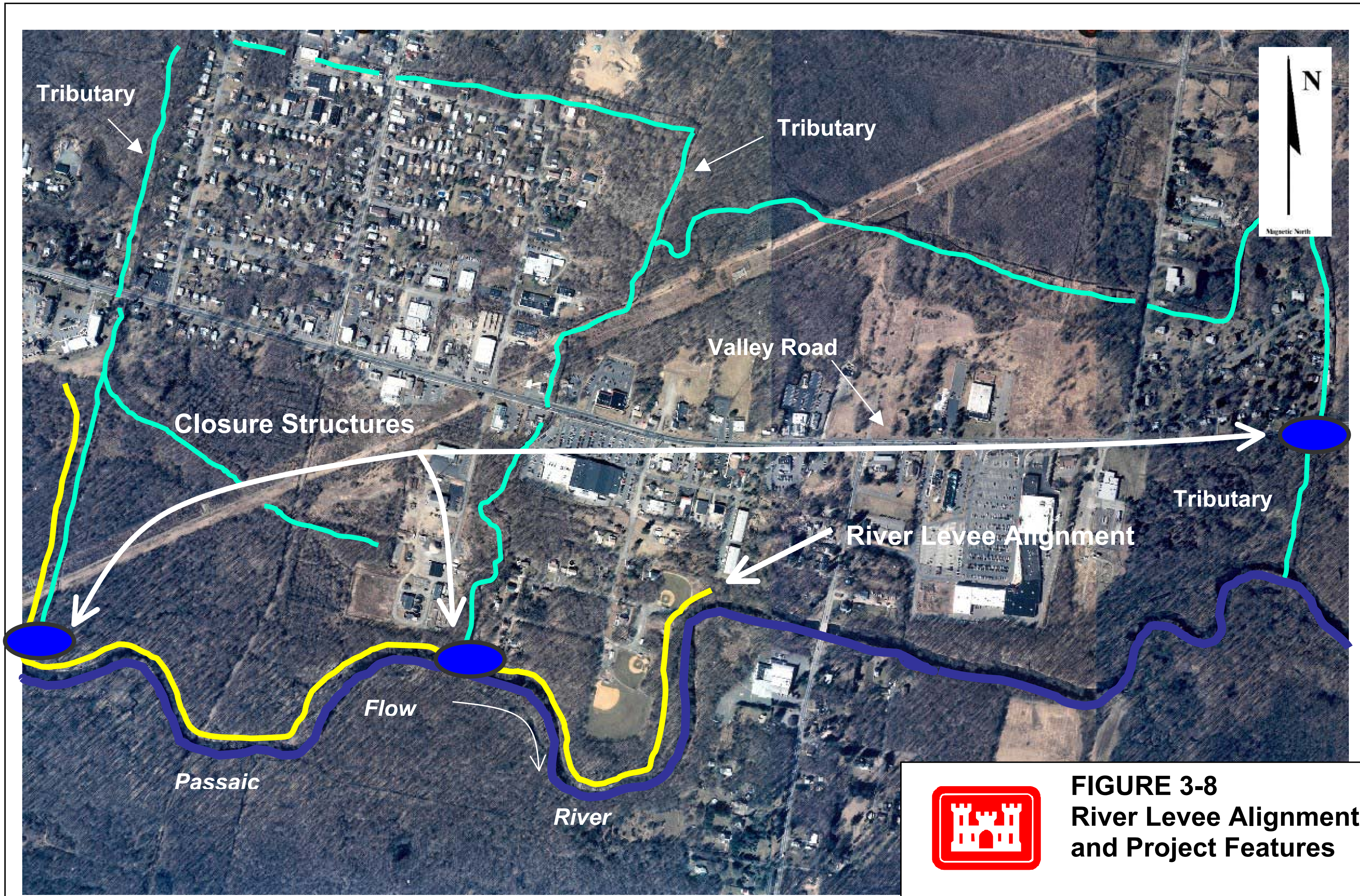
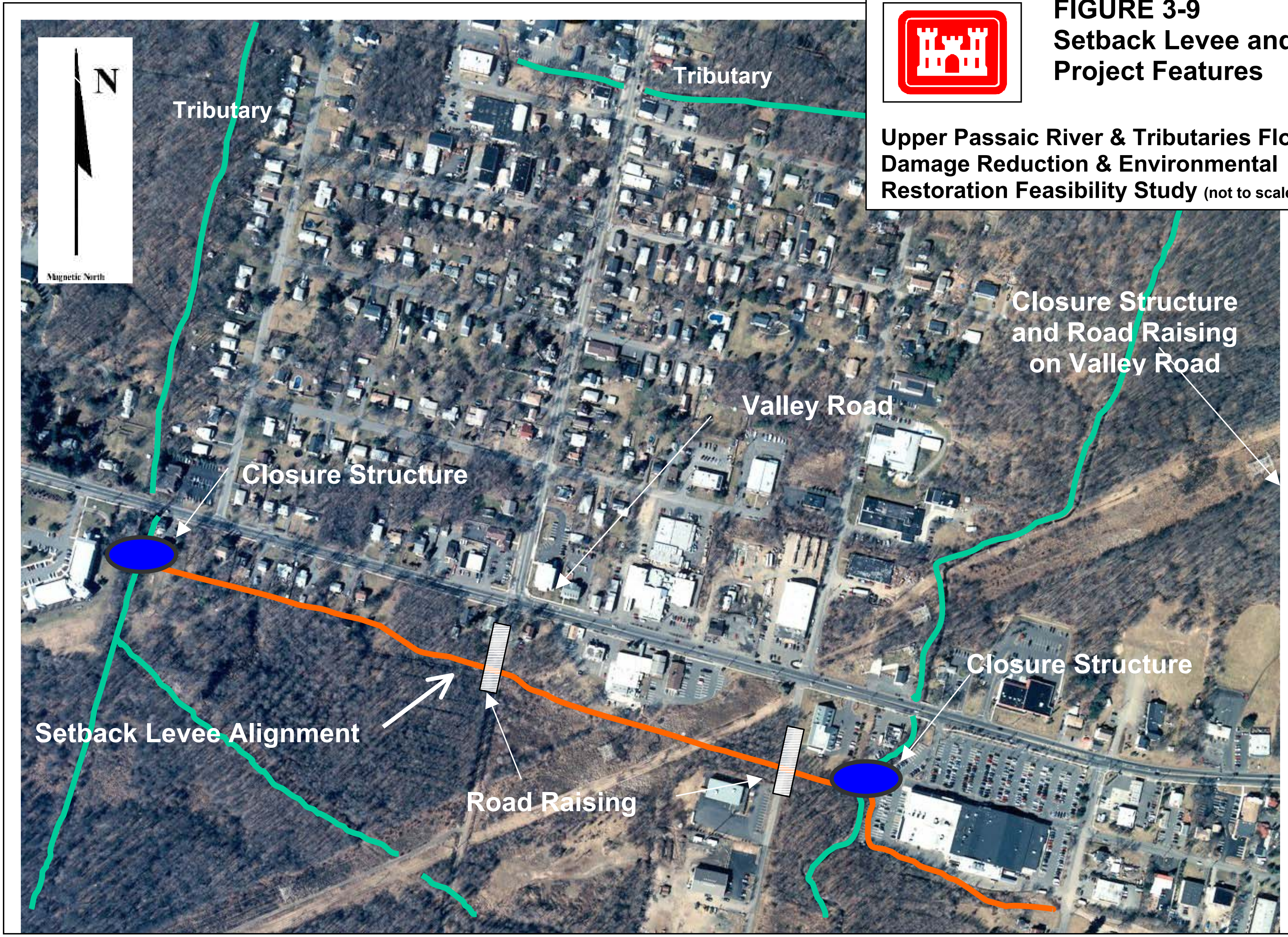



**FIGURE 3-8**
**River Levee Alignment and Project Features**

**Upper Passaic River & Tributaries Flood Damage Reduction & Environmental Restoration Feasibility Study** (not to scale)

## FIGURE 3-9
## Setback Levee and Project Features

**Upper Passaic River & Tributaries Flood Damage Reduction & Environmental Restoration Feasibility Study** (not to scale)



the stream channel will be required to construct a vertically hinged gate that will be closed during a flooding event. A section of stream channel upstream and downstream of the floodwall will require concrete lining with vertical sides at the gate location and trapezoidal sides as the stream discharge is diverted from the natural channel towards the floodwall/gate location.

It was assumed that pump facilities would not be required at each tributary crossing location to deliver the natural discharge of the tributary to the "wet" side of the floodwall. Passive drainage will be required along the entire length of the floodwall and can be achieved by the installation of gated weep holes in low lying areas to allow for minor surface drainage. The weep holes will be sized according to the expected low flow discharge associated with high frequency precipitation events that would not normally cause backwater flooding. The weep hole gates would then be closed during flood events. The weep hole gates also will allow flood waters from high frequency events to flow to wetlands in the area protected by the levee and floodwall to minimize environmental impacts of the flood damage reduction measure. It was estimated that this flood damage reduction measure would result in approximately 1.17 acres of State jurisdictional wetland impacts.

The setback levee/floodwall appears to be an efficient flood damage reduction measure. It was designed to have a minimum impact on wetlands, provides protection from the 1 percent chance exceedance event for the majority of damageable property, and requires less than two acres of land for implementation. This measure was carried forward as a potential component in flood damage reduction alternative plans.

**Raise Valley Road.** Valley Road would be raised between its intersection with Poplar Drive and to a point approximately 300 feet west of Passaic Avenue to provide a barrier to flood waters at the 100-year flood level. The road would be raised between 3 and 4 feet above its current elevation and require a significant amount of grading to achieve stable side slopes. The exiting two-lane road would be raised a vertical distance of approximately three feet in order to provide 100-year level of protection. Roadway work for this project would include the raising of 2,200 linear feet of asphalt road at a standard two-lane width of 32 feet. Construction of this project would begin with the demolition of the existing roadway and the backfill and subgrade preparation in order to attain a new roadway centerline that is three feet higher in elevation than the existing roadway. Borrow material for the structural backfill subgrade would be brought to the site, installed and compacted in preparation to receive the subbase and base course layers. The subgrade thickness will depend on road design parameters such as prevailing soil conditions, climate, vehicle design loadings and type of bituminous pavement to be used.

Construction of the roadway shoulder includes removal of topsoil from the existing grade and the installation of subgrade material to provide a 20-foot inclined slope from the proposed edge of pavement to the existing grade (each side of roadway).

Each roadway entrance and crossing would be assumed to extend 100 feet from the edge of pavement of the proposed surface course to a location that will tie into the existing grade. Construction would include removal of existing entrance paving, stockpiling subbase materials, installation of subgrade structural backfill, and final grading for a 3.5-inch thick asphalt pavement overtop 9 inches of base course materials.

Three closure structures constructed as part of the measure would restrict Passaic River backwater flow along the road raising alignment. Like the setback levee/floodwall, stream channel modifications also would be required for construction of the closures. Portions of the stream channels upstream and downstream of the closure structure would be concrete lined with vertical sides at the gate location and trapezoidal sides. Pump stations were not assumed to be required to deliver the natural discharge of the tributary to the “wet” side of the road raising. It was estimated that this flood damage reduction measure would result in approximately 0.25 acres of permanent wetland impacts from the grading of new side slopes, and 0.65 acres of temporary impacts from installing the three floodgates.

While implementation of this measure would disrupt local traffic patters by closing this section of Valley Road for a period of 6-12 months during construction, it was carried forward as a potential component in alternative flood damage reduction plans.

### 3.5.3 Stream Modifications

Stream modifications are used to protect communities against riverine flooding and stream blockages. Stream modifications can include dredging, channel deepening and widening, as well as modification of bridge and culvert openings. Decreases in water surface elevations and flood damages throughout Long Hill Township would be achieved through a reduction in channel blockages resulting from high sediment loads and bank material transported during flood events. Because minor snagging and clearing would not have a measurable impact on flood stages because even moderate decreases in water surface elevations, implementation of this measure would require significant channel deepening and widening for perhaps <u>dozens</u> of miles downstream of Long Hill Township. In addition, because of extremely flat channel slopes in this area, the channel would require significant widening and deepening to increase conveyance. It is likely that implementation of stream modifications would result in widespread destruction of wetlands and impacts to jurisdictional waters. Environmental mitigation costs would be extremely high, and operations and maintenance costs associated with the extensive stream modifications would be significant.

While stream modifications can be an effective means to reduce flood damages in some cases, it was determined that stream modifications would be neither effective nor economically justified given the relatively small study area and the comparatively immense drainage area of the Passaic River. For these reasons, stream modifications were dropped from further consideration as a flood damage reduction measure.

### 3.5.4 Detention Basins

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. This alternative was considered as a means to create flood storage areas in the flood plain by enclosing a large area with a dike. During floods, the floodwaters would overflow into the storage area. Stored floodwaters would then be released slowly through a downstream outlet. Preliminary investigations based on flood flows determined that placing flood control storage areas in the flood plain would require an extensive amount of land to achieve any measurable water surface elevation reductions. The only large undeveloped area is within the Great Swamp National Wildlife Refuge and cannot be developed as a reservoir because of adverse impacts to the hydrology and flora and fauna of the Wildlife Refuge that would result from detaining additional floodwaters. In addition, there are several buildings along the perimeter of the Wildlife Refuge that would be impacted by increased flood levels in the swamp. Environmental impacts of this option would be substantial. Potential downstream negative effects could include changes in the quality of water flowing out of the reservoir behind a dam and changes in downstream water temperatures. Downstream wetland and riparian areas that are dependent on overbank flows for recharge would probably experience reductions in size. Finally, given the level of existing conditions damages (see Section 3.4 above), economic justification was determined to be highly unlikely for alternatives that rely on detention basins. For these reasons, detention basins were dropped from further consideration.

## 3.6 Screening of Nonstructural Flood Damage Reduction Measures

Nonstructural measures were fully considered in plan formulation. However, full-scale nonstructural measures were screened out early in plan formulation due to the number, age, condition, and location of flood-prone structures in the study area as identified through the inventory of flood-prone structures.. Some nonstructural measures were identified as potentially applicable to flood damage reduction in the study area, including: (1) acquisition of flood-prone property, (2) flood plain zoning, (3) floodproofing, and (4) flood warning systems. Analysis of the nonstructural measures to reduce flood damage reduction eliminated most of these measures as potential stand-alone alternatives. However, some measures were carried forward as potential complements to structural measures. The screening of nonstructural measures is summarized below.

### 3.6.1 Acquisition of Flood-Prone Properties

Permanent evacuation of the flood plain involves acquisition of land and structures by fee purchase or by exercising powers of eminent domain. Following acquisition, all structures and improvements are demolished or relocated. With about 125 structures in the 100-year flood plain, the depreciated replacement cost of structures (approximately $21.6 million) and relocation costs make wholesale acquisition prohibitively expensive.

### 3.6.2 Flood Plain Zoning

Through proper land use regulation, flood plains can be managed to ensure that their use is compatible with the severity of a flood hazard. Several means of regulation are available, including zoning ordinances, subdivision regulations, and building and housing codes. Their purpose is to reduce losses by controlling the future use of flood plain lands. As stated above, Long Hill Township already participates in the National Flood Insurance Program and manages flood plain land uses consistent with the program. Most of the buildings in the study area flood plain were built prior to the adoption of zoning and are not subject to current flood plain zoning regulations. Therefore, zoning can not be considered independently of as a long-term mitigation solution for flood damage reduction to existing structures. However, it is a necessary component of a comprehensive flood damage reduction plan.

### 3.6.3 Floodproofing

Floodproofing reduces flood damages through adjustments to structures and location of building contents. Floodproofing techniques involve keeping water out of the structure, as well as reducing the effects of inundation. Nonstructural adjustments, such as the elevation of structures, can be applied by an individual or as part of a collective action either when flood-prone buildings are under construction or through retrofitting of an existing structure. Floodproofing alone was found to be prohibitively expensive, since a majority of structures would require costly raising. While eliminated as a major element in the formulation of alternative plans, limited floodproofing was retained as a flood damage reduction measure as a part of other comprehensive alternative plans.

### 3.6.4 Flood Warning Systems

Flood warning systems can be utilized to warn property owners of pending floods and provide time for safe evacuation and relocation of movable property subject to flood damage.

The local Flood Warning System for Long Hill Township would be an expansion of the current Passaic River Flood Warning System which provides flood estimates at Millington (upstream of the study area) and Chatham (downstream of the study area). The existing conditions no-project hydrologic and hydraulic models were run for a range of storm durations and intensities to permit the estimation of lead times and threshold precipitation levels that would trigger alarms in a Flood Warning System (FWS). With this information, rainfall thresholds were established for 1-, 3-, 6-, 12-, 24-, and 48-hour storms for four levels of alert:

- Level 0- No Flooding;
- Level 1- Possible Flooding;
- Level 2- Probable Flooding; and
- Level 3- Imminent Flooding.

System requirements include a PC base station at the Long Hill Township Police Station, an additional stream gage at the Plainfield Road bridge, radio or telephone links to receive the rainfall and stream gage data that are currently in the Passaic River Flood Warning System, and Diad Storm Watch software to store and analyze rainfall data and initiate actions such as paging the Mayor, Police Chief, and Director of Emergency Management in Long Hill Township. A Concept of Operations description is included in the H&H Appendix includes a description of the proposed FWS, Institutional Roles and responsibilities, system network description, equipment needs, and installation and operating costs. Rainfall thresholds based on the HEC-HMS are also included in the Hydrology and Hydraulics Appendix as well as a description of how the FWS is to be used.

Although a state-of-the-art flood warning system would increase the awareness of the citizenry and allow for a more orderly evacuation of residents, a warning system alone would not provide sufficient time to significantly reduce flood damages. This flood damage reduction measure, while important as a project feature, was eliminated from consideration as a stand-alone alternative.

## 3.7 Alternative Flood Damage Reduction Plans

As the next step in the plan formulation process, flood damage reduction measures which survived the initial screening were developed in greater detail. The initial screening of flood damage reduction measures resulted in the following structural and nonstructural measures being carried forward for more detailed investigations:

- tributary closure structures;
- levee along the Passaic River;
- setback levee/floodwall south of Valley Road;
- raise Valley Road;
- acquisition of flood-prone properties,
- floodproofing, and
- flood warning system.

Alternative plans were developed incorporating one or more of these flood damage reduction measures to create various flood damage reduction alternative plans. Components of the alternative plans are described below and shown in Table 3-5.

**Alternative 1:** No Action.

**Alternative 2:** Install closure structures on Passaic River tributaries, implement limited nonstructural armoring and structure raisings, and install flood warning system.

**Alternative 3:** Construct a levee along the Passaic River with tributary closure gates, install a tributary closure structure outside of the levee/floodwall line of protection, implement limited nonstructural armoring and structure raisings, and install flood warning system.

**Alternative 4:** Construct a setback levee/floodwall south of Valley road, install tributary closure gates along the levee/floodwall, install a tributary closure structure outside of the levee/floodwall line of protection, implement limited nonstructural armoring and structure raisings, and install flood warning system.

**Alternative 5:** Raise Valley Road, install closure structures on Passaic River tributaries, implement limited nonstructural armoring and structure raisings, and install flood warning system.

***Table 3-5***
***Features of Alternative Plans***

| | Alternative Plans | | | | |
|---|---|---|---|---|---|
| **Plan Features** | **1** | **2** | **3** | **4** | **5** |
| No Action | ✓ | | | | |
| Tributary Closure Structures | | ✓ | ✓ | ✓ | ✓ |
| Raise Valley Road to +216.2 NGVD | | | | | ✓ |
| Levee & Floodwall Along Passaic | | | ✓ | | |
| Setback Floodwall & Levee | | | | ✓ | ✓ |
| Structure armoring & raising | | | | ✓ | ✓ |
| Flood Warning System | | ✓ | ✓ | ✓ | ✓ |

## 3.8 Evaluation of Alternatives

The no action plan (Plan 1) and four alternative plans (Plans 2-5) are evaluated and compared in this section of the report. The comparison of alternatives focuses on the differences between each plan in terms of their beneficial and adverse impacts and contributions to the planning objectives.

### 3.8.1 Alternative Evaluation Economics

This section of the report presents the results of the economic and engineering studies that were conducted to quantify the benefits and costs of the alternatives developed to reduce flood damages along the Passaic River at Long Hill Township.

#### Flood Damage Reduction Benefits

Corps procedures calculate benefits based on the difference between the expected annual damages with and without alternative flood protection plans. The implicit assumption incorporated into this procedure is that the reduction in flood damages is directly translatable into increased net income to flood plain land uses. Benefits from Flood Damage Reduction measures on the Passaic River at Long Hill Township focused on inundation reduction benefits resulting from reduction of physical damages to structures and contents, emergency services cost savings, and traffic delay savings.

Without-project average annual flood damages and with-project average annual residual flood damages are shown in Table 3-6. Average annual damages under without-project conditions equal $780,500 (February 2003 price levels). Average annual residual damages range from $627,500 (Alternative 2) to $172,900 (Alternative 3). The reduction in average annual damages provided by the alternatives ranges from 20% (Alternative 2) to 78% (Alternative 3).

Average annual benefits of the alternatives, which are equal to the difference between residual damages under each alternative and damages under the without project condition are shown in Table 3-7.

**Table 3-6**
**Average Annual Damages of Alternatives 1 Through 5**
**($000)**

| Damage Category and Reach | Alt 1 Without-Project Condition | Alt 2 | Alt 3 | Alt 4 | Alt 5 |
|---|---|---|---|---|---|
| Reach 1 Residential | 94.1 | 94.1 | 16.9 | 47.9 | 94.1 |
| Reach 1 Non-residential | 63.6 | 63.6 | 20.7 | 20.7 | 63.6 |
| Reach 2 Residential | 223.5 | 206.9 | 48.6 | 48.6 | 48.6 |
| Reach 2 Non-residential | 325.7 | 244.1 | 78.1 | 78.1 | 78.1 |
| Traffic Delay Costs | 51.7 | 51.7 | 3.5 | 3.5 | 19.3 |
| Emergency Svcs Costs | 21.9 | 18.8 | 5.1 | 6.0 | 8.8 |
| Total Damages | 780.5 | 679.2 | 172.9 | 204.8 | 312.5 |
| Reach 1 percent Damage Reduction | N/A | 0% | 76% | 56% | 0% |
| Reach 2 percent Damage Reduction | N/A | 18% | 77% | 77% | 77% |
| Total Percent Damage Reduction | N/A | 13% | 78% | 74% | 60% |

**Table 3-7**
**Average Annual Benefits of Alternatives 1 Through 5**
**($000)**

| Damage Category and Reach | Alt 1 Without-Project Condition | Alt 2 | Alt 3 | Alt 4 | Alt 5 |
|---|---|---|---|---|---|
| Reach 1 Residential | 0.0 | 0.0 | 77.2 | 46.2 | 0.0 |
| Reach 1 Non-residential | 0.0 | 0.0 | 42.9 | 42.9 | 0.0 |
| Reach 1 NFIP Admin Savings | 0.0 | 0.0 | 2.7 | 1.3 | 0.0 |
| Reach 2 Residential | 0.0 | 16.6 | 174.9 | 174.9 | 174.9 |
| Reach 2 Non-residential | 0.0 | 81.6 | 247.6 | 247.6 | 247.6 |
| Reach 2 NFIP Admin Savings | 0.0 | 0.0 | 9.0 | 9.0 | 0.0 |
| Transportation Cost Savings | 0.0 | 0.0 | 48.2 | 48.2 | 32.4 |
| Emergency Services Savings | 0.0 | 3.1 | 16.8 | 15.9 | 13.1 |
| Total Benefits | 0.0 | 101.3 | 619.3 | 586.0 | 468.0 |

## Flood Damage Reduction Cost Estimates

Preliminary cost estimates used to screen alternative plans were prepared using February 2003 price levels. Cost estimates for flood damage reduction alternatives were based on calculated quantities and unit prices. Operations and maintenance (O&M) costs were estimated based on the anticipated conditions over a 50-year project life. Preliminary estimates of wetland mitigation costs and land acquisition for feature footprints costs were included. Estimated wetland mitigation costs included $100,000 per acre of wetlands directly impacted by plan features.

Preliminary costs of the alternative plans, which include construction costs, real estate acquisition, engineering and design, environmental mitigation, and interest during construction are shown in Table 3-8. Average annual costs were calculated based on the FY04 Federal discount rate of 5.625 percent and an analysis period of 50 years. Interest during construction was calculated assuming an 18 month construction period for all alternatives except Alternative 3, for which a 24 month construction period was assumed. Annualized costs of the alternatives range from $74,000 (Alternative 2 – Tributary Closure Structures Only) to nearly $1.5 million (Alternative 3 – Levee Along the Passaic River with Tributary Closure Structures). Alternatives 4 and 5 have similar annualized costs of $334,700 and $374,300, respectively.

***Table 3-8***
***Preliminary Costs of Alternative Plans***

| | **Alternative Plans** | | | |
|---|---|---|---|---|
| | **2** | **3** | **4** | **5** |
| Construction Cost, LERRD, PED | 940,700 | 22,330,500 | 5,019,600 | 5,651,900 |
| Interest During Construction | 39,690 | 982,700 | 211,800 | 238,400 |
| Annual O&M Costs | 15,000 | 65,000 | 20,000 | 20,000 |
| Annualized Cost | 74,000 | 1,467,300 | 334,700 | 374,300 |

A preliminary economic comparison of the costs, benefits, residual damages, benefit-to-cost ratios, and net benefits of the alternatives is shown in Table 3-9. Based on the results of the preliminary analysis, the Net Economic Development (NED) Plan is Alternative 4 (Setback Levee/Floodwall South of Valley Road), as this alternative provides the highest benefit-to-cost ratio and the highest net benefits. Alternatives 2 and 5 also are economically justified, with benefit-to-cost ratios of 1.37 and 1.25, respectively.

***Table 3-9***
***Preliminary Economics of Alternative Plans***

| | **Alternative Plans** | | | | |
|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** |
| Annualized Cost | 0 | $ 74,000 | $ 1,467,300 | $ 334,700 | $ 374,300 |
| Total Annual Benefits | 0 | $ 101,300 | $ 619,300 | $ 586,000 | $ 468,000 |
| Total Residual Damages | $ 780,500 | $ 679,200 | $ 172,900 | $ 204,800 | $ 312,500 |
| | | | | | |
| Benefit-to-Cost Ratio | 0.00 | 1.37 | 0.42 | 1.75 | 1.25 |
| Net Benefits | $0 | $ 27,300 | $(848,000) | $ 251,300 | $ 93,700 |

### 3.8.2 Environmental Mitigation Requirements of Alternatives

As this project is a cost-shared feasibility study under the Civil Works (CW) program, the actions of this project must be in compliance with all applicable Federal and State laws and regulations with regard to environmental compliance (ER 1105-2-100 (2-7)). Therefore, according to Federal and State regulations regarding mitigation and restoration of wetlands, the recommended plan chosen by this feasibility study includes all practical measures to avoid wetland impacts, and to minimize those impacts that are unavoidable. When impacts to jurisdictional wetlands are unavoidable, Federal and State guidelines and regulations require compensatory mitigation, on-site or along the same wetland or waterbody as the proposed impacts where feasible and practicable. Ample mitigation opportunities are present within the project corridor to satisfy both Federal and State requirements. Therefore, although off-site mitigation alternatives were investigated the recommended plan focused on mitigation opportunities located within the project corridor.

It is important to note that any State mitigation required in excess of the required Federal mitigation would be the State of New Jersey’s responsibility to locate, finance, implement and monitor. In the event that none of the on-site mitigation opportunities proves feasible due to potential difficulties with private, adjacent lands acquisition, as a last resort, mitigation could be accomplished through off-site mitigation banking.

For purposes of this report, Federal mitigation requirements were calculated by determining the anticipated functional loss using EPW (see below and Sections 2.3.3 and 6.15) an then by determining the amount of mitigation required to off-set those losses on a function for function basis.

#### Alternative 1

The No Action Plan (without project condition) does not result in any environmental impacts.

#### Alternative 2

The Closure Structures Only Alternative consists of installing closure structures on the three major tributaries to the Passaic River that are located within the project corridor. A 100 x 100 square foot area of disturbance would be required to install the closure structures on each of these tributaries, resulting in 10,000 square feet of temporary impact to state jurisdictional freshwater wetlands and state open waters. A total of 30,000 square feet of temporary impacts to wetlands, bank, channel bed and open water would result from implementing this alternative. A temporary stream diversion would be necessary in order to install each of the closure structures.

A flowing stream diversion would be installed to convey water around the work areas to an in-channel location downstream. The flowing stream diversion consists of two sets of wooden, framed, wing-walls connected to a flexible, bag-like PVC tube that is used to convey flowing water around a work area. The premise of the flowing stream diversion is to create a dry work environment without interrupting flow in the target channel. These systems allow wetland dependant and aquatic wildlife to pass both upstream and downstream of the work zone during construction.

The stream diversion would be installed prior to the initiation of construction. The stream diversion is laid in a channel that is excavated adjacent to the culvert that conveys stream flow beneath Valley Road. The downstream end of the diversion is installed in the downstream section of channel first. The upstream end of the diversion is then installed with a set of wing walls into the upstream end of the channel. Water then flows through the stream diversion and bypasses the work area. Flow can be restored to the work area portion of the channel once the tributary closure structure installation is complete.

Proposed mitigation for this alternative would consist of restoring any bed or bank areas disturbed during construction. Mitigation activities may include minor grading, installation of temporary/permanent erosion control measures and planting/seeding with native riparian vegetation. Any restoration efforts would be monitored in accordance with State permit performance standards and monitoring requirements.

| **Alternative 2** | Wetland Impacts | Rest. Area |
|---|---|---|
| **Total For Alternative 2** | **0.69*** | **0.69*** |

*All temporary wetland impacts will be restored, in-situ, to their pre-construction condition.

### Alternative 3

A 7,600 linear feet, 57-foot wide levee along the Passaic River would begin approximately 100 feet west of Poplar Drive and would run south toward the river turning west and running along the Passaic then turning north and ending approximately 300 feet west of Passaic Avenue along Valley Road. Using this alignment would result in approximately 9.5 acres of Federal jurisdictional wetland impacts. The levee is by far the most environmentally damaging and most costly compensatory wetland mitigation alternative considered.

| **Alternative 3** | Wetland Impacts | FCU Impact | Rest. Area | Rest. FCU's |
|---|---|---|---|---|
| **Total For Alternative 3** | **9.5** | **32.30** | **9.5** | **32.30** |

This alternative was rejected during the formulation process on the basis of cost and considerable environmental and wetland impacts. An actual mitigation plan was not formulated. The numbers that appear in the right hand column are for informational purposes only and represent the type specific required mitigation areas based on a wetland impact area of 9.5 acres

### Alternative 4

The setback floodwall and levee alignment was designed to avoid and minimize wetland impacts to the greatest extent possible. In earlier iterations of the floodwall/levee alignment and configuration a levee was designed to bisect lots 18.0 and 18.01 to avoid aesthetic impacts. This resulted in 1.17 acres of wetland impacts. The levee portion of the wall was changed to floodwall which resulted in a 0.07 acre reduction in wetland impacts. Using this alignment/configuration would result in approximately 1.10 acres of Federal jurisdictional wetland impacts. This alternative also includes the installation of tributary closure structures, for which mitigation would be as described above under Alternative 2.

As compensation for the wetland impacts that would result from implementing this alternative, a restoration of degraded emergent wetland to forested wetlands and creation of forested wetlands from uplands would be proposed. Approximately 0.53 acres of degraded wetlands and uplands would be converted to forested wetlands on Lots 16.04, 18.0 and 18.01.

The proposed restoration and creation would consist of excavation and grading followed by planting/seeding with native wetland vegetation. The restoration and creation efforts would be monitored and maintained in accordance with the Federal performance standards for compensatory wetland mitigation. Permanent easements would have to be obtained or the properties would have to be purchased from the current land owners. If the land owners are not willing to cooperate, off-site compensatory mitigation would be considered as a last resort.

| Alternative 4 | Wetland Impacts | FCU Impact | Rest. Area | Rest. FCU's |
|---|---|---|---|---|
| **Total For Alternative 4** | **1.10** | **1.77** | **0.52** | **1.77** |

See Section 6.15 for a more detailed presentation of the proposed mitigation plan.

### Alternative 5

Alternative 5 would result in approximately 0.25 acre of permanent wetland impacts resulting from the grading of new side slopes. This alternative also includes the installation of three tributary closure structures (see discussion of Alternative 2 above). Although executing this option would result in lower wetland, State open waters and transition area impacts, than the other floodwater barrier alternatives (Alternatives 3 and 4), it would significantly disrupt local traffic patters by closing this section of Valley Road for a period of 6-12 months during construction.

If this alternative were pursued the mitigation proposal would consist of restoring approximately 0.12 acres of degraded emergent wetlands to forested wetlands on what is presently a residential lawn. The proposed restoration would be located on Block 1, Lot 16.04.

The degraded wetland areas located on Lot 16.04 are comprised of residential lawn. The proposed restoration would consist of limited excavation/grading followed by planting/seeding with native wetland vegetation. It is important to note that Lot 16.04 is privately owned. Therefore, permanent easements would have to be obtained or the lot would be subdivided and the mitigation areas purchased. A maintenance and monitoring plan would be implemented the Federal performance standards for compensatory wetland mitigation.

| **Alternative 5** | Wetland Impacts | FCU Impact | Rest. Area | Rest. FCU's |
|---|---|---|---|---|
| **Total For Alternative 5** | **0.25** | **0.41** | **0.12** | **0.41** |

### 3.8.3 Comparison of Alternatives

The alternative plans also were compared against the planning objectives and constraints set forth previously in this section. Table 3-10 provides a summary of whether the plan satisfactorily meets the objective or complies with a constraint (designated as "●"), marginally meets the objective or complies with a constraint (designated as "◘"), or fails to meet the objective or comply with the constraint (designated as "○"). The objectives and constraints evaluated against the alternatives are designated in the matrix as A through I, and correspond to:

A. Provide protection from frequent, low-level recurring floods to Reach 1
B. Provide protection from frequent, low-level recurring floods to Reach 2
C. Protect and maintain traffic corridors and ensure the operability of emergency and rescue facilities during storm events.
D. Reduce the frequency and severity of backwater flooding from the Passaic River into the principal tributaries within the study area.
E. Provide a plan that is compatible with future flood damage reduction and economic development opportunities.
F. Minimize potential impacts of the project on other areas and groups.
G. Be likely to receive local support.
H. Avoid and minimize adverse environmental impacts.
I. Average annual economic benefits exceed average annual costs.

***Table 3-10***
***Evaluation of Alternative Plans Against Objectives and Constraints***

| Objective / Constraint | Alternative Plans 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| A | ○ | ○ | ● | ● | ○ |
| B | ○ | ⊙ | ● | ● | ● |
| C | ○ | ○ | ● | ● | ● |
| D | ○ | ⊙ | ● | ● | ● |
| E | ○ | ○ | ● | ● | ○ |
| F | ● | ● | ○ | ● | ○ |
| G | ○ | ⊙ | ⊙ | ● | ○ |
| H | ● | ● | ○ | ● | ● |
| I | ○ | ● | ○ | ● | ● |

As shown in the table, Alternative 4, the Setback Floodwall/Levee, meets the planning objectives and satisfies the constraints set forth at the outset of the formulation process. It is the plan which maximizes net benefits (i.e., the preliminary NED plan) and is an alternative that is successful in avoiding and minimizing environmental impacts. Consequently, Alternative 4 is the selected plan under which incremental justification for non-structural measures will be attempted, and is the plan for which an optimal level of protection will be analyzed.

## 3.9 Non-structural Features Analysis of Alternative 4

Twelve residential structures and the Township's wastewater treatment plant are not protected by the preliminary NED plan (Alternative 4). Low opening elevations of ten of the twelve residential structures are located below the 100 year flood plain. The combined average annual damages of the ten residential structures amounts to approximately $67,500 at elevation +216.2 (the 100 year water surface elevation). Six of the ten structures would be candidates for floodproofing without raising the structures to a higher elevation. Utilities would be relocated to an attached utility shed placed at an elevation one foot higher than the 100 year water surface elevation (to elevation +217.2 NGVD), and basements (if any) would be filled with concrete. Four of the ten structures would need be raised out of the 100 year flood plain, as the first floor elevations of these structures are lower than +216.2 NGVD. Based on current New York District experience, the cost of these types of non-structural measures amounts to roughly $70,000 per residence for general floodproofing, and $135,000 per residence for floodproofing and raising.

Total costs of the non-structural measures amount to $960,000, and average annual costs are $87,250. The average annual cost of this project feature was calculated over a 30 year horizon (period adjusted), and includes contingencies and interest during construction. The benefit-to-cost ratio for the non-structural measures is 0.77 to 1, and net benefits are negative at $19,750.

Because incremental economic justification will not be achieved, the non-structural element of Alternative 4 was eliminated from further consideration.

## 3.10 Selected Plan Optimization

The NED Plan is the plan the Corps of Engineers must recommend unless there is an overriding reason for choosing another plan, which might include local support for an alternative plan. In that case, the Corps would cost-share in construction of the Locally-Preferred Plan (LPP) on the basis of their cost-share in the NED plan.

Economic analysis was used to optimize the level of protection of the selected plan (Alternative 4). The plan would provide protection all structures in Reach 2, most structures in Reach 1, and would protect Valley Road during flood events. Costs were developed for the selected plan with alternative levee/floodwall heights of +215.2, +216.2, +216.9, and +217.6 NGVD. These levels of protection correspond to the 50-year, 100-year, 250-year, and 500-year recurrence intervals without risk and uncertainty adjustments. Costs for the levee/floodwall at the four levels of protection are shown in Table 3-11. Average annual costs were calculated based on the FY04 Federal discount rate of 5.625 percent and an analysis period of 50 years. Interest during construction was calculated assuming an 18 month construction period.

In Table 3-12, the costs and benefits of four levels of protection for the selected plan are compared. As shown in the table, the level of protection with the greatest net benefits was determined to be elevation +217.6 NGVD, which would provide protection from 500-year floods. This NED plan would provide average annual benefits of $685,500 with average annual costs estimated at $396,100. Annual net benefits are estimated to be approximately $289,400, and the benefit-cost ratio is anticipated to be 1.73 to 1.

***Table 3-11***
***Costs of Alternative Levels of Protection – Alternative 4***

| | **Probability of Exceedance** | | | |
|---|---|---|---|---|
| | 0.02 | 0.01 | 0.004 | 0.002 |
| Levee/Floodwall Height (feet NGVD) | 215.2 | 216.2 | 216.9 | 217.6 |
| Construction Cost, LERRD, PED | 4,715,700 | 5,019,600 | 5,336,400 | 5,759,800 |
| Interest During Construction | 199,000 | 211,800 | 225,100 | 243,000 |
| Annualized First Cost | 295,600 | 314,700 | 334,500 | 361,100 |
| Annual O&M Cost | 20,000 | 20,000 | 20,000 | 35,000 |
| Total Annual Costs | 315,600 | 334,700 | 354,500 | 396,100 |

***Table 3-12***
***Benefits and Costs Comparison of Alternative Protection Levels***

| Exceedance Probability | Average Annual Damages Prevented | Reduced Annual FIA & Emgcy Costs | Reduced Traffic Delay Costs | Total Average Annual Benefits | Average Annual Costs* | Average Annual Net Benefits | BCR |
|---|---|---|---|---|---|---|---|
| 0.02 | 352,200 | 13.0 | 32.4 | 397,600 | 315,600 | 82,000 | 1.26 |
| 0.01 | 511,600 | 25.8 | 48.2 | 585,600 | 334,700 | 250,900 | 1.75 |
| 0.004 | 562,600 | 28.0 | 49.7 | 640,300 | 354,500 | 285,800 | 1.81 |
| 0.002 | 605,300 | 28.5 | 51.7 | 685,500 | 396,100 | 289,400 | 1.73 |

Residual risk of the four levels of protection considered for Alternative 4, along with the without-project condition are shown in Table 3-13. The table shows the expected annual probability of each level of protection being exceeded, and the equivalent long-term risk of exceedance over 10, 20, 30, 40, and 50 years. Examination of equivalent long-term risk for the without-project condition shows that the probability of a damaging flood occurring over the next 10 years is about 89 percent (relative certainty) and increases to 100 percent (absolute certainty) over the next 40 years. These long-term risks are consistent with the flood risk that Long Hill Township currently faces. The table also shows a decrease in long-term risk for all levels of protection being considered for Alternative 4, though none of the levels of protection provide a complete elimination of risk. For example, the table shows that even the 500 year level of protection (protection from a flood with a 0.2 percent chance of occurring in any year) does not eliminate the risk of a damaging flood event. Over a 50 year period of analysis there is still a 9.5 percent chance that a damaging flood will occur with a 500 year level of protection.

***Table 3-13***
***Residual Risks of Existing Conditions and Alternative Protection Levels***

| | Expected Annual Probability of Design Being Exceeded | Equivalent Long-Term Risk (Probability of Exceedance Over Time Period) | | | | |
|---|---|---|---|---|---|---|
| | | 10 Years | 20 Years | 30 Years | 40 Years | 50 Years |
| Without-Project | .20 | 0.893 | 0.988 | 0.999 | 1.000 | 1.000 |
| 50 Year Levee | .02 | 0.183 | 0.332 | 0.455 | 0.554 | 0.636 |
| 100 Year Levee | .01 | 0.096 | 0.182 | 0.260 | 0.331 | 0.395 |
| 250 Year Levee | .004 | 0.039 | 0.077 | 0.113 | 0.148 | 0.182 |
| 500 Year Levee | .002 | 0.020 | 0.039 | 0.058 | 0.077 | 0.095 |

## 3.11 Selection of the Recommended Level of Protection

Although the NED plan could potentially be implemented, the NED plan does not have the support of the local sponsor. A change in the FEMA flood hazard mapping will hamper the Township's ability to regulate growth. In addition, the height of the levee/floodwall will be obtrusive at a maximum height above ground of 6.4 feet. The sponsor has identified a preferred level of protection at +216.2 NGVD (100-year level). At this elevation, the levee/floodwall would not block the viewshed (maximum height 5.4 feet), and additional development in the flood plain would not be expected.

Table 3-14 shows the economic differences between the two plans. Average annual benefits of the LPP are $99,900 lower than the NED plan, attributable to a corresponding reduction in residual damages of $99,900 when moving from the level of protection provided by the LPP to the level of protection provided by the NED Plan. Also shown in the table are differences in costs and average annual costs. The increase in construction costs of $740,200 when moving from the LPP to the NED Plan translates to an increase of $61,400 in average annual costs (discounted at 5.625 percent over 50 years after accounting for interest during construction and O&M costs). Additional net benefits of $38,500 would be attained if the NED Plan were selected over the LPP.

***Table 3-14***
***Benefits and Costs Comparison of the LPP and NED Plan***

| Plan | Average Annual Benefits | Average Annual Residual Damages | Construction Costs | Average Annual Costs* | Average Annual Net Benefits | BCR |
|---|---|---|---|---|---|---|
| LPP | 585,600 | 194,900 | 5,019,600 | 334,700 | 250,900 | 1.75 |
| NED | 685,500 | 95,000 | 5,759,800 | 396,100 | 289,400 | 1.73 |
| Difference: | -99,900 | 99,900 | -740,200 | -61,400 | -38,500 | -0.02 |

Differences in level of protection and residual risk between the LPP and NED Plan are shown in Table 3-15. As would be expected, the table shows a reduction in risk when moving from the LPP level of protection to the NED Plan level of protection. For any given 10 year period, the probability of incurring a damaging flood with the NED Plan in place is 2 percent. The residual risk of a damaging event being incurred with the LPP in place increases to 9.6 percent over the same time period. Were the NED Plan constructed, the risk of incurring a damaging flood event over a 50 year period would be 9.5 percent. Residual risks over 50 years increases to 39.5 percent with the LPP in place.

***Table 3-15***
***Level of Protection and Residual Risk Comparison of the LPP and NED Plan***

| | Expected Annual Probability of Design Being Exceeded | Equivalent Long-Term Risk (Probability of Exceedance Over Time Period) | | | | |
|---|---|---|---|---|---|---|
| | | 10 Years | 20 Years | 30 Years | 40 Years | 50 Years |
| LPP | .01 | 0.096 | 0.182 | 0.260 | 0.331 | 0.395 |
| NED | .002 | 0.020 | 0.039 | 0.058 | 0.077 | 0.095 |
| Decrease in Residual Risk from LPP to NED Plan | | 0.076 | 0.143 | 0.202 | 0.254 | 0.300 |

The sponsor's selection of a locally preferred plan (LPP) over the NED plan is permitted under guidance stated in *Planning Guidance Notebook* (ER-1105-2-100, 22 April 2000). The residual risk of the LPP is acceptable to the Sponsor, and the LPP provides greater net benefits than the smaller scale, 50-year level of protection plan. Additional analysis and design of the LPP is provided in Section 5 of this Feasibility Report.